HOW PREDICTABLE IS THE OUTCOME OF STOCKING?

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ABSTRACT

Stocking is a technical intervention into aquatic resource systems of great complexity. The outcomes of stocking are determined by natural, institutional and socio-economic conditions which vary greatly between individual systems, and this implies a need to adapt management regimes to local conditions in order to achieve desired outcomes. Prediction of the outcomes of different potential courses of action is a key step in the development of appropriate management regimes. We describe various models that are available to predict outcomes of stocking in technical, institutional and socio-economic terms. Predictions are usually fraught with uncertainties, which may be extremely large in situations where little knowledge of the resource system and previous experience of stocking outcomes exist. It is therefore important to conduct a broad-based diagnosis of the resource system prior to a prediction of stocking outcomes, and to make provision for adaptive learning from management experience, with consequent changes in policies and procedures. In situations of large uncertainty, deliberate management experiments may be conducted to generate the information needed to develop appropriate management regimes. Rigid guidelines for management may prevent adaptive learning and should be avoided unless there is solid empirical evidence for their superiority over alternative regimes that might evolve from the learning process. The role of analysts should be to facilitate and guide the learning process, rather than to devise rigid guidelines on the basis of insufficient information.

1. INTRODUCTION

Stocking is a technical intervention in existing, often complex aquatic resource systems. The outcome of this intervention is determined by natural, institutional and socio-economic conditions which vary greatly between particular systems. This raises the question to what extent outcomes can be predicted, and how appropriate management regimes for stocked fisheries can be developed when uncertainties are large.

We will address the question of predictability in several steps. In the following section l, we clarify the meaning of “outcome”, and explore how outcomes are determined. We then discuss the role of prediction in management in section 2, and provide an overview of the tools available for prediction in section 3. In section 4, we identify sources of uncertainty in predictions, and in section 5 we outline an approach to the development of stocked fisheries under conditions of large uncertainty. We conclude with a set of key recommendations for the use of predictions in stocking enhancement.

2. OUTCOMES AND HOW THEY ARE DETERMINED

When discussing the outcomes of stocking, the first issue that has to be addressed is “what outcomes of stocking are we interested in measuring or predicting?”

Stocking is the simple technical act of releasing fish into some body of water and, traditionally, outcomes of stocking have also been understood in narrow technical terms such as increases in yield, or high recapture rates. This focus reflects an implicit assumption that an increase in fish production would automatically lead to an improvement in human welfare. It has since been shown that stocking may affect how and by whom aquatic resources are used, with consequences for the equity and sustainability of aquatic resource use (e.g. Samina and Worby, 1994; Garaway, 1995). By catalysing changes to management systems and particularly, rights of access, stocking enterprises can have unexpected and possibly deleterious outcomes for some groups of people. This suggests that “outcomes” need to be considered in broader terms than has traditionally been the case, explicitly measuring affects on human as well as fish populations. A second reason why outcomes need to be considered in broader terms is the tendency of many agencies to set broad objectives for fisheries development, such as sustainability, which encompass a diverse set of attributes.

Any attempt to predict outcomes requires analysis of the variables that determine them. Obviously, the broadening of the concept of outcomes requires a broadening of variables to be analysed, including variables in the socio-economic as well as the biological/technical sphere. Perhaps less obvious is the fact that sometimes, even the technical outcomes of stocking can not be understood on the basis of technical considerations alone. Technical outcomes are the result of the physical and biological nature of the resource and how people interact with it. Many models for predicting the technical/biological outcomes of stocking take the type and level of human interaction with the resource, such as fishing effort, as given or at least controllable. This may be appropriate in environments where human action can easily be controlled, such as when a small number of individuals are employed in a private aquaculture venture. However, the majority of resources targeted for stocking enhancement are common pool resources which are under common property rights or have no property rights attached to them (open access). In such situations, human action is costly or even impossible to control, making models which assume certain types and levels of human interaction as given insufficient for the prediction of outcomes.

What is needed, therefore, is a framework for analysis which allows us to broaden our concept of outcomes while encompassing more of the variables that affect them, including social, economic and institutional variables as well as technical ones. The increasingly multidisciplinary approach to resource management, in general, has enabled such frameworks to be developed.

2.1 A framework for analysis

Oakerson (1992) adapted frameworks for institutional analysis and design (IAD) to specifically relate to the analysis of the commons. His approach shows the interrelation between the resource base and the social organisation that evolves to manage and control it- the underlying determinants of outcomes. The framework is not a fully specified causal model but “a heuristic tool for thinking through the logic of a situation and considering alternative possibilities” (Oakerson, 1992). This has become the conceptual framework within which many analysts are now discussing common property regimes, allowing for comparison of a wide range of systems, including those involving enhancement.

Oakerson's framework is illustrated in Figure 1. There are four main attributes classified as biological, physical and technical attributes of the resource; decision-making arrangements; patterns of interaction; and outcomes. Decision-making arrangements consist of the 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 rules and conditions of collective choice. Patterns of interaction are the aggregation of all the actions taken by individual resource users over a period of time. Outcomes are physical (e.g. production or consumption) 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.

