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Enhancefish

Decision support tool for aquaculture-based fisheries enhancement

Guide to use in management

BETA RELEASE FOR USER TESTING

Kai Lorenzen

Division of Biology
Imperial College London

www.aquaticresources.org/enhancefish

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The ***EnhanceFish*** decision tool and all related documents are available from www.aquaticresources.org/enhancefish.

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1. Introduction

1.1 Purpose of this document

The purpose of this document is to guide aquatic resource management professionals in the use of the ***EnhanceFish*** decision tool. ***EnhanceFish*** is a decision support toolkit for the analysis of aquaculture-based fisheries enhancements. The ***EnhanceFish*** toolkit consists of three parts

(1) The ***EnhanceFish*** decision tool: a software package for quantitative assessment of enhanced fisheries
(2) The ***EnhanceFish*** manual: a technical manual that explains the scientific principles behind the ***EnhanceFish*** package and its use in assessment
(3) The ***EnhanceFish*** guide: practical guidance on how to use ***EnhanceFish*** in the analysis and management of enhancements, particularly in developing areas.

This document is the ***EnhanceFish*** guide.

1.2 Aquaculture-based fisheries enhancement

Aquaculture-based fisheries enhancement is the use of cultured fish or invertebrates to enhance fisheries. Aquaculture-based fisheries are a diverse family of approaches that differ in their objectives, technologies, management practices, and outcomes. However, three main types of aquaculture-based enhancements may be distinguished according to technical criteria:

- **Culture-based fisheries** where catches of the target species are based entirely on stocking, with no or very little natural recruitment
- **Stock enhancement**, where catches of the target species are based on a combination of stocked and naturally recruited fish
- **Restocking or stock rebuilding**, where stocking is carried out as a temporary measure aimed at rebuilding a depleted stock

All of these approaches may be used in the pursuit of a variety of objectives such as producing food, increasing the income of fishers, or restoring a population.

Aquaculture-based enhancements are widespread in inland and increasingly, coastal fisheries. Whilst there are good examples of enhancements that are technically effective, economically beneficial and environmentally sound, many enhancements perform poorly in some or all these respects. Problems that may be associated with enhancements include:

- Lack of ecological-technical effectiveness: enhancement has no effect on stock abundance and fisheries yield;

- Detrimental ecological and genetic impacts on wild fish stocks arising from stocking and harvesting of cultured fish;
- Poor economic performance: low or negative economic returns or contributions to resource user livelihoods;
- Distributional problems and conflicts: benefits from enhancement may not be shared equitably by different resource users, and this may lead to conflicts;
- Low institutional sustainability: difficulties in developing and maintaining rules and regulations required to make the enhancement "work", and compliance with them.

Such problems can often be alleviated by better management of the enhancement system or its components (e.g. seed production techniques, harvesting regime etc.). In other cases the natural or social environment, or technical constraints may make it impossible to develop beneficial enhancements. To be successful, enhancements must involve far more than stocking. For example, stocking and harvesting practices must be coordinated and tailored to the physical and socio-economic environment in order to achieve good production, seed fish must be produced so that they perform well after release, and management institutions must be capable of coordinating these activities. The purpose of the ***EnhanceFish*** toolkit is to promote better management of aquaculture-based fisheries enhancements.

Readers unfamiliar with aquaculture-based enhancements and related management issues are strongly recommended to read some of the recent reviews on the topic, such as Cowx (1994), Blankenship & Leber (1995), Munro & Bell (1997), Travis et al. (1998), Welcomme & Bartley (1998), Waples (1999), Lorenzen et al. (2001), Bell et al. (2005), Lorenzen (2005), and the ***EnhanceFish*** Guide.

1.3 What is EnhaceFish?

EnhanceFish is a decision support toolkit for the analysis of aquaculture-based fisheries enhancements. At the heart of ***EnhanceFish*** is a mathematical population model that predicts fisheries catch and other biological and production attributes for different management controls such as stocking density and fishing effort. ***EnhanceFish*** also calculates basic economic performance indicators such as fishing income, resource rent or the net present value of enhancement approaches. ***EnhanceFish*** thus helps to analyse quantitatively the relationship between inputs and outputs of the enhanced fishery, and its economic performance. It does not model how these inputs are determined (e.g. how management rules influence the level of fishing effort), or how outputs contribute to wider objectives (e.g. whether increased fish catches will alleviate poverty in a fishing community). Such problems are difficult or impossible to

model in the same quantitative fashion as the dynamics of a fish population. Nonetheless, these issues are central to planning and management and must be considered in order for the quantitative biological, technical and economic analysis to contribute to improving management. The aim of this guide is thus to provide a broad-based and integrated introduction to enhancements and their management and to suggest ways in which broad qualitative and more narrow quantitative analyses should be linked in the pursuit of improved management.

2 Understanding aquaculture-based fisheries enhancements

For any analysis aimed at designing or improving a fisheries enhancement, it is very important to gain a broad-based understanding of the enhancement resource system. Typically, this comprises at least the components illustrated in Figure 2.1. At the core of the enhancement system are the enhanced population in its natural or semi-natural habitat, the hatchery operation and seed market, the fishery (harvesting operation), and the produce market. Management institutions are the rules and regulations that affect the different components of the system, and their interactions.

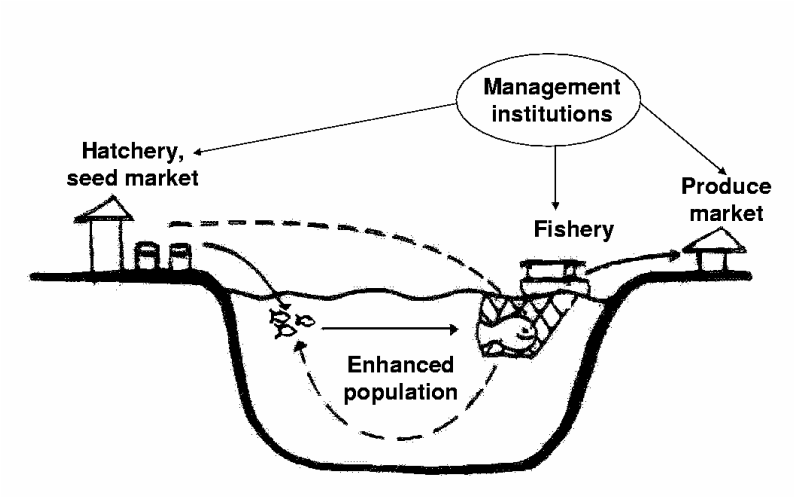

Figure 1. Key components of the enhancement system.

Enhancements combine elements of fisheries (exploitation of aquatic organisms as common pool resources) with aquaculture (farming of aquatic organisms, implying management interventions such as feeding, and private ownership of the stock being farmed). The fact that most fisheries are common pool resources, i.e. exploited jointly by many users who subtract from the shared

resource and the benefits obtainable by others, is a major factor in the management of enhancements.

2.1 Framework for analysing fisheries enhancement systems

A framework for analysing aquaculture-based fisheries enhancement systems is shown in Figure 2. The framework used here has been extended and modified from a general 'institutional analysis' framework for common pool resources (Oakerson 1992; Pido et al. 1996). There are three main types of attributes:

- **Situational variables**, which influence the outcome of fisheries enhancement either directly or through the incentives they provide for resource user action
- **Patterns of interaction**, the aggregated actions of resource users as influenced by incentives provided by the situational variables
- **Outcomes** of resource use as influenced by the physical and biological characteristics of the resource, and its use (patterns of interaction).

