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Abstract

In pursuing their livelihood, fishers develop strategies when faced with changes in regulations and other fishery conditions. Changes involve each individual in a decision-making process governed by his/her own goals or constraints. Despite this reality, the complex dynamics of fishing has usually been ignored in designing management initiatives, which has contributed to management failures in many parts of the world. Fishers have generally been treated as fixed elements, with no consideration of individual attitudes based on their operating scales (geographical, ecological, social and economic) and personal goals. We review existing research on the social, economic and behavioural dynamics of fishing to provide insight into fisher behaviour and its implications for fisheries management. Emphasis is placed on fisher perception, and how fishers develop dynamic fishing tactics and strategies as an adaptive response to changes in resource abundance, environmental conditions and market or regulatory constraints. We conclude that knowledge of these dynamics is essential for effective management, and we discuss how such information can be collected, analysed and integrated into fisheries assessment and management. Particular emphasis is placed on small-scale fisheries, but some examples from industrial fleets are provided to highlight similar issues in different types of fisheries.

Keywords fisheries management, fishing dynamics, fishing strategies, fishing tactics, opportunity cost

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Introduction

One of the many management methods used worldwide is the assignation of property rights to a limited resource to multiple users competing for that resource (Pomeroy and Berkes 1997; Begossi 1998). In fisheries, however, each fisher has different preferences about resource use, depending on their personal or group goals (food, sales or recreation). Limitations imposed by environmental or market variability can also influence the way fishers exploit their resources. In other words, fishers develop and implement fishing strategies and tactics in response to the constraints they encounter and their intended objectives given their particular human, social, cultural and economic contexts (Béné 1996; Hart and Pitcher 1998). Managers, in contrast, have generally made simplistic assumptions about fishers' nature and attitudes when defining management policies. In this sense, Hilborn (1985) suggests that the collapse of many fisheries can best be explained as the result of misunderstanding fisher behaviour, rather than a lack of knowledge of fishery resources. Like Hilborn, others (Hanna and Smith 1993; Robinson and Pascoe 1997; Wilen et al. 2002) stress the need to understand the nature of fishers' operations and responses to regulation or other stimuli in relation to their preferences in order to develop efficient management schemes.

Gaertner et al. (1999) suggest that long-term models, commonly used in fisheries assessment, rarely capture the rapid, short-term changes generated by the decisions that fishers make about when, where and what to fish. As will be illustrated below, the degree of fishers' adaptability to the endogenous variability of a fishery system in which they are involved affects their capacity to diversify activities (Kuperan and Raja-Abdullah 1994; Salas 2000; Castilla and Defeo 2001). Furthermore, by following fishery activities at different time scales, variation in fishing tactics and strategies can be identified, and help in understanding the fishery system in a holistic way.

The above-mentioned aspects are particularly relevant in regions where a combination of vessels and gears can be easily adapted to fish different species in different physical (spatial and temporal) and organizational contexts (McKelvey 1983; Laloé and Samba 1991; Kuperan and Raja-Abdullah 1994). This can make it more difficult to measure the effective fishing effort applied to each of the exploited resources. Ignoring issues relevant to fishers limits the ability to anticipate their responses to changes in resource regulation and management measures such as closed seasons, protected areas, fishing techniques control or government programmes fostering new technology or education. An understanding of fishing dynamics can help to delineate fishing effort more effectively, provide information on the flexibility of fishers in adapting to new situations and thus facilitate implementation of regulatory measures.

Although a number of authors have emphasized the need to understand fisher behaviour and use this knowledge for management (Wilen 1979; Hilborn and Walters 1992; Charles 1995; Wilen et al. 2002), few actually report studies in this area (Dorn 1997; He et al. 1997; Begossi 1998). The literature is even more limited in the case of small-scale fisheries (Cabrera and Defeo 1997; Salas 2000). Consequently, there is a need for work that monitors and anticipates the dynamics and distribution of fishing effort, information that can be used in modern stock assessment (Punt and Hilborn 1997).

This paper reviews the social, economic and behavioural dynamics of fishing, and aims to provide insights into the human component of fishery systems. Emphasis is placed on fishing strategies and tactics in small-scale fisheries, although some examples from industrial fisheries are included. Initially we reviewed basic concepts, followed by examples of tactics and strategies developed by fishers in different parts of the world. This is followed by methods of identifying and evaluating fisher tactics, strategies, and operations. We conclude with a discussion of the potential contribution of the behavioural dynamics of fishers to fisheries assessment and management.

Fishery systems, fisher perceptions, strategies and tactics

Fishing is an uncertain and competitive activity in which strategies are associated not only with biological and technological factors, but also with different ways of operating. Fisher perceptions, preferences, abilities and resource access all play a role in catch size and fishing effort distribution.

