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ENVIRONMENTAL ASSESSMENT

Mekong River Fish Conservation Zones in Southern Laos: Assessing Effectiveness Using Local Ecological Knowledge

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ABSTRACT / Small-scale fisheries are important in Laos, where rural people heavily depend upon Mekong River and tributary fish stocks for their livelihoods. Increasing pressures from human exploitation and habitat disturbance, however, have raised serious concerns about the potential depletion of various species. This has led to the establishment of large numbers of Fish Conservation Zones (FCZs) or ``no-take'' fish sanctuaries in southern Laos based on a ``community-based fisheries co-management'' framework. This study uses the local ecological knowledge (LEK) of fishers to assess the effectiveness of village-managed FCZs in enhancing fish stocks in the mainstream Mekong River in Khong District, Champasak Province. Focus group interviews about species that are believed to have benefited from different FCZs are compared with parameters such as FCZ area, age, depth, localized gradient, water velocity, and the presence of wetland forests nearby. The results suggest that no one aspect is likely to account for variations in fish stocks; rather, it is the interaction between numerous factors that has the largest impact. Secondly, the results indicate that microhabitat diversity and protection are critical for maintaining and enhancing Mekong fisheries. Deep-water pools are particularly important as dry season refuges for many fish species, and FCZ depth may be the single most important environmental factor affecting the success of FCZs in the Mekong River. FCZs have the most potential to benefit relatively sedentary species, but may also benefit highly migratory species, given the right conditions. This study shows that integrated approaches to stock assessment that employ LEK and scientific fisheries management have considerable potential for improving Mekong capture-fisheries management.

Wild fish stocks are critical for meeting the subsistence needs of much of the world's population. Although commercial harvesting of marine and freshwater species now accounts for the largest volume of fish caught, artisinal fishing is still of critical importance to many indigent communities (Bush 2003, Sjorslev 2000, Hubbel 1999, Hirsch and Noraseng 1999, Ahmed and others 1998, Pomeroy and Carlos 1997). Unfortunately, many artisinal fisheries are experiencing increasing pressure from human exploitation, habitat disturbances, and degradation. There is growing concern over the actual and/or potential depletion of many fisheries, and the social and economic hardships that are befalling people in resource-dependent communities (Dudgeon 2002, Thorburn 2001, Bakker 1999, Matics 1997, Abramovitz 1996, Roberts 1993a, 1993b, 1993c). This, in turn, has underscored calls to develop long-term management strategies to conserve and enhance wild fish stocks (see, for example, Pomeroy and others 2001, Garaway 1999, Olomola 1998, Johnson 1998).

Historically, fisheries management has tended to focus more on the resources than on the people who use them. Management programs have relied heavily upon biological investigations undertaken to monitor the abundance of fish populations (Johannes 1998). Conventional fish stock assessments, however, typically require detailed knowledge of the biology of the targeted species, and are highly dependent upon the availability of accurate catch-per-unit-effort (CPUE) data or other ''hard'' fisheries data. In most nonindustrialized nations, however, such data have not been collected for even the most important river systems or fish species (Johannes 1998, Kottelat and Whitten

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1996). Moreover, a variety of technical concerns exist that make the assessment of fish stocks in tropical riverine systems highly complex (see, for example, Baird and others 1999b, 1998a, Cowx 1991). These factors have contributed to a growing advocacy for developing management regimes that give greater voice to the roles of local resource users (Memon and others 2003, Pomeroy and others 2001, Jentoft and others 1998, McCay and Jentoft 1996). Indeed, broad-scale citizen participation and empowerment are now considered critical objectives in many natural resource management activities (Pomeroy and others 2001, Colchester and Erni 1998, IIED 1997).

Many analysts believe that decentralization and the devolution of decision-making powers to the local level, along with greater government accountability and transparency, are essential for ensuring effective use of natural resource endowments (Pomeroy and others 2001, Russ and Alcala 1999, Jentoft and others 1998, McCay and Jentoft 1996). Management programs for Small-scale fisheries, then, should incorporate the knowledge and insights of local fishers (see, for example, Haggan and others 2005, Poulsen and Valbo-Jorgensen 2001b), although there are limitations to this type of work that require careful consideration by practitioners (see Fischer 2000, Batterbury and others 1997). There have also been calls for fisheries management systems that are less dependent on the types of quantitative data required for the development of statistical models that predict the effects of various management actions within useful confidence limits (Johannes 1998). While biological investigations can continue to play an important role in developing fisheries management strategies, the integration of biological data with Local Ecological Knowledge (LEK) and socio-cultural information is now seen as a more viable way of assessing the impact of alternative fisheries management actions.