Relationships between the attributes are represented by arrows in Figure 1. Some biological, physical and technical attributes of the resource are hard constraints in that they affect the outcome of resource use independent of human action (e.g. natural productivity or population dynamics). These attributes set the limits to what outcomes are achievable in any given system (arrow a). However, the physical and technical attributes of the resource also affect outcomes indirectly by influencing human action. The nature of the resource, along with rules in place to determine its use (decision-making arrangements), provide the range of opportunities open to users of the resource. Individuals make decisions on the basis of these (arrow b and c) and their resulting actions (patterns of interaction) directly affect outcomes (arrow d).

Interactions between attributes of the resource system are classified here as two types. Operational interactions determine outcomes during normal resource use, when physical, technical and biological attributes and decision-making arrangements are fixed. Hence operational interactions, indicated by arrows in Figure 1, always lead from the nature of the resource and decision-making arrangements to outcomes.

Dynamic interactions involve changes to the decision-making arrangements or the biological, physical and technical attributes of the resource, and typically occur over longer time spans. Such dynamic relationships are complex and interactions may originate from any attribute, including the outcomes, and lead to any other attribute. To understand dynamic relationships, particularly changes in decision-making arrangements requires the use of a multilevel framework. It is beyond the scope of this paper to describe this framework in full (for more information see Kiser and Ostrom, 1982). In short, three levels of analysis are commonly recognised: the operational level, the collective choice level and the constitutional (external arrangements) level. These have been represented in Figure 2, specifically relating them to common property resources. Using this framework, institutional change at one level (e.g. operational level) is described as the outcome of patterns of interaction at the previous level (collective choice level). This is represented by the solid lines in Figure 2. For example, whilst individual resource users can change their own actions within a certain set of operational rules (operational level), changing the rules requires decisions made by a collective. Who can do this and how this can be done is defined by the collective choice rules in place (collective choice level). What changes will be made to operational rules (outcomes) will depend on the patterns of interaction of these decision makers. The broken lines in Figure 2 represent some of the places where, if at all, information that can catalyse change is fed back into the system. It shows that change can be catalysed at all levels as a result of new information, if that information is made available.

Figure 1. Framework for analysing the commons (Oakerson, 1992).