The fishery system and its human component

A complete fishery system (Seijo et al. 1998; Charles 2000) is defined as a combination of subsystems (e.g. human, natural resources and management) that interact dynamically and are influenced by external and internal factors. For long time, natural resources were the main consideration to evaluate fisheries. A recently learned, and frequently ignored, lesson is that fishers are not inactive components within a fishery system, they respond to changes in their surroundings and adapt to these changes as best they can.

The human component of a fishery involves more than the fishers themselves, because they form part of a web of community interactions (traditions, community roles, relationships with marketers and distributors, etc.). Hence, managers should assess the full impact of changed regulations. For example, what is the economic impact of a catch quota, area closure, or trip limit on individual fishers in the fleet? How much is their income reduced and what alternatives could compensate for any deficit? In the face of such management constraints, fishers develop strategies that allow them to maintain or increase catch rates by increasing the number of fishing days, using cooperative effort, personal skills or through technical modifications to boats and equipment (Charles 1995; Ruttan 1998; Salas 2000). Moreover, it is unhelpful to regulate the number of vessels in a fishery if catches are highly influenced by fisher experience (Durrenberger 1993). Likewise, it is not worthwhile to search for specific impacts of fisher experience in a fleet with highly developed technology.

Understanding how people operate in the fishery system helps to understand how the system works. To properly plan and set management objectives, a thorough understanding is needed of coastal resources, institutional arrangements and the social, cultural and economic values of fishing and the overall environment in which fishers operate. Fishers operating with different objectives constitute a heterogeneous element that poses a serious challenge to decision-makers in fisheries planning and managing. Without detailed knowledge of variation among fishers, attempts to manage fisheries will likely meet serious resistance and lead to serious non-compliance (Kuperan and Raja-Abdullah 1994).

Concepts of fishing strategy and tactics

Some authors define fishery strategies and tactics as involving selection of a particular fishing method, fishing area, target species and organizational process (Laloé and Samba 1991; Sampson 1991; Ferraris 1995). Here, strategy and tactics are defined in the Clauswitzian (military) sense. Tactics are individual actions designed to meet an immediate challenge, such as moving to a series of small bays as a fish stock migrates past the home port, while a strategy is a time-planned action or to achieve a general goal, such as moving to where the fish are in relation to travel costs (Gaertner et al.1999). Moreover, a succession of tactics in time adopted by an individual fisher can constitute a strategy if this coordinated behaviour has been planned previously. Either can be individual or collective. Hence, strategies include a decision making process which considers all factors that affect the ability to reach a particular objective (Béné 1996). In this sense, every individual fisher defines his/her objectives based on personal goals, and their particular perception within specific circumstances. Fishers develop strategies by learning and modifying them once initial goals have been fulfilled (Brown 1995), and, in tightly knit coastal communities, this process may be collective.

Are fishing strategies and tactics associated with maximization?

The idea that fishers respond to economic stimuli in determining tactics and strategies is controversial, with some authors clearly in favour (Bockstael and Opaluch 1983; Dorn 1997) and others in disagreement (Hanna and Smith 1993; Jacobson and Thomson 1993).

An example of the former is Lane (1988), who, using a model to test long-term policies, found that individual fishers behave as independent decisionmakers operating in a competitive environment in an effort to gain maximum benefit. The collective action of independent operators, however, does not imply that all fishers' benefits are simultaneously maximized by this action. Over the short-term, individual fishers invest in competition to improve their own position without considering collective economic benefit, yet, over the long-term they want to preserve the fishing resource for their own benefit by moderating other catches, an example of the 'prisoners dilemma'. Spatial tactics that maximize individual profit are often employed in modelling the complexities of effort dynamics (Eales and Wilen 1986; Lane 1988; Sampson, 1991; Holland and Sutinen 1999).

Robinson and Pascoe (1997), in contrast, analyse the validity of the 'economic maximization' concept as a fisher's objective when fishing (based on a broad literature review and empirical studies). They conclude that this may be true for some fishers, like those that they studied in the English Channel, but does not completely explain all fisher behaviour. In addition to economics, other stimuli influence behaviour and should thus be taken into account when evaluating fishing dynamics.

It has been suggested that the profit maximization concept is more applicable to industrial fishers than small-scale fishers. However, this generalization may not always apply, because in some cases small-scale fishers are more strongly linked to private property (e.g. owner-driver vessels) than to vessel size and operational levels (McGoodwin 1990; Kuperan and Raja-Abdullah 1994). For instance, some small-scale fishers in developed countries may have quite large vessels and appear motivated by economic goals, but others, generally with small vessels, may have other considerations in mind (Roy 1998). In this sense, Chaboud (1995) suggests that fishers operating in unstable fisheries are less likely to have profit maximization goals, and more likely aim only to obtain enough revenue to cover travel costs, situations also observed in some small-scale fisheries. Cabrera and Defeo (1997) arrived at similar conclusions when they evaluate the lobster fishery in Yucatan, Mexico.