An innovative approach to the management of fishery resources by local fishers was initiated in southern Laos in the early 1990s. Several small fishing communities along the Mekong River established ‘‘Fish Conservation Zones’’ (FCZs), or ‘‘no take’’ fish sanctuaries based on their LEK (Baird 2001b). This article starts by describing the community-based fisheries co-management initiative that led to the adoption of FCZs as a management strategy, and then describes the ways FCZs are managed. The main objective of this article is, however, to present an integrated framework for assessing the effectiveness of tropical river FCZs combining insights from LEK and biology. We believe that combining LEK with scientific fisheries management, including statistical tools, can contribute to improved management of small-scale fisheries. All over the world, and especially in nonindustrialized countries, there is a critical need for increased integration of different knowledge systems in natural resource management.

Mekong River Fish, Fishers, and Fishery Governance

Mekong River

The Mekong is the hydrological life-blood of Lao People’s Democratic Republic (Lao PDR or Laos), flowing for some 1860 km through the country. About 25% of the Mekong River Basin is located in Laos, which contributes 35% of the Mekong’s total flow (FAO 1999). One important characteristic of the Mekong River Basin is the diversity of its aquatic habitats. There are many kinds of rapids, deep-water pools, flooded forests, and a rich array of aquatic animals and plants (Baird 2001a, Claridge 1996, Rainboth 1996, Kottelat and Whitten 1996). Indeed, the Mekong River Basin supports the third most diverse fish fauna in the world, and more fish species than any other river basin in Asia. It has been estimated that 1200 species could occur in the Mekong Basin, although many have not yet been taxonomically described (Rainboth 1996).

Siphandone Wetlands

The Siphandone Wetlands are situated in the extreme south of Laos, in an area bordering Cambodia to the south, southeast, and southwest. They are one of the most complex ecosystems in the mainstream Mekong River, made up of a multitude of large and small inhabited and uninhabited islands, narrow channels, seasonally inundated forests, deep-water pools, rapids and waterfalls (Daconto 2001, Claridge 1996). The wetlands are largely situated in Khong District, which is in the southernmost part of Champasak Province (Figure 1). The aquatic environment is characterized by especially high biodiversity and productivity (Baird 2001a, Daconto 2001). So far, 201 fish species have been recorded from fish catches just below the Khone Falls in Khong District, of which about 165 are considered economically significant to fishers in the Khone Falls area (Baird 2001a).

Small-scale Fishers in Southern Laos

Laos is one of the world’s most economically disadvantaged nations, with an estimated per capita