Between the attributes, there are two types of **interactions: Operational interactions** (solid lines) determine outcomes in the short term when the situational variables are fixed. In **dynamic interactions** (dashed lines) situational variables are modified in response to the outcomes of operational interactions. Both types of interactions may involve direct physical-biological effects, and interactions mediated by stakeholder action. For example, life history characteristics of the target fish population will directly affect yield through ecological processes. Life history characteristics such as migratory behaviour will also influence the incentives for fishers to restrict exploitation (in anticipation of future benefits), thus influencing yields via the resulting pattern of exploitation. Similarly, dynamic interactions could involve direct biological feedback (such as a decline in wild stock productivity due to competition with stocked fish), or modification by stakeholders of harvest rules or aquaculture production techniques in the light of outcomes seen as undesirable.

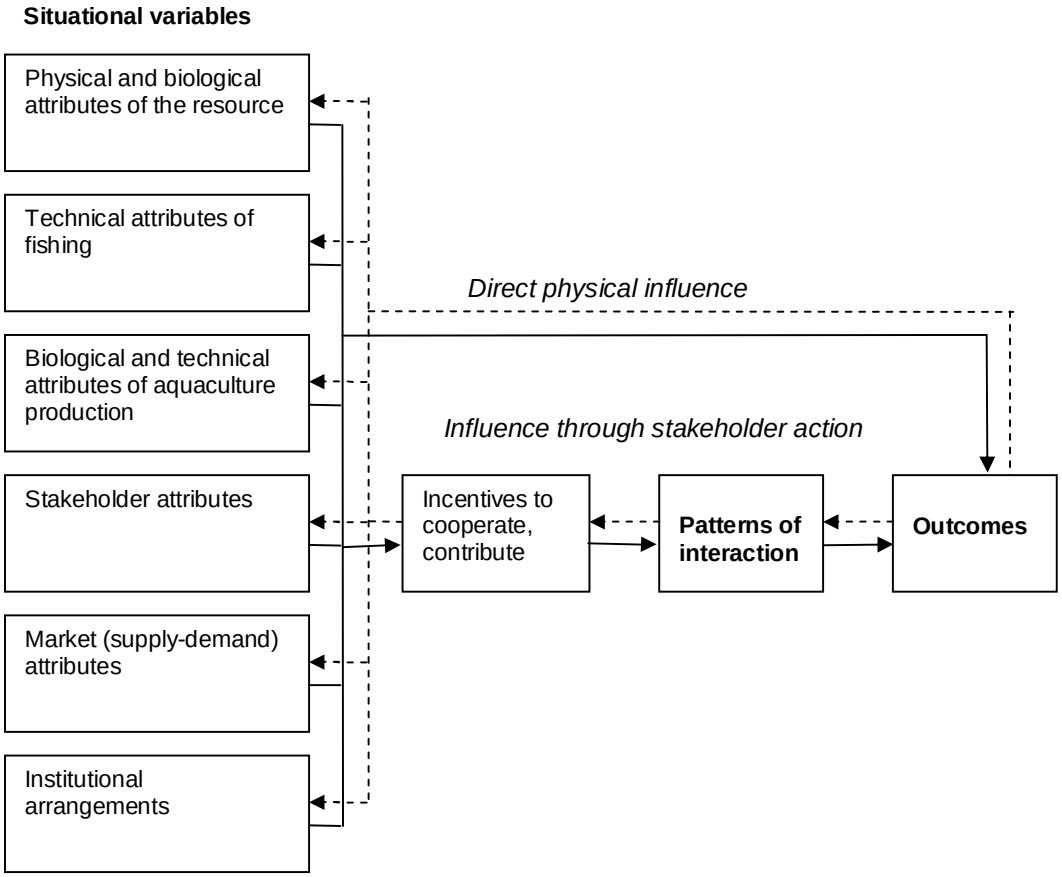

Figure 2: Framework for analysing fisheries enhancement systems. Adapted from Oakerson (1992) and Pido et al. (1996).

The **situational variables** are structured in six groups:

1) Physical and biological attributes of the resource
   - The physical environment
   - The ecology of aquatic resource production

2) Technical attributes of fishing
   - Efficiency and selectivity of fishing techniques

3) Biological and technical attributes of aquaculture production
   - Techniques used in aquaculture production and release for enhancement

4) Attributes of stakeholders
   - Livelihoods of primary stakeholders: resource users and seed producers
   - Interests and influence of other stakeholders

5) Market (supply and demand) attributes
- The economic environment
- The state and accessibility of markets for labour, and input and outputs of the fishery

6) Institutional arrangements
- Operational rules for resource use (rules that determine by whom, where, when and how resources may be used)
- Conditions of collective choice, which are the set of rules which determine how operational rules can be made
- External arrangements pertaining to rules and conditions of collective choice.

Patterns of interaction are the aggregation of all the actions taken by individual resource users, in the light of situational attributes, over a period of time. For example, individual fishers will decide how much effort to expend on fishing in the light of the status of stocks (biological attribute), the value they place on fishing compared to alternative activities (stakeholder attributes), the market price of fish (economic attributes), and the rules for resource use as well as the expected penalty for breaking these (institutional attributes). Aggregated over all fishers and a period of time, these decisions define the level of harvesting effort in the fishery.

Outcomes of resource use are physical (e.g. stock abundance or production) at the most basic level. Stakeholders attach values to physical outcomes according to their own objectives and situations, and thereby translate physical outcomes into benefits and costs.

2.2 Objectives and the valuation of outcomes

As mentioned above, stakeholders attach values to outcomes and thereby convert them into benefits and costs. In most aquaculture-based fisheries there are many stakeholders, from fishers and seed producers to organisations with a general interest in conservation. Different stakeholders may have very different objectives, for example:
- Maximising fisheries production (government fisheries department)
- Maximizing economic rent form the fishery (government)
- Meeting subsistence food demand (subsistence-oriented fishers)
- Maximising cash income (commercially oriented fishers)
- Preserving or restoring the wild population of the target species (conservation organizations)

Not surprisingly, stakeholders with such different objectives will use different criteria and indicators to evaluate outcomes of enhancement. A broad range of criteria must therefore be considered in analyzing an enhancement system.
An overview of criteria likely to be relevant is given in Table 1.

Table 1. Criteria by which outcomes of enhancement may be valued and specific indicators

Outcome criteria	Specific indicators (examples)
Biological production	• Total yield of target species • Total yield from fishery • Size distribution of catch
Biological resource conservation	• Abundance of wild target population • Abundance of other wild fish populations • Natural productivity of target population • Genetic integrity of target population
Economic benefits and costs	• Economic rent from the enhanced fishery • Income flow • Costs of management (transaction costs) • Costs of benefits from wild fish harvesting foregone
Contribution to livelihoods	In addition to the above: • Equity of benefits • Health benefits • Skills and knowledge developed • Networks and associations created • Trust • Access to wider institutions
Institutional sustainability	• Persistence of management institutions • Rules are followed by stakeholders • Rules adapt to changing conditions
Broader sustainability	• Resilience of ecosystem maintained or increased

Further reading: For more information on evaluation criteria and indicators see Allison & Ellis 2001; Smith et al. 2005; and Holmlund & Hammer 2003.

2.3 Influences from and on situational variables

Having introduced a framework for analysing enhancement systems, we now review briefly how the main situational variables influences outcomes through operational interactions, and how the variable in turn may be modified through dynamic interactions. In the longer term, both operational and dynamic interactions are likely to be important.