Illustrative examples of fishing strategies and tactics

We discuss some fishing strategies and tactics reported from fishing communities, groups and individual fishers. Examples illustrate the adaptation processes of fishers confronting different types of limitations and stimuli in their activities and have been chosen to illustrate the concepts described above. They include: (a) specialization processes; (b) cooperative work; and (c) changes of behaviour in response to fishing efficiency.

Specialists and generalists

Several researchers (Apostle et al. 1985; Begossi 1996; Pet-Soede et al. 2001) have demonstrated that fishers are not homogeneous and may differ substantially in the ways they operate. Sometimes fishers' strategies may be divided into specialists and generalists (Smith and McKelvey 1986). Specialists concentrate in one area, on one species, or a fishing method (e.g. lobster fishery in eastern Canada; see Miller 1995). Specialized technology can facilitate intensive fishing of species of high economic value. However, this level of investment is not flexible, implying possible economic or personal risks. Generalist fishers, in contrast, can more easily switch activities, (e.g. line fishing, dragnet fishing), and even engage in activities unrelated to fishing. They can thus more easily change target species, fishing methods or even activities (Table 1).

Changing target species is a common tactic in coastal fishing communities, so most small-scale fishers are considered as generalists. For example, although some fishers in the coastal communities of Yucatan, Mexico, claim that they specialize in lobster, this specialization has not been confirmed. In fact, the same fishers commonly land other species such as octopus and demersal fishes (Salas et al. 1991; Salas 2000; Cabrera and Defeo 2001).

Table 1. Differences between generalist and specialist fishers (adapted from Smith and McKelvey 1986).

Characteristics	Generalist	Specialist
Time frame	Short	Long
Flexibility	High	Low
Technology	Not specialized	More specialized
Activities	Wide range	Limited
Fix costs	Low	High
Operation costs	Variable	Variable
Opportunity costs (due to change of activity)	Low	High

As illustrated above, specialization is not always found in small-scale fisheries, although fishers do express preferences for certain target species, fishing gear or areas. However, generalist fishers do not necessarily fish randomly. Salas (2000), in comparing three communities on the coast of Yucatan, Mexico, observed that fishers from an area with a longer fishing tradition concentrated mainly on lobster. Two communities with less of a fishing tradition, including one of rural migrants, switched between lobster and other species, such as demersal fishes and octopus, throughout the lobster season despite lobsters' profitability. Octopus is selected mainly by rural migrant fishers because it requires fewer technical abilities and involves lower operating costs and personal risk.

It has also been argued that fishers can develop more efficient fishing tactics using a specific fishing method and highly developed technology, in other words a specialist strategy (Palsson and Durrenberger 1982; Gatewood 1984a). However, this extreme differentiation is hard to defend. For instance, trawl fishers can be considered generalists because their catches include a mix of species, although those specializing in a particular area would argue against this classification. Sequential fisheries can also be interpreted as specialized because two fleets target different components of the same population, for example, shrimp fisheries in which one fleet concentrates on juveniles and the other on adults (Seijo et al. 1998), although some incidental species may be captured in the process.

Larger, more autonomous vessels with advanced technology are usually assumed to fall within the specialized strategy, but vessel size and level of technology are not the only factors that need to be accounted. For example, in the Venezuelan tuna fishery, the largest and most modern purse seiners specialize in adult yellowfin tuna, which fetches a higher price than smaller fish. These vessels spend most of the year targeting adult yellowfin schools associated with dolphins in the eastern Pacific Ocean, and then enter the Caribbean seasonally to fish non-associated schools of yellowfin. Older, slower purse seiners, in contrast, stay in the Caribbean all year and fish mixed schools of juvenile yellowfin, skipjack and other tuna species. Due to the steep thermocline of the western Atlantic Ocean, these vessels require the assistance of a bait boat (vessels that fish using poles baited with live sardines) to increase the probability of a successful purse seine set (Gaertner et al. 1996). Therefore, it is difficult to assign meaningfully the terms generalist and specialist strategies to such vessels. This apparent behaviour reflects more the fact that fishers are forced to use some practices rather than a real strategy (Miller and Maanen 1979).

Some authors report that fishers are often ‘forced’ to use some practices, rather than ‘selecting’ them (Miller and Maanen 1979; Erdmann and Pet-Soede 1996). For example, in the coral reef fishery in Sperdmonde Archipelago, Indonesia, fishers commonly target all available resources using illegal blast fishing and electrofishing. According to Erdmann and Pet-Soede (1996) lack of alternative sources of income, expected economic rewards, negligible enforcement and competition ‘forces’ encourages fishers to behave in this way. They usually remain in the fishery with the expectation that damaged resources will recover. On the contrary, strongly enforced regulations can also produce a direct ‘forcing’, for example when a limited-entry system restricts fishers to a single licensed fishery, making it impossible to acquire licenses for multiple fisheries (Hilborn et al. 2001).