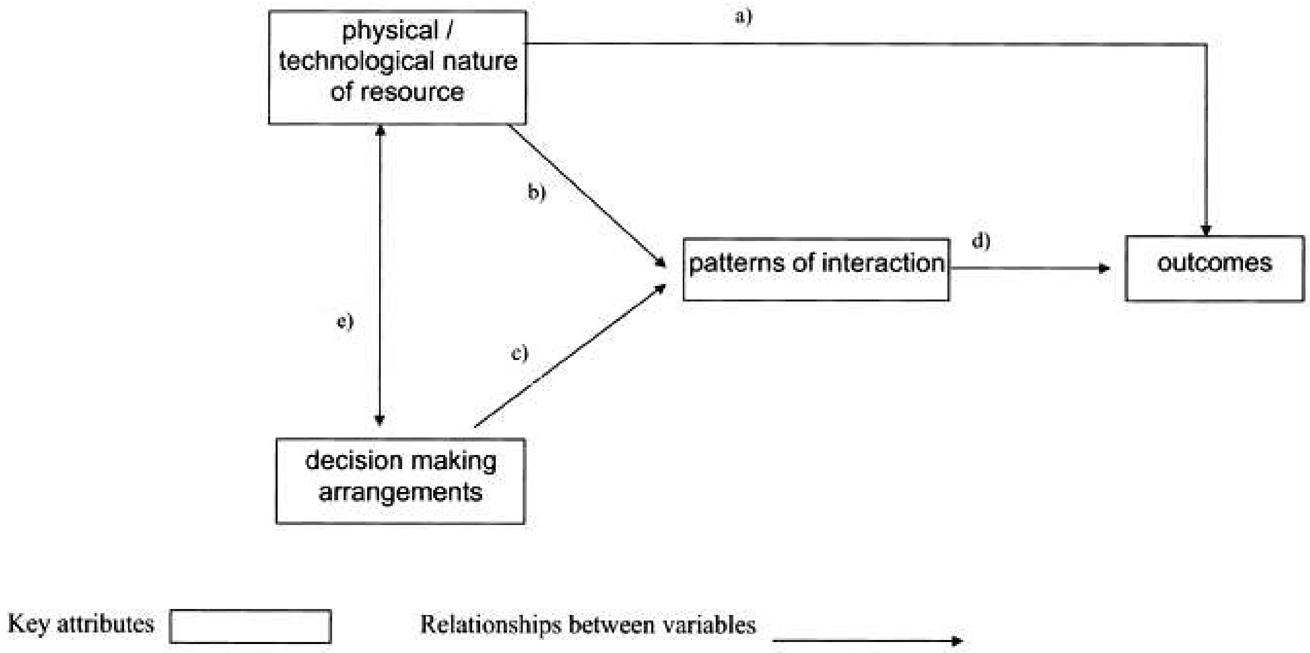
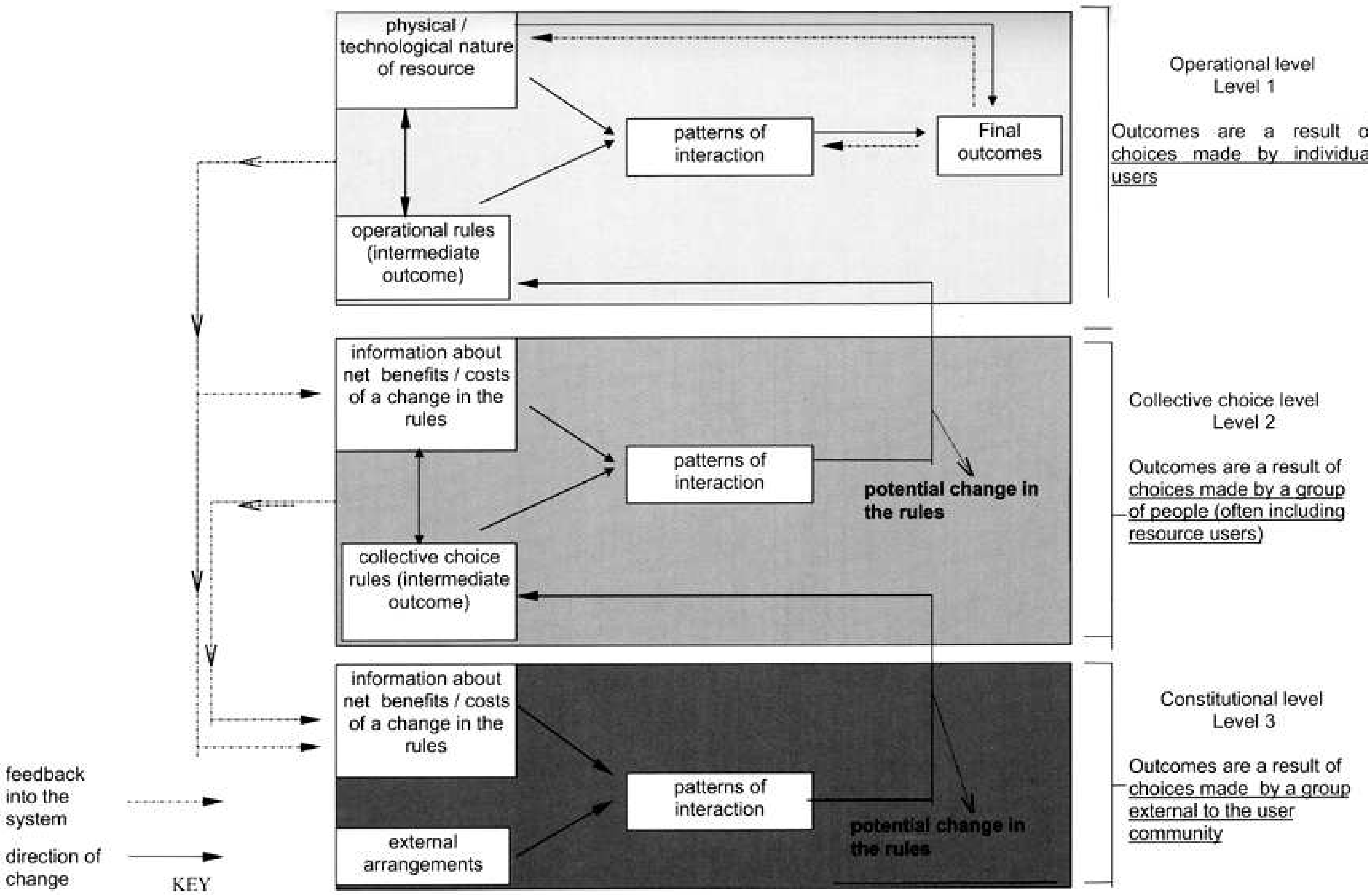


Figure 2. Framework for analysing institutional change in common property resources (by Garaway, C.J. -based on Kiser and Ostrom, 1982; Oakerson, 1992; Ostrom, 1990).



An example from our ongoing research shows briefly how the framework illustrated in Figures 1 and 2 can be used to understand the logic of a situation that has been affected by stocking. Later in the paper, we discuss how the framework, along with other tools, can be used to diagnose the causes of problems linked to stocking outcomes, and evaluate possible solutions.

2.2 An example

In Savannakhet Province, Lao PDR, stocking of small reservoirs and lakes is actively promoted by the government and the practice is spreading rapidly. In some cases, particularly where water bodies in the immediate vicinity of the village have been stocked, the stocking has altered the type, degree and distribution of benefits obtained from small reservoirs.

Traditionally, lakes and reservoirs in Savannakhet are open for fishing by all members of the local community, although some restrictions may apply. Most households engage in subsistence fishing on a part-time basis, but it is widely perceived that the poorest members of the community fish the most and sell fish, usually on an ad hoc basis.

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 reservoirs 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. Changes in the fish yield are difficult to assess because the previous consumptive uses are almost impossible to quantify. However, comparative test fishing information suggests that standing stocks of fish are higher in stocked lakes than in non-stocked lakes. In particular, stocks of wild fish seem to be consistently high in stocked lakes, while the contribution of the stocked species is variable. This suggests that the change in management has effectively lowered fishing pressure, and that this indirect effect of stocking may affect standing stocks and probably yields to a greater extent than the direct effect of creating a new stock.