2.3.1 Physical, biological and technical attributes of the resource

The physical environment and ecosystem

The physical aquatic and neighbouring terrestrial environment have important implications for the production ecology of aquatic resources, and the incentives for resource users to adopt particular modes of action. Overall fisheries productivity in inland and coastal systems is closely linked to physical properties of the aquatic system such as depth, and the nutrient inputs received from terrestrial systems. Highly modified ecosystems such as reservoirs may offer greater opportunities for enhancement than near-pristine environments, as many local species may not be able to complete their life cycle in the modified environment. The degree to which a system is closed or open, together with the mobility of the target organism, influences whether those who undertake enhancement activities will be able to reap the benefits. Where this is not the case, resource-user led enhancements are unlikely to emerge or be sustained. Whether a system is 'open' or 'closed' of course is matter scale of the physical environment and human organisation. Finally, even in closed systems enhancements are unlikely to be sustained unless resource user actions are easily monitored.

Figure 3. Two contrasting physical environments for enhancement: small lake near a village in Laos (left), and Amazon river floodplain in Brazil (right). The Lao lake is closed, easily monitored, and sustains an enhanced fishery. The Amazon floodplain is open and difficult to monitor, so that there is little incentive to invest in enhancement.

Influences of enhancement on the physical environment are rare, but impacts on foodweb structure and functioning can be significant. This is the case for example in predator stocking, or the release of grass carp to control aquatic vegetation. In other cases, ecosystem level impacts have been found to be surprisingly limited despite intensive stocking of exotic species such as tilpias and

Chinese carps.

Further reading: For relationships between environmental variables and enhancement yields see De Silva et al. (1992, 2001) and Lorenzen et al. (1998b). Impacts of enhancements on ecosystems are reviewed in FAO (1999).

The target fish population

Biological characteristics of the target population influence outcomes directly and through the incentives they provide for resource users. Life history parameters such as growth, mortality and the strength of density-dependent processes are the major determinants of biological enhancement potential. Closely linked are genetic attributes such as adaptation to local environmental conditions and genetic diversity which directly affect ecological performance and its resilience to environmental change. Hence the ecological (e.g. exploitation) and genetic status of the wild target population (where one exists) also influence enhancement potential. As already mentioned, the mobility of the target species has important implications for the potential for institutionally sustainable enhancements to emerge.

Effective enhancement of course aims at increasing and thus modifying the target population. Where a wild target population exists, it will almost inevitably be impacted to some extent through ecological and genetic interactions with the stocked cultured fish. This may lead to partial or complete replacement of the 'wild' type fish by 'hatchery' type fish that differ genetically and ecologically from the wild type. In general such interactions are undesirable and management will be aimed at minimizing them through appropriate genetic management, stocking and harvesting. Analysing the population dynamics of enhancement, including impacts on the wild component of target stocks, is the core function of ***EnhanceFish***.

Further reading: For an overview of the population dynamics of enhancements see Lorenzen (2005). Caddy & Defeo (2003) cover aspects of the dynamics of marine invertebrates. Genetic issues are discussed in Utter (1998), Utter & Epifanio (2002), Frankham et al. (2002), and Miller & Kapuscinski (2003).

2.3.2 Technical attributes of fishing

Fishing practices comprise the use of different gear types, their selectivity characteristics for species and sizes of fish, and the overall level of fishing effort. Clearly, fishing practices have a major influence on the yield and economic

benefits obtained from enhancements. Highly selective fishing techniques allow effective harvesting of stocked fish and at least in principle can be used to greatly reduce intra- and interspecific impacts of enhancement on wild populations.

Fishing practices may be modified in the course of developing enhancements, with positive or negative impacts on the wild and stocked populations harvested. In principle, measures such as conditioning of juveniles before release can be used to develop fishing methods that are highly selective for stocked fish, but this has not been applied beyond the experimental stage.

Analysing the effects of different fishing practices and the interaction between fishing and stocking regimes is a core purpose of the ***EnhanceFish*** tool.

2.3.3 Biological and technical attributes of aquaculture production and release

Aquaculture production, transport and release strongly influence the performance of hatchery fish after release, and the outcome of interactions with wild conspecifics.

Aquaculture production

Aquaculture production practices influence both the phenotypic and the genetic quality of seed fish and thus, the effectiveness of enhancement and its impact on any wild population component. This starts with the sourcing of broodstock from either a local, or a geographically and genetically distant population. Maintenance of broodstock and rearing of offspring in captivity has strong, almost always negative impacts on the capacity of hatchery fish to survive, grow and reproduce in the wild. These impacts arise from plastic developmental responses and an altered selection regime in the hatchery. Rearing in semi-natural environments, or provision of specific conditions and stimuli in more controlled environments can be effective in minimising such impacts. Transport practices and distance from the hatchery to the release site can also have strong impacts on post-stocking survival.

Aquaculture practices, from genetic management to rearing techniques, may be modified and improved in the light of enhancement outcomes. Specialist enhancement hatcheries often implement such techniques, and produce fish of better quality for enhancement purposes than those derived from commercial hatcheries.

Stocking

Release location and timing, and the size and density of fish released strongly influence the biological processes to which fish are subjected after release. Some of these aspects (stocking size and density) are subject to generalisations that can be analysed using the ***EnhanceFish*** tool. Location and timing effects are less easily generalised, but significantly improved stocking strategies can often be identified experimentally. Again, modification of practices in the light of enhancement outcomes is possible and desirable.

Figure 4. Releasing hatchery fish from plastic bags. Aquaculture production, transport and release practices have a strong influence on post-release performance of hatchery fish in the wild. (Photo: Ouk Vibol)

Further reading: The influence of aquaculture production and release practices on enhancement outcomes is reviewed in Olla et al. (1998), Utter (1998); Brown & Dey (2001); Utter & Epifanio (2002).

2.3.4 Stakeholder attributes

Stakeholders are those persons, groups and organisations with a valid interest in the fishery. This includes the primary stakeholders whose livelihoods are connected to it (e.g. fishers, seed producers, or fish traders), and secondary stakeholders who may influencing the way a fishery is managed without being

directly affected by the outcome (e.g. government officers, conservation organizations).

Primary stakeholders and livelihoods

Characteristics of the primary stakeholders influence many technical and institutional aspects of the enhancement, as well as the patterns of interaction (aggregated action of primary stakeholders in the light of incentives provided by the situational variables).

A good way of understanding key attributes of primary stakeholders is through analysis of their livelihoods and the role of aquatic resource use within them. A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. Many primary stakeholders, in particular fishers may rely on a diverse portfolio of activities and social support capabilities in order to survive and to improve their standards of living. Fishing can play a variety of roles in such livelihoods as outlined in Table 2. The role of fishing in livelihoods has important implications for enhancements. Fishers with 'survival' or 'semi-subsistence' livelihoods strategies may lack the means and interest to engage in enhancement activities as fishing is primarily a fallback activity that is important precisely because it requires few resources.

Table 2. Livelihood functions of fishing as household incomes rise and livelihood strategies develop (Smith et al. 2005)

Livelihood strategy	Livelihood functions of fishing
'Survival'	Subsistence (food production and income) Nutrition – protein, micronutrients, vitamins
'Semi-subsistence' diversification	Own consumption – food security and nutrition Complementarities in labour use with farming Means for barter, or for participation in reciprocal exchange and social networks Occasional cash source Diversification for: labour and consumption 'smoothing' risk reduction as a coping strategy/buffering against shocks.
'Specialisation' (as fishers)	Market production and income Accumulation
'Diversification for accumulation'	Accumulation Retention in a diversified accumulation strategy.