The types of fishers described here are not unchangeable categories, but rather indicate dynamic responses to changing conditions. McKelvey (1983) confirms that a combination of different fisher types with diverse fishing strategies will be reflected in heterogeneous groups operating in a changing environment. Thus, in changing conditions, a mix of specialist and generalist fishers can maintain a stable community income. Hilborn et al. (2001) show that the flexibility to switch to a larger range of target species, or to non-fishing activities, gives fishers the option to create economic diversification and relieve pressure on fish resources. These opportunities to earn outside the fishery form the basis of the sustainable livelihoods approach to small-scale fishery management (Scoones 1998; Allison and Frank 2001). Resource depletion caused by serious over-fishing can, however, override any fishers’ strategies, as in the Sperdmonde Archipelago where limited options and false expectations keep fishers in the activity and increase pressure on resources even after they have declined. Furthermore, an understanding of fisher strategies as modified by particular contexts can help in defining management policies that have a higher probability of success. Uncertain resource abundance and weak institutional arrangements, however, imply that risk and uncertainty be integratedinto the diagnoses that researchers provide to administrators (Francis and Shotton 1997; Hilborn et al. 2001).

Cooperative work

Although fishing is usually perceived as a competitive rather than a cooperative activity, cooperative actions among both small-scale and industrial fishers have been reported worldwide (Alaska, Gatewood 1984b; Senegal, Fonteneau and Diouf 1994; Indonesia, Ruttan 1998; Venezuela, Gaertner et al. 1996; Brazil, Begossi 1996; Mexico, Salas 2000; the USA, Eales and Wilen 1986; Hilborn et al. 2001; the English Channel, Blyth et al. 2002). These cooperative mechanisms are generated as a way of facing catch variability, reducing personal risks or minimizing conflicts while fishing.

As catch variability is related to uncertainty (recruitment, resource availability and environmental conditions, among others), one of the ways to deal with these problems has been through information exchange. The existence of fisher ‘codegroups’ or ‘teams’ for information exchange in some fisheries is well known (e.g. Maine lobster, Acheson 1975). Information management is especially important when dealing with highly aggregated migratory resources, such as sardine and tuna schools, because rapid localization and exploitation of these concentrations is fundamental to ensuring the economic survival of these fisheries. Simulation studies have shown that captains belonging to efficient fisher ‘code groups’ have a greater probability of locating a tuna concentration than does an isolated fisher (Dreyfus-Leon and Gaertner 2002).

Another common form of cooperation is catch sharing, for example, during the north wind season (October to February) in Dzilam Bravo, Yucatan, Mexico, catch variability is extremely high because strong winds and storms limit fishing activity. Fishers compensate for losses by sharing catches in port, regardless of who caught more, effectively ensuring a minimum catch for each fisher for every fishing trip (Salas 2000).

Regulation can also generate cooperative catch sharing. For instance, when individual fishers are faced with a quota system, there is considerable resistance because they expect a reduction in average catch rates and a quota-pooling strategy may evolve to compensate for the risks. For example, in the spawn herring purse seine fisheries on the north-west coast of the USA and Canada, fishers face a short fishing season (sometimes lasting no more than 15 min), so risk-averse fishers pool their catches to be competitive, while more risk-prone fishers work on their own (Hilborn et al. 2001).

The perceived benefits of cooperation are synergistic, not cumulative, in that the final effect appears to be greater than the sum of the independent actions (Guttman 1996). So, if this synergism can be attained through cooperation, then why is there no cooperation among all fishers? Some argue that lack of information and a sense of independence are limiting factors in cooperative activities. This explains why some fishers in Alaska prefer to demonstrate that they are capable of efficiently managing themselves independently, and some who regularly share information are reluctant to negotiate combined capture quotas, although they recognize the advantages of working cooperatively (Gatewood 1984b). In the Yucatan, Dzilam Bravo fishers share catches during the north wind season, but they compete individually for the best fishing grounds at the beginning of the lobster season, when the highest profits of the year are generated (Salas 2000). In this sense, cooperation may often be seen as a tactic to reduce risk, rather than an overall strategy.

Kinship and friendship relations seem to be important in defining cooperative alliances among fishers. Group size can also be significant in facilitating communication among different group members. In the tuna purse seiner fleets operating in the eastern Atlantic Ocean and the Indian Ocean, 'sharing of the gains' is a more common practice among boats in the Spanish fleet than the French fleet, probably because of the smaller size of the Spanish tuna companies (Gaertner and Pallares 2002).

In many cases, social norms and relationships define the rules of cooperation and the forms of interaction. There are cases in which cooperative relationships do not always operate based on reciprocity. For example, in eastern Indonesia, tribal or family leaders receive a greater portion of the benefits generated by the collectivity (the 'sassi' system: Ruttan 1998).