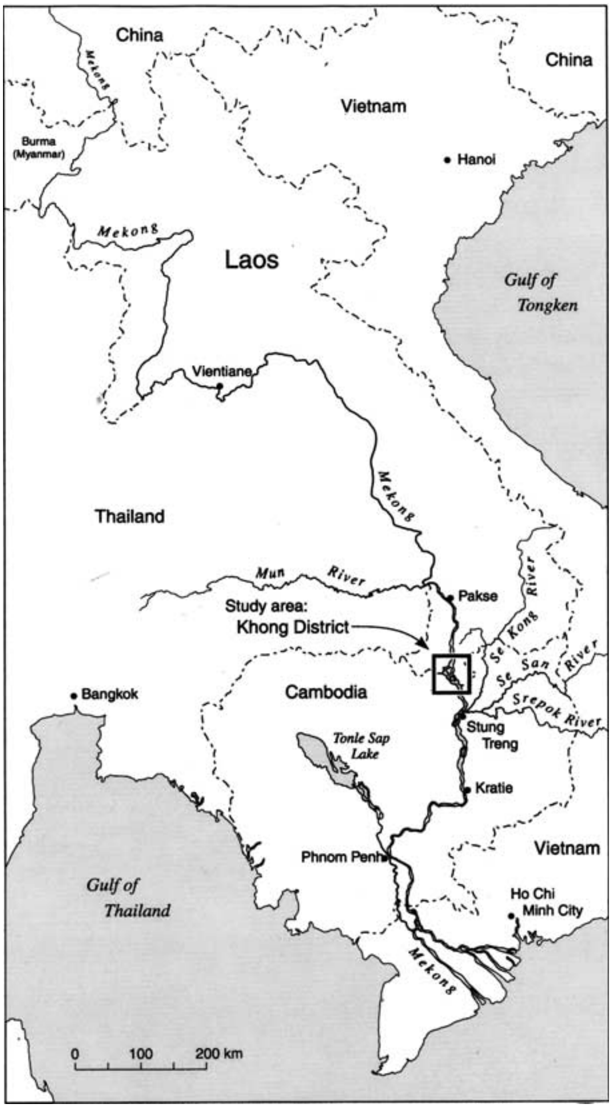

Figure 1. Khong District, Champasak Province, southern Lao PDR.

nominal Gross Domestic Product (GDP) in 1997 of US$ 362, and is heavily dependent on natural resources to provide livelihoods for its population and to earn foreign exchange (UNDP 1999). As is the case throughout most of the Lower Mekong River Basin, small semi-subsistence farming and fishing in rural communities remains the dominant way of life. As the country is landlocked, the Mekong River and her tributaries are the main sources of capture fisheries, which are a major source of both protein and cash income (Bush 2003, Sjorslev 2000). A large variety of fishing methods are used, each based on particular habitats and fishing seasons, as well as the ethnicity and socio-economic conditions of the fishers (Claridge and others 1997). The fishing methods employed are also dependent on targeted fish species, and knowledge of the biology and behavior of the fish (Baird and others 2003, 2001a, 1998a, Claridge and others 1997). In these fishing dependent communities, the LEK of fishers contributes greatly to people's ability to feed their families and generate income. In recent years, however, human populations have grown, fishing implements have modernized, markets have become more accessible, and development projects ranging from small irrigation initiatives to large hydroelectric dams have multiplied. These have all combined to impact negatively on fish populations (Bush 2004, Baird 2001b, IRN 1999, Claridge and others 1997, Roberts 1993b). Although there are few official data, there are increasing reports of significant declines in fish catches (Baird and others, 2001a, 2001b, Hogan 1997, Roberts and Baird 1995, Lieng and others 1995, Roberts 1993c).

Over 65,000 people live in Khong District, the vast majority of whom are ethnic Lao rural peasants. They are mainly semisubsistence rice paddy farmers, and have long inhabited the area. People from Khong are probably more dependent on wild capture fisheries for their livelihoods than are people from any other parts of Laos. Of the 136 villages in Khong, 86 are situated on islands, and most of the rest are along the eastern bank of the Mekong River. Approximately 94% of families in the district participate in artisinal fisheries at a subsistence level or as a way of generating income. In 1996/1997, it was estimated that 4,000,000 kgs of fish were caught in Khong District, and that over US$ 1 million worth of wild fish and fish products from Khong were sold outside of the district (Baird 2001b, Baird and others 1998b).

Fishery Governance

In the Mekong River Basin, wild capture fisheries management faces many challenges that, if left unaddressed, have the potential to cause significant habitat degradation that crosses international borders (Baird and others 2003, IRN 1999, Bakker 1999, Roberts 1993b). The Yali Falls dam in Vietnam's Central Highlands, for example, has already generated significant impacts downstream in northeast Cambodia (Hirsch and Wyatt 2004, Baird and Dearden 2003, Fisheries Office and NTFP 2000). The Mekong River Commission (MRC), which should facilitate the solving of serious transboundary aquatic resource management problems like this one, has so far failed to be effective (Hirsch and Wyatt 2004, Fisheries Office and

NTFP 2000). Dams built in Laos are believed to have had a serious negative impact on fisheries (IRN 1999), but quantitative data about fisheries resources are very limited and fragmented (Kottelat and Whitten 1996, Roberts and Warren 1994, Hill and Hill 1994, Roberts 1993c). There are large knowledge gaps regarding the many small-scale fishers operating throughout the Mekong countries (Baird and others 2001a, Ahmed and others 1998, Hill and Hill 1994). Furthermore, the Mekong basin system has many fisheries, some large and others small, each operating differently, which adds even more complexity to the problem of developing effective management programs (Baird and others 2003, 1998b, Ahmed and others 1998, Claridge and others 1997). Many fisheries are in remote areas, making government management difficult, costly, and generally unrealistic (Cunningham 1998). Centrally imposed natural resource management systems generally require large amounts of human and financial resources from governments for monitoring and regulating resources use. Unfortunately, the fisheries departments in the Mekong Basin are typically understaffed and underfunded (Baird 2001b, Johannes 1998, Cunningham 1998, Kottelat and Whitten 1996). The Mekong Basin also falls within the national boundaries of six nations, China, Burma, Thailand, Laos, Cambodia, and Vietnam, increasing the complexity. Many fish species move between two or more of those countries, and are highly migratory (Baird and others 2003, 2001a, 1999a, Poulsen and Valbo-Jorgensen 2001b, Warren and others 1998, Roberts and Baird 1995, Lieng and others 1995, Roberts and Baird 1995, Hill and Hill 1994, Roberts 1993b).