Enhancement may offer opportunities for the more entrepreneurial 'specialized' and 'diversified for accumulation' fishers to improve income, and those fishers are often prepared to invest in enhancement if institutional arrangements are such the they can expect to reap the benefits. Community-based enhancements

can be feasible and yield multiple benefits even where fishing serves survival or semi-subsistence functions. Benefits may include cash income at the community level, strengthening of social relationships and organisational structures, and opportunities to lever funding from other sources. It is thus important to conduct a broad-based participatory livelihoods assessment in order to establish livelihoods implications of enhancement.

Where fishers with different livelihoods strategies coexist, enhancement can lead to conflicts and may disadvantage fishers with 'survival' or 'semi-subsistence' strategies. However, such conflicts can often be resolved through appropriate institutional arrangements. It must also be appreciated that even fishers with 'survival' or 'semi-subsistence' strategies can benefit from enhancements if measures are taken to ensure that access to wild fisheries resources is not unduly restricted, and the fishers share in the benefits from enhancement. An example is that of Lao community fisheries, where access arrangements are designed to allow for subsistence fishing and all community members share in the benefits from enhancement through better village services and reduced contributions.

Figure 5. Part-time subsistence fishing makes an important contribution to rural livelihoods in many developing regions. Where enhancements are being developed, care should be taken not to disadvantage the poorest fishers.

Aquaculture producers are the second major group of primary stakeholders, although they tend to be far less numerous than fishers. Aquaculture producers in general have greater resources at their disposal than many fishers, and tend to participate fully in markets even in economies with strong subsistence components. Clearly, the resources and technical expertise available to aquaculture producers have a major impact on the production techniques employed, and the resulting quality and quantity of seed available for enhancement.

Secondary stakeholders

Secondary stakeholders may be a diverse group of organisations and individuals influencing enhancements through, for example: access regulation, conflict resolution, stocking decisions, financial management, or research. The configuration of secondary stakeholders and their influence on the enhancement will vary widely between systems, and should be assessed on a case by case basis.

In some cases, virtually all key decisions on aquaculture production, stocking, and the permissible level of harvesting are made by government agencies (a secondary stakeholder). In other cases, all such decisions may be made by a formal or informal resource user association with only minimal influence by secondary stakeholders.

Interactions between stakeholders

The extent to which stakeholders do or do not interact has major implications for the outcome of enhancements. As a rule, the potential of enhancements can be realized only if key components such as aquaculture production and fishing regulation are coordinated, and the objectives of different stakeholders are taken into account in decision making. Unfortunately, there is often little interaction between for example aquaculture producers and those who fish or regulate the fishery.

Further reading: See Grimble & Chan (1995) for an introduction to stakeholder analysis. Allison & Ellis (2001) and Smith et al. (2005) discuss livelihoods aspects of fishing, and Garaway (2006) provides a detailed case study of enhancement impacts on entitlements.

2.3.5 Market attributes

Many inputs and outputs of enhancements are marketed, and the availability for markets for input and outputs affects the development options available as well as the economic performance of enhancements. Often, enhancements participate in markets where supply and demand are driven by other sectors such as commercial aquaculture or capture fisheries. Many enhancements for example rely on the availability of seed fish for commercial culture. The size and quality of such fish seed may not be ideal for enhancement purposes, but on the other hand costs per fish may be very much lower. Produce from enhancement generally enters markets where prices are driven by supply and demand for capture fisheries or increasingly, aquaculture outputs. Where aquaculture

production is expanding, prices may be declining and this may affect the economic benefits realized form enhancements. Finally, other inputs such as labour are also marketable and labour demand in other sectors such as agriculture or industry can make enhancements more or less attractive. It is thus important to consider present markets and their future development when analysing enhancements.

Further reading: Arnason (2001) reviews economic aspects of enhancements including markets. See Delgado et al. (2003) for a general outlook on fish supply and demand.

2.3.6 Institutional arrangements

Institutional arrangements consist of three types and levels:

- Operational rules for resource use (rules that determine by whom, where, when and how resources may be used);
- Conditions of collective choice, which are the set of rules which determine how operational rules can be made; and
- External arrangements pertaining to both operational rules and conditions of collective choice.

At all three levels, rules may be formal or informal. In many fisheries and enhancement systems, informal rules are important and their influence should not be overlooked.

Operational rules in enhancement systems concern all aspects of management including aquaculture production and release, as well as the fishing. Many western countries have detailed formal rules on aquatic animal husbandry, disease control, release of culture fish into natural waterbodies, fishing gear, intensity and timing of fishing, marketing of fish, and the financing of enhancements. Not all of these rules are made with enhancement systems in mind and some may hinder rather than promote the development of good enhancement approaches. Rules that restrict the introduction of wild fish into hatchery broodstock with a view to minimizing disease risks in aquaculture, for example, may cause problems for enhancements where the use of local wild broodstock can increase post-stocking performance and reduce ecological risks. In many areas of the world, rules are less detailed and many aspects may be entirely unregulated. Most enhancement systems require operational rules, formal or informal, binding or on a recommendation basis, to function effectively. Knowing the rules in existence and considering the design of new rules that may improve the functioning of enhancement systems are key elements of development.

The effects of most operational rules have already been considered under the technical/biological, stakeholder and market attributes influenced by them. One area that deserves particular attention here is the financing of enhancements. Enhancements require investment into a common pool resource, and arrangements to raise and sustain such investment can be very difficult to make even if the outcome is highly beneficial.

Conditions of collective choice are the rules by which stakeholders, usually primary stakeholders, make decisions about operational rules. This level can be quite irrelevant in some fisheries management systems where decisions are made by government agencies with minimal input from primary stakeholders. In many systems however, this level is crucial to decision making. Moreover, rules made with strong input from primary stakeholders are much more likely to be respected and followed. Most institutionally sustainable enhancement systems rely on rules made at this level, often with supportive external arrangements.

External arrangements concern the way in which secondary stakeholders influence the operational and collective choice rules in the enhancement system. This includes formal laws that may stipulate technical details of operational rules such as closed seasons, or the way primary stakeholders are allowed to organise and make decisions at collective choice level. Research providers, analysts and extension officers (the target audience of this guide) also form part of the external arrangements. Being aware of this role and understanding and improving links to the collective choice level is an important element of effective support for the development of enhancements.

Institutional arrangements and patterns of interaction

Patterns of interaction are the aggregated actions of primary stakeholders, as influenced by the incentives provided by situational variables. The key issue here is that, although rules are designed to be followed, whether individuals decide to do so or not is dependent on their own decisions. Frequently there is a significant difference between what rules prescribe and what is actually done. This applies to both the stocking and fishing aspects of enhancement systems: rogue stocking of exotic species or fish infected with diseases can be as much of a problem as poaching.

An individual's decision whether or not to follow rules is influenced by his or her expectations of costs and benefits of different courses of action, internal norms of behaviour and discount rates. The actions of primary stakeholder are thus determined in a complex way not only by existing rules, but by their perception of benefits from following the rules, the degree to which others follow rules, the likelihood of getting caught when breaking rules, etc.

Institutional analysis and design (IAD) has identified properties of institutional arrangements that are often associated with good rule compliance and institutional sustainability in common pool resource systems (Table 3). These characteristics are highly relevant to the design of institutions for enhancement systems.