Sometimes, cooperative tactics evolve to reduce damage from conflicts over who fishes (Acheson et al. 1998), and may extend to informal demarcation of no-take areas and zones from which gear-types are mutually excluded. After new fishing technology increased conflicts among gear sectors in the 1970s, over 20 years, inshore fishers in the western English Channel conceived, established and maintained a spatial zoning agreement between those operating static gears (pots and anchored gill nets) and those using towed gears (trawls and dredges) (Hart 1998; Blyth et al. 2002).

Cooperation can change over time via the learning process. Associations can disintegrate or maintain themselves depending on the mutual benefits they generate. For example, cooperative group creates an alliance among its members, but maintains a competitive attitude towards those outside, or towards a former member if conditions change (Spagnolo 1999). Other groups appear to keep alliances over long periods of time by maintaining stable reciprocity in their cooperation, like some Brazilian fishers (Begossi 1996).

Changes in tactics affecting fishing efficiency

Fishing efficiency can be conceptualized in different ways (Cove 1973; Gatewood 1984a; Salas 2000), reported and evaluated in different forms and using different 'units' (e.g. catch, money and prestige).These units are not necessarily independent, as an efficient skipper can, for instance, be recognized as successful and can recruit better crew, which will in turn result in higher long-term catches and income. For example, in the Venezuelan tuna fishery, enterprises put their best captains in the most modern vessels with the best technology (Gaertner et al. 1999). Hence, fishers are driven by different goals and priorities which define their strategies, and consequently affect their fishing efficiency. This efficiency can then be defined in terms of an input–output process in which 'units' will be defined according to the goals, priorities and limitations imposed by the system. The established changes then depend on factors such as technology, fisher experience, fishing intensity, spatial and temporal observational scales.

Fishers can develop tactics, often involving technological innovation that allows them to attain greater catches than their counterparts. The resulting differences in catch rates have been defined as relative fishing efficiency or fishing performance (Palsson and Durrenberger 1982; Hilborn 1985). As a result, fishers in apparently similar vessels may produce substantial differences in catch and income. This phenomenon can be seen in three fishing communities in Yucatan, Mexico (San Felipe, Sisal and Dzilam Bravo). Some fishers can land catches twice as large as others from the same community (Sisal and San Felipe). In an extreme case (Dzilam Bravo), some fishers landed catches 10 times higher than others during two consecutive fishing seasons (Salas 2000). Fishing experience of individuals and fishing intensity (number of fishing trips) appear to be important factors related to reported catch levels. In Dzilam Bravo, some fishers also operate cooperatively. This means that regulations attempting to restrict effort by controlling the number of vessels, as is traditionally carried out in the Yucatan, may be compromised. In fact, in Dzilam Bravo, overall fishing effort is higher than in other communities with larger, but less-efficient fleets.

Another common tactic for mitigating catch variability has been the use of artificial aggregation devices. Some examples can be seen in the Philippines in the form of hand-made ‘payaos’, Fish Aggregating Devices used by tuna vessels in the world ocean (Gaertner et al. 1996), artificial habitats (casitas) used in Cuba and Mexico to concentrate lobster for fishing purposes (Seijo and Fuentes 1989), and human-made reef structures in southern USA, Mediterranean and elsewhere (Pitcher and Seaman 2000).

Not all fishers will tend to maximize their catch. Many appear to be satisfied with recovering their operating costs or keeping catch constant so as to remain in the activity without needing to re-invest profits (Jacobson and Thomson 1993; Roy 1998; Babcock and Pikitch 2000). This is more common in small-scale fisheries, where lower capital investment is required. For instance, fishers in San Felipe, Yucatan, Mexico, have to maintain an average capture of approximately 300 kg a month to keep their membership in the fishing cooperative (Salas 2000), and some concentrate only on meeting this quota. Similarly, Roy (1998) reports that fishers in Newfoundland, Canada have to cover an average number of fishing days to be able to claim unemployment insurance. So catch rates depend on personal objectives, which can vary in time according to specific goals, experience in diverse productive activities and ability to adapt to diverse conditions given personal resources and available infrastructure.

Some fishers seem willing to sacrifice high catches to minimize personal (physical) and economic risks by selecting fishing areas close to the community and using fishing methods requiring lower operating costs (Seijo and Defeo 1994; Cabrera and Defeo 1997; Helu et al. 1999). They are less willing to use their time travelling in search of better fishing grounds, preferring to fish. Small-scale fishers in Sperdmonde, Indonesia, for example, concentrate on ‘safer’ locations closer to their areas of origin, with inconsistent patterns in more distant zones. As they do not venture into other areas, they cannot easily perceive larger scale contrasts in catch rates for species (Pet-Soede et al. 2001). In Yucatan, Cabrera and Defeo (2001) observed that some small-scale boats targeting shellfish and small fishes, consistently selected the fishing ground nearest their home port, regardless of the catch of previous days, while others remained at the same location only if it systematically provided good catches.