The Oakerson framework can be used to describe how and why these changes came about. The change in fishing effort (patterns of interaction), one of the two major determinants in the physical outcomes of stocking (yields), can only be explained with reference to the rule changes that accompanied the stocking and the incentives these created for rule compliance. These changes to the operational rules can only be explained, in turn, with reference to the biological, physical and technological nature of the resource and the external arrangements and conditions for collective choice (decision-making arrangements).

The investment in stocking (change in technology) has increased the perceived value of the resource. Stocking was only possible due to, firstly, the provision of credit, advice, fingerlings and transportation by the government hatchery, and, secondly, government policy, which gives villages *de facto* property rights over communal water bodies in/near their village (external arrangements). It is these rights which encouraged villagers to invest in their natural aquatic resources in the first instance. Government policy also gave legitimisation/authority to collective choice rules, thereby allowing villagers to change and implement new and binding operational rules regarding the use of small water bodies.

The operational rules put in place were designed taking into consideration the objectives of the community, the nature and rights of community members and the nature of the resource itself. Rules were chosen that would keep operational costs (including monitoring and enforcement) at a minimum. This appears to be more important than maximising yields/benefits from the resource. For example, only lakes in the vicinity of villages, which are easier to police, were developed as community fish ponds. Also use rules generally include a total ban on individual use and a restriction of community fishing to the period after rice harvesting and before planting. A total ban can be more easily monitored by villagers as they go about their work. The restricted fishing season reflects the time availability of village members. These factors are the primary determinants of the resulting decline in fishing effort.

Rules for distribution of the benefit are chosen to satisfy the need to repay the fingerling loan, the desire for community income, and the rights of all villagers to benefit from the resource. Setting up a collective enterprise (production and consumption) was perceived to be the least costly way of achieving this. Some additional benefits are also directed towards poorer members of the community and to those who are actively involved in the maintenance of the system.

This example illustrates how the simple act of stocking can precipitate dynamic changes affecting virtually all attributes of the resource system, and how even basic technical outcomes may be difficult to understand without reference to institutional dynamics.

3. THE ROLE OF PREDICTION IN RESOURCE MANAGEMENT

Prediction is a key ingredient of aquatic resource use and management. Patterns of interaction result from the choices that stakeholders make following an evaluation of the expected costs and benefits of different strategies/courses of action. These could be actions as a resource user, directly affecting the resource, or indirect actions as a decision maker, making rules to determine resource use. Assuming the principles of rational choice (as defined by Farr, 1985), individuals will choose those strategies which they predict will produce the greatest net benefits (including non-financial benefits). Ostrom (1990) identified four internal variables that affect an individual's choice of strategies: expected costs, expected benefits, internal norms and discount rates. Predictions and perceptions of benefits and costs are dependent on the information available to decision makers. Judgements on the individual importance of the perceived benefits and costs are affected by the internal norms and discount rates that individuals possess. Internal norms are the values that individuals place on actions or strategies in and of themselves, irrespective of immediate consequences (these could include the values individuals place on keeping a promise or doing their share of work). Discount rates are the extent to which individuals discount future benefits at the expense of short-term gains.

The ability of stakeholders to predict outcomes thus 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. Predictions affect the actions of stakeholders at all levels, from direct users to external agents. Unless effective communication is established between these levels, different stakeholders will act on different expectations, and the outcomes are likely to be surprising or even undesirable.

4. TOOLS FOR PREDICTION: MODELS

What models are used or may be used for the prediction of stocking outcomes? This paper is written by and for outside analysts, and we will therefore concentrate on the models that may be used by the likes of us. This should not distract from the importance of the models that resource users themselves use to predict outcomes, and we will later outline ways in which the models used by outsiders and resource users may be integrated.

We have already drawn attention to the importance of integrated analysis, combining variables traditionally associated with different disciplines, in order to predict the outcomes of stocking. Oakerson's framework (Fig. 1) may be used to illustrate the relationship between the fields of analysis and to facilitate integration. In this framework, an institutional analysis is concerned with, amongst other things, explaining and predicting patterns of interaction at the three levels of analysis mentioned earlier. An institutional analyst may, for example, predict what choices fishers will make given the physical characteristics of a resource and the operational rules in place. A technical analysis is concerned with the operational interactions leading to outcomes, both directly from the attributes of the resource system and indirectly, through the patterns of interaction. For such models the patterns of interaction are taken as given. A technical analysis will, for example, predict the yield from stocking based on growth and mortality patterns (attributes of the resource) and fishing practices (patterns of interaction).

4.1 Institutional analysis

Institutional analysis has rarely been applied in the context of stocked fisheries, although Hartmann (1995) and Middendorp et al.. (1996) have covered some ground. Methods of institutional analysis are still at an early stage of development, but we discuss some of the most promising approaches used at present.