Table 3. Design principles illustrated by long-enduring CPR institutions (Ostrom 1990)

1. Boundaries of the resource and those who can use it are clearly defined
2. Appropriation and provision rules are adapted to local conditions
3. Collective-choice arrangements allow participation of resource users in designing operational rules
4. Rule monitors are appropriators or at least are accountable to them
5. Sanctions are graduated, taking consideration of the seriousness and frequency of the infraction
6. Low-cost conflict resolution mechanisms exist to solve disputes
7. Rights of user-communities to devise institutional arrangements are not challenged by external government authorities.

Enhancement and institutional transformations

Often, existing institutions must be transformed to allow sustainable enhancements to develop. The introduction of new enhancement technologies can provide strong incentives for collective action by resource users where users themselves invest in the technology, and conducive conditions exist (Table 5). This has been demonstrated for example in small waterbody fisheries in Laos where stocking has precipitated the rapid proliferation of community management systems, and in coastal scallop enhancements in New Zealand. It has long been recognized that perceived crises such as stock collapses can provide the impetus for collective action and co-management, and the experiences from Laos and elsewhere suggest that perceived opportunities for enhancement can play a similar role.

Table 4. Characteristics encouraging institutional transformation (Adapted from Garaway 1999).

1. Number of decision makers low
2. Similarities of interest of decision makers and resource users
3. Number of participants minimally necessary to achieve collective benefit is low
4. Presence of skilful leaders
5. Presence of individuals willing to undertake entrepreneurial efforts or persuade existing organisations to be involved
6. Presence of shared norms that restrain opportunistic behaviour and create conditions for mutual trust and reciprocity
7. History or prior experience of similar institutional transformations
8. Autonomy to change rules
9. Characteristics of the external political regime
10. A crisis or significant opportunity perceived by all key stakeholders

Further reading: See Ostrom (1990); Pomeroy & Berkes (1997); Lorenzen & Garaway (1998); Pickering (1999); Garaway et al. (2006), and Drummond (2004) for key aspects of institutional arrangements relevant to enhancement.

2.4 The importance of system level dynamics

Often, outcomes of enhancements can be understood on the basis of a small number of key influence pathways. Many of the pathways, both 'operational' and 'dynamic' likely to be of interest have been mentioned in the previous section. In some cases however, outcomes involve radical transformations of many aspects of the resource system which are not easily predicted when viewing individual pathways in isolation. Interactions may act synergistically, and system level dynamics can then only be understood in an integrated framework.

An example of such a radical, system level transformation is the development of enhanced community fisheries in Laos. Small water bodies in Laos are used intensively by rural people engaged in diversified semi-subsistence livelihoods. The development of aquaculture-based enhancements in these systems has radically altered virtually all aspects of the fisheries system. With the advent of stocking, instead of individuals fishing at their own discretion, the fishing and subsequent utilisation of fish (usually sold to generate community income) is organised collectively by the village community, with individual use of the waterbodies restricted, if not banned completely. Benefit has therefore turned predominantly from direct individual benefit to community benefit and from a source of individual nutrition and possibly income to community income (part of which is returned to individuals in the form of reduced contributions to community activities). Water bodies managed as aquaculture-enhanced fisheries are characterised by higher yields and lower levels of fishing effort on average than comparable water bodies managed as unrestricted capture fisheries. The resulting yield and efficiency gains are attributable to both, increased ecological fish production from the stocked species and reduced harvesting effort. In addition and perhaps surprisingly, the abundance of wild fish stocks is also higher in aquaculture-enhanced community fisheries; a result of harvest restrictions that effectively create a refuge for small indigenous fishes.

Further reading: Lorenzen & Garaway (1998); Lorenzen et al. (1998a) Drummond (2004) and Garaway et al. (2006).

3 Analysing fisheries enhancement systems

It is clear from the general outline of fisheries enhancement systems above that in order for an analysis to contribute effectively to the sustainable development of such systems, it must:

- Engage with key stakeholders through a participatory analysis and planning process
- Use a systems perspective and framework to capture the multiple factors that determine the effectiveness of enhancements, and their interactions
- Provide quantitative predictions of the effect of alternative development options on core biological-technical and economic indicators

This section outlines a participatory, integrated process framework for such an analysis and its interface to the quantitative analyses supported by the ***EnhanceFish*** tool.

3.1 Analysis as a learning process

An overview of a participatory, integrated process for analysing and developing fisheries enhancements is given in Figure 6. The process has five steps, four of which may be iterated repeatedly throughout the development process.

Step 1: Engage stakeholders

In this initial step, stakeholders are identified and engaged in the development and analysis process. Baseline information required for a broad, integrated analysis of the enhancement system is obtained from a variety of sources including the stakeholders. An important output of this step should be the creation of institutional arrangements (formal or informal) that allow effective two-way interaction between analysts and other stakeholders.

Step 2: Understand the enhancement system

A broad, integrated analysis of the enhancement system is conducted. This is best done by an interdisciplinary team in direct interaction with stakeholders. The process should foster a joint and integrated understanding of the system, problems affecting its effectiveness and sustainability, and realistic options for improving the system.

Step 3: Conduct ***EnhanceFish*** analysis

EnhanceFish analysis is carried out by qualified resource management professionals. It involves translating the broad and often qualitative system

properties and development options identified in Step 2 into quantitative parameters and controls used in ***EnhanceFish***, and vice versa.

Step 4: Initiate management action and monitoring

Outcomes of the ***EnhanceFish*** analysis are communicated to stakeholders. Stakeholder decision making on management and development options is facilitated as required, and a monitoring programme set up to allow subsequent evaluation of development outcomes. Depending on the level of uncertainty in predicted outcomes and associated risks, explicitly experimental management options may be implemented in order to reduce uncertainties.

Step 5: Evaluate outcomes

Outcomes are evaluated jointly by analysts and other stakeholders. If outcomes are judged to be unsatisfactory or sub-optimal, the analysis process may be re-iterated. Knowledge gained is incorporated into the understanding of the enhancement system (Step 2), the ***EnhanceFish*** analysis refined (Step 3) etc.

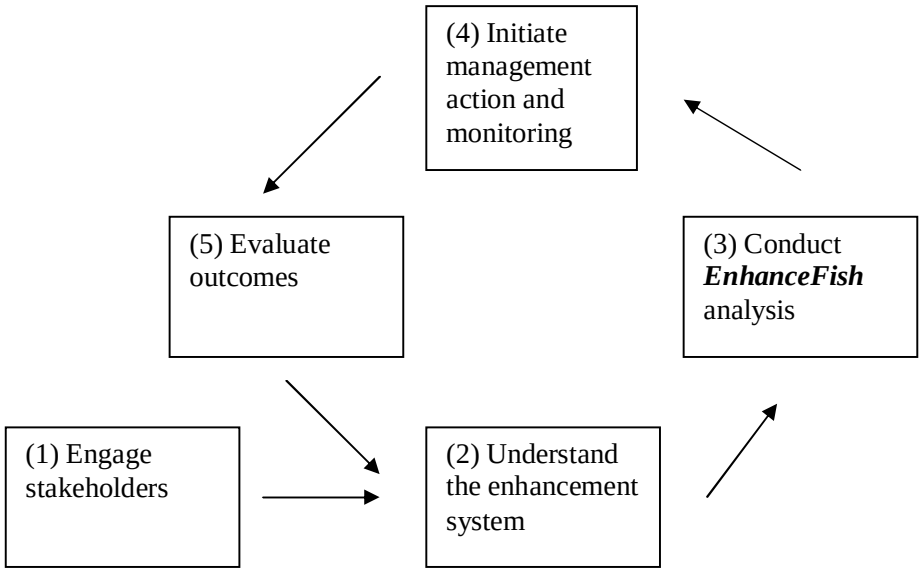

Figure 6: Suggested process for developing or improving fisheries enhancements, and the role of the *EnhanceFish* analysis

Further reading: Lorenzen & Garaway (1998); Garaway & Arthur (2002).