As illustrated above, catch performance can show fisher response to changing conditions in fisheries. Bioeconomic performance variables in fishing operations at different spatial and temporal scales (biomass, catches, rent, travel costs) can provide information about fisher preferences in resource use (Sampson 1991; Seijo and Defeo 1994; Dorn 1997; Sarda and Maynou 1998). Information on social and cultural context is also necessary to understand some responses not explained by economics (Hanna and Smith 1993; Jacobson and Thomson 1993;Wilen et al. 2002).

Identifying and evaluating fishing tactics and strategies

Typology of fishing tactics and strategies

Classification of different fishing strategies and tactics related to identifiable behaviour (i.e. typology) is a practical method for studying fisher's actions, especially when dealing with large data sets. In reality, an average fisher rarely exists, so the creation of this typology is a statistical strategy for synthesis of the distinct activities developed by fishers over time and space that may help in evaluating fleet dynamics.

Statistical methods that can be used for the analysis include generalized linear models, segmentation and multivariate analysis (Laloé and Samba 1991; He et al. 1997; Pech and Laloé 1997; Gaertner et al. 1998, 1999; Pelletier and Ferraris 2000). Another approach that has been explored to evaluate fishing strategies is optimal foraging theory (Aswani 1998). Once the strategies are identified, several approaches can be employed to identify factors involved in the decision-making process or to model fishing behaviour under different management scenarios.

Decision making

Identification of fisher tactics and strategies requires evaluation of the factors that influence fisher decisions. Probability decision models implicitly capture this problem's uncertain nature by predicting the probability of an individual choosing a given alternative, or that a given event occurs. They also help to identify the factors involved in the decision-making process by selection from a set of candidate variables that can be continuous, dichotomous or a mix of types. One can use the estimated probabilities to predict the proportion of each group of individuals that select a particular alternative using a logit or probit approach (see Gaertner et al. 1996; Holland and Sutinen 1999; Salas 2000).

The decision trees approach uses probability models as well. This approach provides a schematic representation of sequential decision processes by breaking the complexity into its constituent parts. For instance, decision tree analysis allows a simple chronological representation of risks and profits associated with fishing tactics used by fishers, or alternative management actions recommended by decision makers. As different combinations of decisions and natural conditions (uncertainty) generate different profits, it is easy to rank the decisions by desirability or uncertainty of each outcome (Gaertner et al. 1996).

The effect of information sharing among fisher groups (e.g. to search for schools of fish) can be determined using an artificial neural network (Dreyfus-Leon 1999; Dreyfus-Leon and Gaertner 2002). This approach involves sophisticated modeling techniques capable of modelling complex functions, particularly non-linear functions with many variables. Neural networks can mimic human behaviour and are consequently an ideal tool for representing fisher behaviour and decision-making.

Dynamic programming, in which each decision is made in order to maximize or minimize a function (e.g. catches, revenues or costs), has been used to model condition-dependent decisions over time. The condition state is made discrete and the algorithm calculates the maximum or minimum and the corresponding optimal choice at every possible condition state in each time (Mangel and Clark 1988). The optimal choice for each period can then be used to calculate the probable choices in each time step from various conditions (for example by simulating fishing trips). This approach, applied in evaluation of fishing strategies to examine target behaviour to define trip limits, was used by Babcock and Pikitch (2000) in multispecies trawl fisheries.

Uncertainty can also be incorporated when evaluating fishing strategy and tactics. For instance, Vaca-Rodriguez and Dreyfus-Leon (2000) model fishing effort distribution using a Monte Carlo simulation to evaluate the effect of fishing effort on the age-structure of Pacific yellowfin tuna, which affects fisher revenues depending on market conditions and management policies.

Markov chains can also be used as a tool for finescale analysis of fisher behaviour (Dorn 1997; Hernandez 2000). This kind of probability model allows evaluation of sequential actions according to preferences, assuming the influence of some variables.For example, Hernandez (2000) used a Markov model to evaluate the daily decisions of small-scale fishers about their time budgets (i.e. fishing vs. other activities). Environmental conditions, the previous day's revenues, time for leisure or other activities, and opportunity costs were variables included in the decision-making process. The fleet exhibited a heterogeneous group of fishers and the results highlighted the importance of opportunity costs when selecting fishing over other activities like tourism or cattle ranching.

In addition to statistical analysis, ethnographic and participatory research should be considered because they can provide in-depth information on fishers' perceptions, and aid in understanding social, economic and cultural patterns in fishing communities. Just as biological and physical aspects have been considered in the past, these social system components need to be assessed and recorded scientifically (Seijo and Fuentes 1989; Jacobson and Thomson 1993; Seijo et al. 1998; Chuenpagdee et al. 2002). As outsiders are sometimes suspect, involvement with the fishers to accomplish research is often helpful and frequently essential to collecting reliable information.