Situational analysis

As mentioned above, assuming the principle of rational choice, individuals make decisions on the basis of expected benefits and costs as affected by internal norms and discount rates. Unfortunately accurate summary variables of these are rarely available to resource users let alone outside analysts, therefore no simple calculation process can be employed. Instead, situational analysis (Farr, 1985) is often used to investigate institutional arrangements of common property resource (CPR) management. The approach taken is to describe as fully and as rigorously as possible the situational variables that affect these summary variables in order to describe the decision situation individuals find themselves in. These variables will include attributes of institutional arrangements, attributes of events (in this case the physical, technical and biological nature of the resource) and attributes of the community. The work of Ostrom (1990) has been seminal in providing a framework of situational variables to be described in CPR situations. Having used situational analysis to describe the attributes of a decision situation and by making some assumptions about the individual making decisions, predictions can be made on what individuals are more or less likely to do (Kiser and Ostrom, 1982; Farr, 1985; Ostrom, 1990; Tang, 1995). Assumptions about individual calculation processes are informed by the work of social psychologists.

Game theory

Game theory has more recently been used to predict actions and strategies of “players” in CPR situations (e.g. Ostrom et al., 1994). On the basis of the description of the decision situation, game theorists model situations by manipulating variables such as: possibilities for communication; number of decision makers; repetitiveness of actions. Such models have great analytical and predictive potential. However, the approaches are still being developed and presently are confined to fairly specific decision situations.

There are other models and tools being brought into the study of CPR's from the fields of organisational behaviour (e.g. Robertson and Tang, 1995) and transaction cost economics.

4.2 Technical analysis

Heuristic models

Certain models which make predictions on the basis of general concepts or experience, but not strictly grounded in empirical evidence, are best referred to as heuristic models. Examples are potential yield predictions based on food organism abundance and trophic transfer efficiencies, species choices based on “empty niche” concepts, or “biostandards” of stocking return (examples described in Jhingran, 1986; Li and Xu, 1995; Welcomme and Bartley, this publication). Statistical models are also sometimes used in a heuristic way when they are applied to systems other than those for which they have been derived (e.g. when an empirical yield model for African lakes is applied to Asian reservoirs). Heuristic models are widely used in the context of stocking, to provide indications of development potential as well as specific management guidelines. Unfortunately, it is often difficult or impossible to assess the uncertainties associated with predictions from heuristic models. In practice, there is a tendency for analysts to disregard the often large uncertainties and to mistake heuristic predictions for scientific evidence. If such predictions are translated into management strategies or policy, sub-optimal practices may become engrained and the potential to develop better regimes through experimentation is forgone. Hence heuristic models must be applied very critically, and should be used only to gain initial indications which must be subjected to more rigorous analysis based on empirical evidence and the use of statistical or analytical models. In fact, it may sometimes be better not to use heuristic models at all, but to treat outcomes as entirely unpredictable and to use an explicitly experimental approach to reduce uncertainty.

Statistical models

Statistical models are derived by fitting mathematical formulae to observed data relating yield to environmental and/or management variables. Statistical models describe observed relationships, and are not based on an understanding of underlying processes. Statistical models are derived for a specific fishery or a set of fisheries, usually by analysing representative samples from the full set, and can not be applied to fisheries outside the original set.

Statistical models for stocked fisheries may use explanatory variables such as stocking density, fishing effort and trophic status indicators (e.g. morphoedaphic index, total phosphorus concentration, primary production) to predict yield, with well-defined confidence limits. Statistical models are most useful when substantial data are available or can be collected quickly, and when there is sufficient variation (contrast) in explanatory variables to allow relationships between management variables and outcomes to be estimated. Statistical models may be derived for individual fisheries with long time series of data, or for sets of fisheries which differ with respect to the management variables and natural conditions of interest (e.g. De Silva et al., 1992; Middendorp et al., 1996; Welcomme and Bartley, this publication; Lorenzen et al., in press).

Because statistical models are not based on conceptual insights, they can not predict effects for which there are no empirical data. Statistical models derived for a set of reservoirs which are fished at the same level of effort can not predict what the effects of changes in effort would be.

Analytical models

Analytical models are based on a quantitative understanding of the processes that determine the outcomes of management actions, and may provide general insights into the dynamics of stocked fisheries (e.g. Botsford and Hobbs, 1984; Lorenzen, 1995). In fisheries where sufficient data are available to estimate the parameters of key process models, analytical models are powerful tools for the quantitative evaluation of management options (e.g. Lorenzen et al., in press). Because analytical models are based on an understanding of the mechanisms determining outcomes, their predictions are not limited to management actions for which empirical data on outcomes are available. The development of predictive analytical models is indicated for fisheries where management can be controlled and optimised at a high level of detail (stocking size and density, gear selectivity and fishing effort), and where the value of the fishery justifies the cost of data collection and model development.

Work on models for individual population processes indicates that some parameters may be species specific, or invariant at even higher levels such as ecosystems. The allometric scaling of natural mortality with body weight for example, a key parameter for the assessment of stocking size, appears to be invariant across freshwater and marine ecosystems as well as ecological levels from populations to communities (Lorenzen, 1996). Meta-analysis of parameter estimates from a range of systems may identify other parameters which are invariant or may be described by empirical relationships, and in the future this may drastically reduce the number of parameters that must be estimated for each particular fishery.