3.2 Getting started

3.2.1 Collating existing information

The first step is always to collate and synthesize existing information. Where analysis is carried out as part of development projects, information on many aspects may be extensive and well documented. The Checklist in Appendix 1 may be used to ensure that key areas of information are covered.

3.2.2 Engaging stakeholders

Engaging stakeholders early on the process is crucial for the analysis to contribute to sustained action and better management of the enhancement. Stakeholder participation in analysis and decision making exploits local knowledge and promotes ownership of outcomes and their implementation.

Some recommended principles of stakeholder engagement and participation are (adapted from Lorenzen et al. 2006):

- Clear affirmation of the roles of all stakeholders is needed at each stage of the analysis. Opportunities should be created for all views to carry weight.
- Inclusiveness is important, and an initial stakeholder analysis (during screening and scoping) plays a key role in identifying and classifying all relevant stakeholders.
- Appropriate mechanisms and methods should be used to facilitate participation.
- Flows of information and feedback should be maintained throughout the process to all stakeholders. Dissemination of information to all groups should be in a common user-friendly format.

Further reading: World Bank (1996); ELDIS (2006).

Figure 7. Engaging stakeholders at all relevant levels is crucial to the development of enhancements.

3.2.3 Stakeholder analysis

Stakeholder analysis is a tool commonly used to initiate participatory processes, and to identify and invite participation by stakeholders. The analysis helps to ensure that all potential views are adequately considered in the planning and decision making process. It will ideally be conducted as one of the initial activities in the analysis process, and involves

- Identifying all stakeholders (persons, groups and organisations with a valid interest in the fishery).
- Establishing the nature and strength of each stakeholder's interests, and the interactions between stakeholders. Visualizations techniques such as diagrams mapping stakeholders and their interactions can be very helpful, particularly if used in a workshop setting.
- Assessing whether the identified stakeholders should be subdivided further, for example by wealth, gender, or occupational groups.

Further reading: ODA (1995); Grimble & Chan (1995).

3.2.4 Participatory appraisal

Rapid and participatory appraisal (RRA and PRA) is a suite of approaches designed to facilitate constructive interaction between development professionals and local people, usually within a project framework. RRA is more extractive, aiming principally to help the development professional to understand the local situation, whilst PRA aims to foster decision making and sustained action by local people. RRA and PRA are flexible and open-ended approaches which seek multiple perspectives and use systematic cross-checking rather than statistical analyses to judge information credibility. A wide range of specific methods including semi-structured interviews and visualization techniques such as mapping, scoring and ranking are used to facilitate communication between development practitioners and local people.

Participatory appraisals should not only gain relevant information for outside analysts and stakeholders, but also establish a rapport with stakeholders and catalyse processes of co-operative decision making (i.e. create common decision making arrangements between resource users and outsiders). This is a crucial step in setting up an adaptive management regime, and the difficulties involved should not be underestimated. Details of implementation will depend on specific circumstances.

Most development practitioners will already be familiar with PRA. For those who are not, we recommend the further reading below. PRA approaches are best

learned through practice, therefore attending a practical course or working alongside an experienced practitioner is highly recommended.

Further reading: Chambers (1992); Townsley (1996).

3.2.5 Livelihoods analysis

It is not usually necessary to conduct a full livelihoods analysis as part the development of enhancements, unless major livelihoods impacts are foreseen or the poverty alleviation is the primary reason for developing the enhancement. However, an assessment should be made of the role of fishing in livelihoods, guided by the questions:

- To what extent is fishing a sole source of livelihood, or a supplement to farming and other activities?
- What are the characteristics and importance of the other main livelihood activities, e.g. farming.
- To what extent do the poorest and most vulnerable households rely on fishing as part of their livelihood strategy?

Further reading: DFID (1999); Ellis (2000); Allison & Ellis (2001); Smith et al. 2005.

3.3 Understanding the enhancement system

The aim of gaining a broad-based and integrated understanding of the enhancement system is to establish key factors determining the current outcome of fisheries resource use. This understanding also forms a good basis for assessing how any changes in situational variables are likely to influence outcomes. The analysis thus has two main stages: understanding causes of current outcomes, and predicting the effects of interventions on the system. Both stages make use of the enhancement systems framework outlined in Section 2.

3.3.1 Understanding causes of current outcomes

Causes of current outcome are best understood by synthesizing the information on the system attributes within the framework of Figure 2. The checklist in Appendix 1 covers key aspects of all attributes, arranged so that it should be straightforward to transfer the information into the framework of Figure 2. Once information has been synthesized in this way, the analysis involves establishing linkages between the attributes. A useful approach is to work backwards through the framework, starting from the outcomes (physical as well as livelihoods

outcomes) and tracing these back to situational variables directly, and to the patterns of interaction. The factors determining the latter can then be traced back to the situational variables on the left hand side of the diagram. An example of this diagnosis is given in Figure 8.

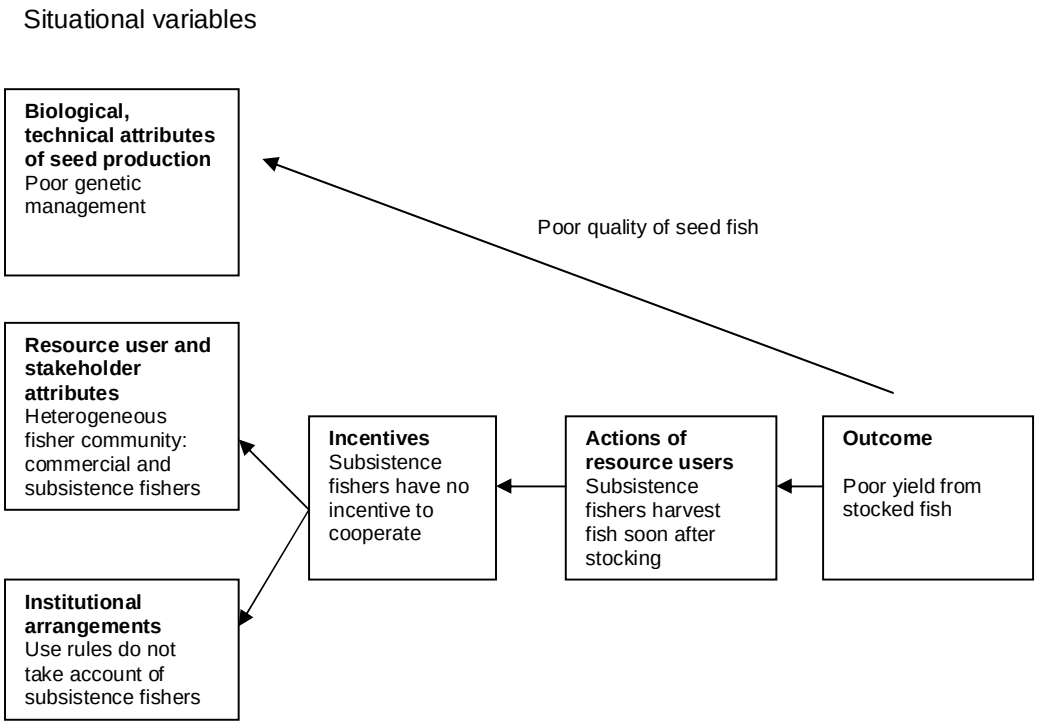

Figure 8: Example of 'working backwards' through the enhancement system framework to identify reasons for an observed outcome (poor yield).