Applications in fisheries assessment and management

Changes on fishing tactics and strategies can change the spatial and seasonal distribution of fishing effort, and information in this regard should be included in fisheries assessment. Considering the complexity of a fishery system, simulation models can be built incorporating both fish population dynamics and fishing effort dynamics. Yew and Heaps (1996), for example, developed a model incorporating bio-socioeconomic effects of alternative management policies for a small pelagic fishery in north-west peninsular Malaysia. They showed that the existing policy of limited entry licensing would not achieve the expected outcome as fishers could increase effort by fishing more days or by 'capital stuffing' their vessels. Yew and Heaps highlight the need for effort reduction by increasing employment opportunities outside the fishing sector and fostering skills for other activities through job training.

Similarly, Dorn (1997) evaluated the effect of a night-time fishing ban in a trawl fishery on the Pacific coast of the USA. His results showed that fishers accumulated catch during the day, and daily revenues did not decline significantly, another example of a management strategy that did not provide the expected results, as effective fishing effort was not reduced.

Resource management agencies are not the only source of restriction on landed catch. Sometimes processors and dealers impose market limits by fixing the amount of fish they will buy per delivery, leading to excess fish being discarded at sea. Moreover, the co-occurrence of regulated and unregulated species also limits fishers, because the only way they can avoid catching regulated species is to forego fishing altogether. Only prosperous fishers can afford to sacrifice the benefits of fishing, especially if no alternative areas are available (Crowder and Murawski 1998).

Understanding fishing dynamics

Understanding fishing tactics and strategies for management purposes goes beyond the observation of fishers' response to a changing environment and regulations; it is necessary to evaluate the costs of changes among alternatives given the type of fishery, fisher experience, risk perception and the like. Responses vary depending on the value fishers place on their money, abilities, time and flexibility in changing activity or their tactics and strategies. In this context, the concept of opportunity cost, (defined as the benefit lost by rejecting an alternative use of resources; Jacobson and Thomson 1993), plays a vital role in fisher decisions.

Given the multiple sources of variability in fisheries, fishers diversify their activities by making optimal use of their knowledge of seasonal changes in resources and the environment. This adaptive response provides them with the flexibility needed to increase, or at least maintain, their income. Fishing is not only a source of income; it also represents a way of life. Apostle et al. (1985) consider that a sense of independence and control (i.e. being one's own boss) is one of the main reasons that individual fishers remain in the activity. In addition, several factors may direct individuals towards fishing, such as lack of options, socialization processes focused on fishing (e.g. early exposure for those born into fishing families), or a lack of opportunities to compare fishing with other options (Miller and Maanen 1979).

Behavioural similarities between fishers and farmers in responses to changing conditions may be noted, especially in developing countries. Agricultural practices adopted to mitigate risk include dispersing cultivation areas and species (portfolio building), and cooperative work. In fishing, especially in small-scale fisheries, activity diversification throughout the year is common (changing target species, fishing method). This process has been termed ‘switching fishing practice’ (Seijo et al. 1998; Salas 2000) when it occurs within the same fishing activity, or ‘occupational pluralism’ when fishers use resources unassociated with fishing (Paré and Fraga 1994).

In some places, changes to fishery management may be introduced into communities without public consultation to determine if there is interest in the programme, and usually without evaluating impact on the communities. Here, insight of fisher dynamics may be particularly important in understanding flexibility in adapting to new situations.

Fishery development programmes are quite common in coastal areas. Pauly (1997) discusses small scale fisheries where fleet expansion has been promoted without considering resource conditions or user preferences. A prime example is a policy in Yucatan implemented in the early 1990s. The State government promoted introduction of medium-draft vessels to reduce fishing pressure on shallow coastal areas and increase fisher income. However, no training in operating of the new vessels was provided, and the fisher’s perspectives and preferences were never considered. Fishers consequently operated the new, larger vessels as if they were their former shallow-draft vessels, fishing near the coast to avoid risk and catch variability. In this way, the policy resulted in greater pressure on coastal zone resources, no increase in fisher income and under-utilization of the new government-subsidized fleet (Salas 2000).

We may use agriculture as a comparison in searching for the reasons behind these kinds of failures. Technological innovations in Africa, for instance, were rejected by small-scale farmers if the yield increase was associated with a strong rise in crop variance (Brossier 1989). This demonstrates that variability is indispensable in explaining resource user behaviour and decisions.

Recognizing fishers’ preferences is vital to ensuring a close partnership between resource users and managers so that they can share responsibility for resource management and development, and implementation of community programmes and compliance is increased to effective levels. In other words, community members should be seen as active participants in these programmes, rather than passive beneficiaries (Pomeroy and Berkes 1997; Pomeroy and Carlos 1997; Castilla and Defeo 2001). There is no magic formula for success, but these actions could increase the chances of improving management and ensuring programmes and projects sustainability.