Despite the challenges noted above, local fisheries management can still play an important role in enhancing fish stocks. Some fish migrate only locally, or are relatively sedentary (Baird and others 2001b, Baird 2001a, 2001b, Baird and others 1999a, Rainboth 1996). There is also a potential for synergistic and cumulative positive impacts when nearby villages independently take responsibility for fish stocks in their individual areas of control (Baird 2001b, Poulsen 2001, Baird and others 1999b, 1998a). Essentially, the more communities that participate, the more the examples of positive results can be scaled up. Given the pressing need for improved natural resource management, alternative decentralized management models that involve governments, but that rely on local communities to regulate fisheries, are gaining popularity, and not only in the Mekong region (Pomeroy and others 2001, Baird 2001b, Hirsch and Noraseng 1999, Masae and others 1999, Cunningham 1998, Johannes 1998, Pomeroy and Carlos 1997, Hogan 1997).

Fisheries Co-Management and Fish Conservation Zones

Fisheries Community-Based Co-management

Natural resource ‘‘co-management’’ (CM) can be defined as, ‘‘the collaborative and participatory process of regulatory decision-making among representatives of user-groups, government agencies and research institutes’’ (Jentoft and others 1998: 423). The term ‘‘co-management’’ is useful for demonstrating that fisheries management is a joint effort between resource users and government. However, some CM programs are strongly government dominated, with little real decision-making powers being devolved to resource users. Because of this uncertainty, some scholars and practitioners prefer to use the term ‘‘community-based natural resource management’’ (CBNRM), as it emphasizes that local communities are the center of the management structures (see, for example, Bawa Village Community 1997). Nevertheless, the term CBNRM is somewhat limited in that it does not explicitly recognize the role of governments in management systems, including partnerships or agreements between governments and users. Most fishing communities require some level of government support to effectively defend community resource areas covered under local management regulations (Pomeroy and others 2001). We, therefore, use the term ‘‘community-based fisheries co-management’’ (CBFC). This hybrid conveys more effectively the message that management systems are centered in communities, with users having considerable management decision-making powers. Although government participates in the process, it recognizes the validity of user tenure over resources.

The systems in place in Khong District fit quite well into this framework. With the support, but only minimal interference from the government or other outsiders, a regulatory system has been adopted that allows individual villages to establish and enforce regulations for managing living aquatic resources. No two villages have adopted exactly the same measures, but the establishment of FCZs has been a common initiative among the communities. Regulations restricting and banning the use of particular fishing methods or gears all year round or in particular seasons have also been adopted, as have regulations restricting the harvesting of frogs and certain species of juvenile fish (see Baird 2001b).

Fish Conservation Zones

FCZs, in the context of the mainstream Mekong River in Khong District, are defined as ‘‘fish sanctuaries'' or ''no-fishing zones'' that operate year round or part of the year, and are initiated and managed by communities while being approved by local government (Baird 2001b). Individual communities in Khong District manage each FCZ differently. Two or three villages manage some jointly, but most villages have their own FCZs, and a few have two or three each. Based on LEK, local people in Khong insist that deep-water pools in the Mekong River should be prime sites for establishing FCZs. Fishers believe that deep-water pools are extremely important dry season refuges for many species of fish, especially large ones, and that they are important spawning grounds for some species (see also Kolding 2002, Baird and others 2001b, 1998a, Poulsen and Valbo-Jorgensen 2001a, Chomchanta and others 2000, Cunningham 1998).

The original idea to establish FCZs, or *Vang Sangouan* in Lao, came from small-scale fishers in Hang Khong village, Khong District. However, nongovernment organization (NGO) support was required to gain district and provincial government agreement for the formal establishment of FCZs by villagers. The first author played a major role in these NGO efforts, along with his Lao government colleagues. Once regulations related to FCZs are proposed by villages and are approved by government, it is the responsibility of village administrations, led by village chiefs, to manage and protect the FCZs (Baird 2001b).