3.3.2 Predicting the effects of interventions on the system

Once an initial diagnosis of the system has been conducted, it is time to identify immediate development objectives and possible courses of action that may lead to the achievement of those objectives. The identification of immediate objectives and possible courses of action is a participatory process, which follows naturally from participatory approaches to information gathering. The role of the analysts is to facilitate the process, and to contribute their analytical skills, and their general knowledge and experience. It is best to identify a range of possible options, including "do nothing". Options may involve institutional as well as technical aspects.

To predict likely outcomes of the different courses of action, it is best to work forwards through the framework established in Section 3.3.1. The approach is to ask 'if we change attribute X, how will this affect the outcomes directly, and via its influence on resource user action (patterns of interaction)?' Predictions at this stage will be qualitative, but all those questions that involve responses in biological-technical aspects of the enhancement may be 'translated' into quantitative analyses that can be conducted using ***EnhanceFish***.

Further reading: Pido et al. (1996).

3.4 EnhanceFish analysis

The ***EnhanceFish*** tool supports quantitative analyses of responses in

- overall economic rent
- yield from wild and stocked population components
- biomass of wild and stocked population components
- age structure of wild and stocked population components

to changes in

- fishing effort,
- gear selectivity,
- stocking density, and
- stocking size
- quality of stocked fish

For details of the ***EnhanceFish*** tool and the analyses it supports, see the ***EnhanceFish*** manual.

An important task in the ***EnhanceFish*** analysis is to 'translate' qualitative understanding of the system and management options into quantitative parameters and controls used in ***EnhanceFish***. Likewise, quantitative predictions may have to be translated back into more synthetic and possibly qualitative indicators used by stakeholders in decision making. These translation processes linking ***EnhanceFish*** to the wider analysis and development process outlined here are illustrated in Figure 9.

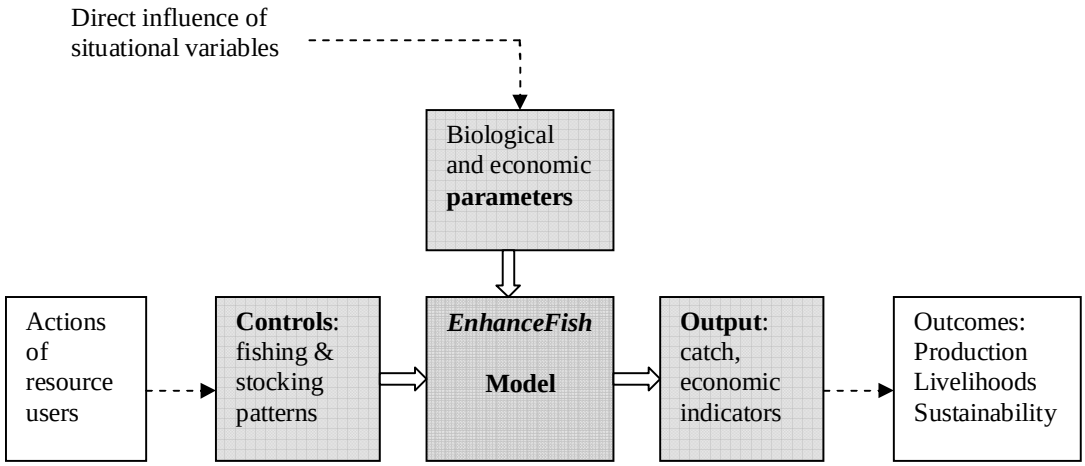

Figure 9: The *EnhanceFish* model and its links with the enhancement systems framework (Figure 2). Dashed arrows indicate translations from broad, sometimes qualitative system properties into quantitative inputs of *EnhanceFish*, and vice versa.

3.5 Initiating management action, monitoring and evaluation

Initiation of management action should not be particularly difficult if joint decision making arrangements have been established, and stakeholders engaged in the previous steps of the analysis.

Key steps will involve

- Communicating analysis results to stakeholders
- Facilitating decision making
- Possibly, conducting management experiments
- Setting up a monitoring system
- Evaluating outcomes of management

3.5.1 Communicating analysis results to stakeholders

The ability of stakeholders to predict outcomes directly affects the patterns of interaction, and ultimately the outcomes themselves. Predictions made by external analysts may precipitate changes in technology or operational rules and therefore have a more indirect effect on outcomes. For predictions by external agents to be useful in resource management, they must be relevant to the objectives of stakeholders and the courses of action available to them. The

confidence stakeholders place in such predictions may also have a major impact on actions.

Effective communication between analysts and other stakeholders is thus of utmost importance. A good approach is to review the role of different stakeholders in the enhancement system, and to define specific communication objectives for each group of stakeholders. This helps to target communication to the needs of the particular stakeholder group. It may be useful to draw up a communication matrix such as that outlined in Table 5.

Table 5. Outline communication matrix

Communication stakeholders	**Current knowledge, attitude, practice of stakeholders**	**Desired outcome of communication**	**Communication channels and media**
Fishers	Fishing targets the full size range of fish present	Fishers appreciate that targeting only larger fish can increase yield from the enhancement	Village meetings
Aquaculture producers	Fingerlings for stocking are transported in open truck during the day and released immediately	Aquaculture producers understand that transport during the night and acclimatization before release improve survival	Extension materials
State fisheries department	Fisheries department records only stocking numbers and does not monitor or evaluate effectiveness of enhancement	Fisheries officers understand that effectiveness of enhancements can be improved by monitoring and evaluation using EnhanceFish	Policy brief for senior fisheries officers

Further reading: Norrish et al. (2001).

3.5.2 Decision making

Decision making about courses of action flows naturally from the participatory processes of resource system analysis and evaluation of options. This does not mean, however, that decision making is straightforward. Decisions about enhancements often involve conflicting interests, multiple objectives, and large uncertainties.

Trade-off analysis is a process in which stakeholders and analysts engage to assess the merits of different management options, and to explicitly determine priorities and make choices. It uses the information generated, and framework established in Step 2 and Step 3. Trade-off analysis is a tool that can help decision-makers understand resource use conflicts and stakeholders preferences for management.

The major stages in a trade-off analysis are as follows:

1. Begin by drawing on the stakeholder analysis to establish stakeholders, their interests and possible conflicts (Steps 1 and 2 in Figure 6).
2. Generate a set of possible management options and evaluate the likely effects of different options and criteria against which to assess these (Steps 2 and 3 in Figure 6).
3. Use multi-criteria analysis to generate a ranking of options from least preferred to most preferred outcome.
4. Subject the results to sensitivity analysis and/or scenario planning to assess uncertainty.
5. Seek final decisions on preferred alternatives through review and iteration of the analysis with stakeholders

Trade-off analysis as outlined above can be undertaken at a range of levels of participation and available information.

Further reading: Janssen (1994); Brown et al. (2001); Lorenzen et al. (2006).