Implications for fisheries management

Management approaches in fisheries have traditionally had an emphasis on fish population dynamics and protection of the environment. In addition, most management advances have been made in the technical area of developing harvest control rules, often overlooking the effect these have on fishers and their communities (Wilen 1979; Hilborn et al. 2001; Wilen et al. 2002). Fisheries have generally been managed by rules of ‘how much can be taken’ rather than by evaluating and controlling ‘how, when and where’ people fish. This presents a problem when fishing effort needs to be defined, measured and controlled.

Fishing effort is usually considered as an aggregate of different variables, which respond to shifts in the level of profits within a fishery (Bockstael and Opaluch 1983). This aggregate not only includes fishing gear and time but also fisher decisions, which affect fleet dynamics and profits derived from the activity. Thus, knowledge of fisher behavior can help in transforming nominal effort measurements into effective fishing effort measurements, if this is the variable to be controlled. That is, a specific unit of nominal effort could produce distinct vectors for fishing mortality, depending on the different fishing tactics adopted by fishers (e.g. the combined effect of cooperative groups plus fisher performance in Dzilam Bravo, Mexico). In the same way, a predetermined fishing mortality reference point (e.g. Fmsy, F0.1) could result from distinct combinations of nominal effort units. The challenge in this context, then, is to identify what elements are included in the evaluation, how fishing effort should be evaluated and how managers can adjust fishing effort to produce the desired result without too strongly affecting resource users.

If fisher response is not included and the inherent variability in fisheries that they respond to is ignored, predictions of changes in fishing effort can be wrong. Data on variation by vessel class, technological changes, specialization processes or cooperative efforts among fishers could help managers to understand fisher operations and how they respond to different regulatory policies or other stimuli (Wilen 1979; Charles 1995; Béné 1996; Wilen et al. 2002).

Hart and Pitcher (1998) state that conflicts between fishers and fishery managers can be reduced if managers adjust their cost-benefit functions to produce management objectives that include fisher interests, and acknowledge their dynamic behaviour within their specific contexts. This becomes a dynamic process requiring constant evaluation and management objectives have to be stated implicitly, rather than explicitly, because it may not be possible to pursue them simultaneously or they may not be effectively applicable under different conditions. For instance, management regulations that function for a group with a long fishing tradition may not be so effective in a group of rural immigrants new to fishing. Similarly, fishing quotas are impractical in countries where there is only limited knowledge of the resource, and hard to enforce at remote ports where local measurement units may be used (e.g. Peru where catch is recorded by pieces, baskets, bunches or dozens; Wosnitza 1992). Furthermore, cooperation between managers and the communities that depend on the resources is essential in designing different policies (Hilborn and Walters 1992; Pomeroy and Carlos 1997; Jentoft et al. 1998).

No single formula exists for successful management, because the answer depends on site-specific situations and is ultimately a political decision. Policies favouring co-management have been suggested as a way to manage small-scale fisheries (Kuperan and Raja-Abdullah 1994; Pomeroy and Berkes 1997; Castilla and Defeo 2001). Co-management aims at greater participation by resource users in the fisheries management process, more self-reliance in local-level institutions and a decentralization of power from institutions to the community. However, calling for community involvement is not enough, and recognition needs to be given legal rights, fisher participation fostered, and legitimacy and accountability created for local organizations and institutional arrangements. For example, in the English Channel, the informal fishing zones have recently been formally recognized by the management authority, although their continued management is very much still in local fisher's hands (Blyth et al. 2002). Successful fishery management requires the democratization and development of local communities, and an understanding of leadership, local institutions' resources and capabilities, social and political stability, and improvement in scientific information about the ecological, economic and behavioural dynamics of the fishery system.

Conclusions

The long-term goal of maintaining fisheries resources in a way that provides sustained income for fishing communities cannot be attained with open fishery access or with regulations based solely on natural resources data. Interactions between the species that form an ecosystem need to be taken into account, as well as user responses to changes in resource dynamics and the fishery system in general (including socioeconomic impacts that change in a fishery can generate in fisher operations). Ignoring these processes has lead to management failures in the past and will continue to do so if they are not included in the resource management assessment.

It may be quite some time before the inclusion of fisher dynamics becomes more common in fisheries assessment. Analyses of this sort require interdisciplinary and integrated studies using multiple information sources, innovative methodologies (which include spatial and temporal components) and recognition of fishers' potential contribution in the form of knowledge and participation in fisheries assessment and management. For successful fisheries management, decision making needs to go beyond fishery outputs (allowable catches, revenues generated) and adopt a multidimensional view that incorporates ecological, socioeconomic, community and institutional arrangements in the total system evaluation. Fisheries management should generate a 'portfolio' of approaches to provide multidimensional solutions to the multifaceted problems that it must address.

Most vital of all is to recognize the need for a change in institutional regulatory arrangements that allow more active participation by resource users. This will require recognition and understanding of organizational levels within communities, occupational pluralism, fisher risk perceptions and fisher attitude towards resource use. The proposals made here go beyond differences in concept, scale and observational unit definition, and include fishers in the definition of fishery policies.

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