4.3 Integrating institutional and technical analysis

The integration of institutional and technical analysis for a comprehensive prediction of stocking outcomes has rarely been attempted, and little definitive guidance can be given in this area. The approach to be used will depend on the specific situation. An initial assessment may show that only isolated attributes (e.g. technical aspects) of the resource system are amenable or liable to change. In this case the predictive analysis can be restricted to the relevant attributes which may lie within the realm of a single discipline. More dynamic situations may occur where resource users respond to and in turn effect changes in outcomes. In this situation, particularly where responses can be readily understood in economic terms, bio-economic or bio-socio-economic models may provide a useful framework for integrated analysis (Charles, 1995). In the most open and dynamic situations, where stakeholders act on expectations and there is little knowledge or experience of outcomes (such as in the example from Laos in section 1), an integrated analysis is most difficult. A possible approach may be to iteratively work through Oakerson's framework, starting where the intervention (e.g. stocking) would have the most immediate effect, and then working through the other attributes that may become affected.

The integration of institutional and technical analyses in areas where these are intimately linked, such as in the intensification of common property resource use, urgently requires further research.

5. UNCERTAINTIES IN PREDICTIONS

Uncertainties in predictions may be categorised broadly as noise, uncertainties about the present state of the resource system, and uncertainties about dynamic behaviour of the system.

5.1 Noise

Noise refers to essentially unpredictable “random” variation in outcomes, often linked to variation in external conditions such as rainfall. Noise can be substantial in stocked fisheries owing to their dependence on natural conditions. In a Chinese reservoir culture fishery under stable management, annual yields fluctuated from 146 t to 309 t around a mean of 233 t over a ten-year period (ZIFF, 1994). A high level of noise means that investment in stocking carries a high risk in the short term, even if average (long term) returns are good. Noise also makes it more difficult to learn from management experience, because responses to management may be difficult to disentangle from noise.

5.2 Uncertainties about the present state of the resource system

Uncertainties about the present state of a resource system necessarily cause uncertainties in predictions. Uncertainties about the present state often concern a wide range of attributes, from the identification of stakeholders and their objectives through to decision-making arrangements, and of course technical aspects such as fishing effort, yield or fish growth rates. Uncertainties about the present state of the system can be reduced almost immediately, prior to any intervention. Often, however, such uncertainties are underestimated by analysts and stakeholders who may be overconfident in heuristic models or disregard important attributes of the resource system altogether. Several documented examples concern lack of consideration of, or simplistic assumptions and over-generalisation with regards to social and institutional aspects of stocked fisheries (Chantarawarathit, 1989; Wood, 1994; Garaway, 1995; Kumar and Hartmann, 1995; Cowan et al., 1997). It is also common for analysts to base management and development recommendations on biased and inaccurate catch data, particularly where small-scale and subsistence fisheries are concerned (Lorenzen, pers. obs.; Coates, 1996).

5.3 Uncertainties about dynamic behaviour of the resource system

Even when the present attributes of a resource system are well known, its dynamic response to change may remain uncertain. For example, even if the conditions of collective choice are well understood, it may be difficult to predict changes in operational rules and therefore outcomes that may result from the introduction of stocking (see the example in section 2). Technically optimal management regimes are determined largely by density-dependent responses in growth or mortality of stocked fish, yet such responses may be difficult or impossible to predict even when accurate estimates of present population parameters are available. Such dynamic uncertainties can only be resolved by actually observing dynamic variation, either over time (e.g. Lorenzen et al., in press) or across systems under different management (Middendorp et al., 1996; Lorenzen et al., subm.). Variation may occur due to factors beyond management control, or may be brought about deliberately.

6. DEALING WITH UNCERTAINTIES IN THE DEVELOPMENT OF STOCKED FISHERIES

Different stocked fisheries may be characterised by widely different levels of uncertainty. At one end of the spectrum are fisheries that operate in a stable institutional environment, and for which there is a large body of specific knowledge and experience that may be used to evaluate management options with a high degree of certainty. Management responsibility may rest with technical specialists who can exert a high degree of control over resource use through established enforcement channels. In such fisheries decision making may follow a “programmed” approach, relying heavily on pre-defined rules and regulations which reflect established management objectives and technical knowledge (Berman, 1980). Programmed approaches to stocking implementation are promoted, but not necessarily followed, in European and North American inland fisheries (Cowx, 1994).

At the opposite end of the uncertainty spectrum are stocked fisheries that operate in a highly dynamic institutional environment, and for which there is little specific knowledge or experience relevant to the evaluation of management options. Technical specialists involved with the management of such fisheries may lack understanding of stakeholders and their objectives, the specific knowledge and experience required to evaluate management options, and the power to enforce management decisions. Under such circumstances, a programmed approach to management and development is unlikely to succeed, and a more adaptive approach is required. An adaptive approach acknowledges uncertainty and lack of control by analysts and planners, and emphasises stakeholder participation and learning from management experience to deal with these problems and to achieve desirable outcomes (Holling, 1978; Berman, 1980; Walters, 1986; Rondinelli, 1989).