3.5.3 Experimental management

If uncertainties in the outcome of alternative management options are low and courses of action can be identified that will almost certainly lead to the achievement of objectives, these courses of action may be implemented. If uncertainties are high, it is important to assess whether a reduction in these uncertainties is likely to allow substantially improved management regimes to be developed. When this is the case, the reduction of uncertainties becomes an important objective in its own right, and courses of action should be evaluated for their potential to yield the necessary information. Experimental management may be passive, i.e. rely on "natural" variation in management regimes to generate information, or active when variation is introduced deliberately. Which of the two adaptive strategies is implemented will depend on specific circumstances, including the degree of control that can be exercised over management actions.

The costs of setting up, monitoring and evaluating management experiments can be considerable, and therefore experimental management should be implemented only where anticipated benefits warrant this expenditure.

Steps in designing experimental management interventions should include:

1) Identify/clarify the management intervention(s) to be implemented experimentally.
2) Identify specific and measurable criteria for the success of the intervention (e.g. increase in yield by at least 20%).
3) Decide on an experimental design and monitoring programme. Key issues are:
   - replication - ideally, this should be temporal (before and after intervention) as well as spatial (parallel measurements at similar sites where no intervention has been carried out);
   - contrast - the intervention should be substantial in order to have a measurable effect;
   - sampling effort - each replicate unit must be sampled with sufficient intensity to allow detection of an impact of the expected magnitude.
4) Calculate and compare costs and expected benefits of experimental management.

Further reading: McAllister & Peterman (1992); Walters (1997); Lorenzen & Garaway (1998); Garaway & Arthur (2002).

3.5.4 Monitoring and evaluation

The design of monitoring programmes should be based on the relevance of indicators and principles of sound experimental design. In particular, adequate temporal and spatial replication should be ensured, and experimental treatments should offer sufficient contrast to yield the required information.

Monitoring programmes for outcomes of interventions in enhancement systems should encompass indicators of key attributes of the fisheries system as outlined in Section 2. In general, monitoring a limited number of simple indicators will be sufficient. Where a decision making process is in place, it is best to determine indicators and sampling strategies within this process.

Further reading: McAllister & Peterman (1992); SEAFDEC (2004).

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Appendix 1: Checklist

The following checklist is intended to aid the collection and synthesis of information required for analysis of the enhancement system. The questions assume that an enhancement is already operational, but most apply in a similar way to planned enhancements.

Situational variables

The physical environment and ecosystem

- Briefly describe the basic physical characteristics of environment in which the enhancement operates. Is the environment coastal, riverine, a lake or reservoir? How large? Is it natural, modified or man-made?
- What are the main aquatic resource species known to occur in the environment?
- Is it easy to monitor fishing activities in this environment?

The target population

- What are the target species for enhancement?
- Are naturally recruiting populations of the target species present?
- Are the target species native to the area?
- Are any existing populations of the target species deemed to be in decline or threatened? Why?

Fishing techniques

- What gear types are used in the fishery?
- How selective are the different gear types for species and sizes?
- How many fishers operate in the fishery?

Aquaculture production and stocking

- Briefly describe how the seed fish are produced (broodstock, hatchery and nursery facilities and practices)?
- Are the seed fish produced in commercial hatcheries supplying the aquaculture industry, or in specialist enhancement hatcheries?
- Where does the broodstock originate from? For how many generations has it been maintained in captivity?
- Is any genetic management being carried out in the broodstock, e.g. inbreeding avoidance or selective breeding?
- Are any specific measures taken to promote post-release survival of seed fish in the wild?
- At what size, and in what numbers are the target species stocked?

Stakeholders

- Who are the primary and secondary stakeholders in the fishery? Primary stakeholders are those who gain benefits or bear costs of the fishery, e.g. fishers, seed producers, and owners of fishing rights. Secondary stakeholders are others who influence the fishery, e.g. the fisheries department, veterinary officers or conservation organisations.
- Are the identified groups heterogeneous? For example, are there groups of fishers that differ in terms of the gears they use, their access to the fishery, the role fishing plays in their livelihoods, etc.?
- Characterize the role fishing plays in the livelihoods of fishers. Is fishing geared mainly towards household consumption or the generation of cash income? What other livelihoods activities do fishers engage in?
- What functions are performed by the secondary stakeholders? E.g. access regulation, conflict resolution, stocking decisions, financial management, research?
- How do the different stakeholders interact?
- What are the objectives of the different stakeholders with respect to the fisheries enhancement?

Markets

- Are there markets for seed fish used in fisheries enhancement? Briefly describe the marketing arrangements.
- Are the products of enhancement marketed? Briefly describe the marketing arrangements.
- Is there significant capture fisheries or aquaculture production of the same or similar commodities?
- Do fishers participate in the general labour market? Are they known to take jobs outside the fishing sector at times?
- How is the fisheries enhancement financed?

Institutional arrangements (rules and regulations)

(a) Operational rules (rules about how the fisheries resource can be used)

- Is access to the fishery open to all, communal (limited to members of a community or group), or subject to private use rights (e.g. leased to an individual)?
- What are the formal rules (i.e. laws, regulations) that apply to stocking and fishing?
- Are there any informal rules?
- Are the activities of stocking and harvesting coordinated in any way? If so, how and by whom?
- To what extent do beneficiaries contribute to costs?
- Would it be possible to recover costs from beneficiaries if this is not presently the case?

(b) Collective choice and external arrangements (these determine how the operational rules are made)

- How and by whom are operational rules made?
- Are fishers involved in making operational rules, either by themselves or in cooperation with government or other outside organisations?
- Have there been any changes to institutional arrangements in the recent past? If so, why?
- Do arrangements change frequently (e.g. water bodies that are rented out in some years and not in others?)

Patterns of interaction among resource users

- In general, do resource users follow the formal and informal rules described? Why or why not?
- Are there known conflicts between users or specific groups?

Outcomes

- What is the total fisheries catch? If expressed per area (e.g kg/ha), how does this productivity compare to other fisheries?
- Size distribution of the catch. Are fish harvested at a small or relatively large size?
- What is the catch of stocked species? What is the contribution of stocking to total catch?
- Is there any indication of negative impacts of enhancement on natural populations?
- Do fishers share equitably in any benefit from enhancement? Are any fishers disadvantaged as a result of the enhancement, e.g. people no longer allowed to fish or use certain gear types?
- Do stakeholders consider the enhancement beneficial? Why or why not?

Research and communication

- How are the different 'controls' (management variables) of the enhancement fishery determined: target species, stocking size, stocking density, fishing effort, selectivity of fishing gear?
- Has systematic research been carried out on any of these controls? If so, has this influenced the way the fishery is actually managed?
- Which organisations are involved in research on the fishery?
- How do researchers communicate with other stakeholders, e.g. through participatory appraisals or planning, formal surveys, extension messages?
- Can you think of ways in which the interaction between researchers and other stakeholders can be made more efficient?

Specific quantitative data

Certain kinds of quantitative data are very useful for the ***EnhanceFish*** analysis, and you may want to check for the availability of such data at the time of completing the checklist.

Technical fisheries data

- Fisheries catch, broken down by species if possible
- Length frequency distribution of catches, broken down by species if possible
- Stocking data: number and size released
- Has the fishery been stocked in the past, are there reliable stocking data?
- Stocking and recapture data for marked fish
- Have any genetic studies been carried out on the target populations?

Economics/markets

- Costs of seed fish on the market, or estimated production costs when markets do not exist. Break down by size of seed fish if this information is available.
- Costs of fishing gear: nets, boats etc. How long do these items normally last?
- Cost of labour: what is the going wage rate for fishers in the fishing sector and elsewhere?
- Price achieved by fishers for the produce. Break down into wild and stocked species and different sizes where relevant.