6.1 Outline of an adaptive approach

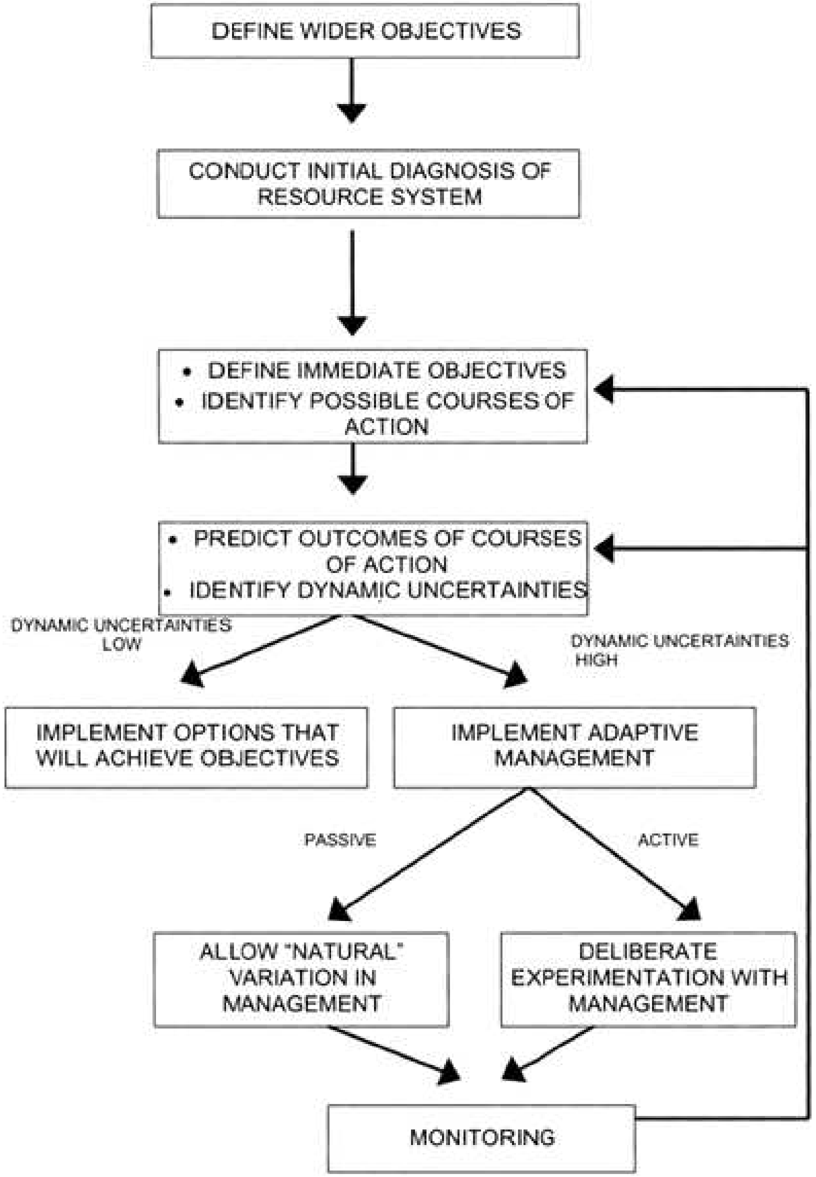
An overview of an adaptive, process-orientated approach to the development of stocked fisheries is given in Figure 3. The process starts with the definition of wider development objectives. Immediate objectives are specified only once a sufficient understanding of the resource system has been achieved and joint decision-making arrangements with stakeholders have been created.

A broad-based initial diagnosis of the resource system is conducted primarily to reduce uncertainty about its present state. However, some information on dynamic relationships may be acquired by analysing historical changes, or by enquiring about the reasons for present attributes. It is also useful to gain some information pertaining to the level of noise that can be expected, i.e. variations in catches, water levels, prices, etc. over the past years. Initial diagnosis rests strongly on participatory/rapid rural appraisal methods, which are highly efficient in gaining an overview of attributes and relationships in the resource system (Chambers, 1992; Cowan, 1995; Garaway, 1995; Pido et al., 1996). Analysts may refer to the frameworks in Figures. 1 and 2, and to checklists such as those given in ODA (1988), Winpenny (1991) and ODA (1995) to ensure that all important attributes of the resource system have been covered in the appraisals. 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.

Once an initial diagnosis has been conducted and joint decision-making arrangements created, 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 courses of action, including “do nothing”. Courses of action may involve institutional as well as technical aspects.

Once possible courses of action have been identified, it is important to analyse their likely outcomes and the uncertainties surrounding these using the predictive tools described in section 3. How one proceeds further is dependent primarily on the degree of dynamic uncertainty identified in this analysis. If dynamic uncertainties are low and courses of action can be identified that will almost certainly lead to the achievement of objectives, these courses of action can be implemented. If dynamic 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. Adaptive learning 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. For passive adaptive management, recommendations are given only in vague terms or not at all, so as not to reduce “natural” variability in management or discourage informal experimentation by stakeholders. For active adaptive management, variation is deliberately introduced in order to generate information. As an example, different fisheries may be stocked at different densities so that an optimal density can be determined. Whether and how active experiments can be conducted on institutional arrangements is open to debate.

Figure 3. Outline of an adaptive management approach to the development of stocked fisheries under uncertainty.



Whether active or passive, adaptive learning requires the monitoring of outcomes. The design of monitoring programmes and, where appropriate, experimental interventions should be based on principles of sound experimental design (for a useful review see McAllister and Peterman, 1992). In particular, adequate temporal and spatial replication is required, and experimental treatments should offer sufficient contrast to yield the required information. Models of the adaptive learning process may be used to evaluate different experimental designs.

Decision making about courses of action flows naturally from the participatory processes of resource system diagnosis and evaluation of options. This does not mean, however, that decision making is straightforward. Decisions are likely to involve conflicting interests, multiple objectives, and large uncertainties. Often there is a trade-off between the potential benefits of an option and the uncertainty of its outcome. Attitudes to risk among resource users are then of key importance to decision making. Stakeholders in some culture fisheries systems may be prepared to take substantial risks, and may often do so by radically changing operational rules on their own accord. This is the case for example in the community fisheries in Thailand and Laos. In other fisheries stakeholders may be more risk averse, particularly where livelihoods depend strongly on the fishery. Large-scale stocking programmes may be designed to compensate stakeholders for risks involved in active adaptive management.

6.2 Implementing an adaptive approach: opportunities and constraints

Adaptive management is a constructive way of dealing with inevitable uncertainties in the development of stocked fisheries. Because adaptive management emphasises learning from action, not on-station experiments, the approach is well suited for situations where swift action is demanded by stakeholders.

Problems in the implementation of adaptive policies are linked to the necessity of admitting uncertainty and lack of control by external specialists and agencies. The need to take risks is also seen as a fundamental drawback of adaptive policies. However, some degree of risk-taking is inevitable where a new technology such as stocking is introduced, and adaptive management allows to deal with such risks in a constructive and efficient manner. Passive adaptive management, letting stakeholders decide on courses of action, need not involve much risk-taking by external agents at all, and the stakeholders may well be prepared to take the inevitable risks involved. While taking risks is a key feature of adaptive management, this does not include risks which are deemed unacceptable or may lead to irreversible outcomes. Introductions of new species, for example, may entail risks that are considered too great to make experimental introduction worthwhile.

The use of adaptive management may be expected to result in a reduction of uncertainties and a stabilisation of the institutional environment. Where this is the case, an adaptive approach may effectively be superseded by programmed approach. A move in the opposite direction may occur when major changes in natural conditions or external arrangements (such as, for example, economic liberalisation) create a more open, dynamic and uncertain situation which calls for a more adaptive approach. The key to successful development is to match the approach to the situation (Berman, 1980). Where uncertainties are limited to certain aspects of the stocked aquatic resource system, a mixed approach combining programmed decision making on some aspects with adaptive experimentation on others may be most appropriate.

At present there is only limited experience with the implementation of adaptive management systems in enhanced fisheries. Active adaptive approaches have been limited to technical aspects, usually within a stable institutional environment. Examples are certain Chinese reservoir fisheries where active experimentation commenced in the 1970s (Lorenzen et al., in press), and large-scale salmon enhancement programmes in North America (e.g. Peterman and Routledge, 1983; Lee and Lawrence, 1986). Passive adaptive approaches are more common and may encompass institutional and socio-economic as well as technical aspects. In some oxbow lake fisheries in Bangladesh, for example, analysts have facilitated the formation of local management groups, utilised the variability in management between lakes to develop empirical yield models, and provided feedback to management groups for the improvement of stocking regimes (Middendorp et al., 1996).

Adaptive approaches to the development of stocked fisheries urgently require further research, with regards to both institutional aspects and the scientific methods that may be used in the learning process.

7. CONCLUSIONS

Stocking can precipitate dynamic changes in aquatic resource systems, and affect total yield as well as the efficiency, equity and sustainability of resource use. A broad understanding of the resource system in technical, institutional and socio-economic terms is often necessary to predict even basic technical outcomes. More detailed predictions, for example of distributional effects, are increasingly required.

A number of useful tools for the analysis of resource systems in which stocking takes place have been developed in recent years. Institutional analysis and design (IAD) provides a broad framework to integrate technical, institutional and socio-economic analysis. Analytical population models have provided new insights into the technical basis of stocking, and allow a detailed evaluation of management options.

While these tools greatly facilitate the analysis of stocked fisheries, large uncertainties about the status and dynamics of individual fisheries severely limit the predictability of outcomes. This implies that a programmed evaluation of management options is often impossible, and an adaptive approach based on the participation of stakeholders and learning from management experience is required.

8. RECOMMENDATIONS

1. Relevant prediction of outcomes is a joint responsibility of natural and social scientists and requires true collaboration between the two.

2. Prediction of the outcomes of stocking should begin with a broad-based, rapid appraisal of the resource system for which stocking is being considered.

3. Recently developed institutional and technical models should be used to evaluate a range of possible management options, to pinpoint uncertainties, and to assess the potential benefits of adaptive management.

4. Stocking programmes should make provision for adaptive learning, and allow for consequent changes in policies and procedures.

5. Rigid guidelines for management preclude learning and should be avoided unless there is clear evidence of their superiority over alternative systems that might evolve through experimentation by stakeholders.

6. Analysts involved in stocking programmes should be critical of their own predictions and explicit about uncertainties. The analyst's key role is to advise on the learning process, not to give weak predictions.

7. The ability of stakeholders to understand and predict outcomes of their actions is crucial to successful development, and therefore learning (adaptive management) procedures should involve stakeholders at all stages (planning, data collection, and analysis).

8. Active experimental management (i.e. management explicitly aimed at gaining knowledge) should be encouraged and supported where large uncertainties exist.

9. Further research on the institutionalisation of adaptive management systems in enhanced fisheries is urgently required.

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