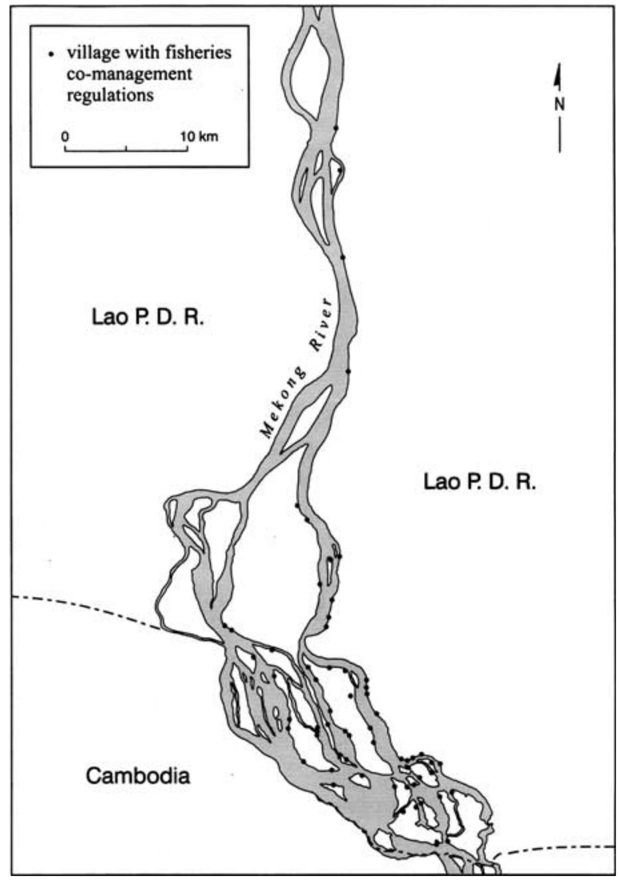

Figure 2. Villages in Khong District with fisheries co-management regulations.

FCZ Monitoring and Evaluation Program

Beneficiaries

The FCZ monitoring work in Khong District was started in 1997 by local fishers, local government, and the NGO CESVI Cooperation and Development. The objective was to provide fishers with a tool for learning about the effectiveness of their FCZs. This monitoring contributed to an adaptive management process, providing locals, who are the *de facto* resource managers, with information useful for assessing the impact of their management decisions, and for adjusting and improving management strategies (Baird 2001b, Baird and others 1999b). It also provided information to government technical agencies and decision-makers in Laos and elsewhere, who have become interested in the design, implementation, and effectiveness of FCZs (Kolding 2002, Poulsen 2001, Poulsen and Valbo-Jorgensen 2001a, Chomchanta and others 2000, Baird and others 1999b, 1998a).

Methodology

Between December 1993 and August 1999, 60 of 63 villages participating in the aquatic resource community-based co-management program in Khong established 68 FCZs (Figure 2). The FCZs are not uniform in size or many other characteristics, owing to the highly diverse nature of the habitats. The largest is 18 ha, the smallest is 0.25 ha, and the mean size is 3.5 ha. The deepest FCZ is approximately 50 m in the dry season, the shallowest is about 2.5 m, and the mean depth is 19.5 m (Baird 2001b).

Villagers defined the locations and boundaries of the FCZs, based on LEK, which has been accumulated through generations of fishing experience, and through the personal experiences and observations of local fishers. As mentioned above, fishers believe that large numbers of individual fish species, especially large ones, congregate in deep parts of the Mekong River at the height of the low-water season. The dry season is the main fishing season for most people in Khong (Baird 2001b, Baird and others 1998b). Water levels decline 30-fold in comparison to the wet season (Cunningham 1998), which makes many fish species vulnerable to harvesting pressures. Villagers believe that by banning or significantly limiting fishing activities in key deep-water areas that serve as dry-season refuges and sometimes spawning grounds for fish, the impact of fish harvesting can be reduced, resulting in increased or at least more stable fish stocks (Baird 2001b).

Prior to this study, Khong villagers reported that the establishment of FCZs resulted in significant increases in the stocks of at least 51 fish species (Baird and others 1998a). The beliefs of fishers were largely based on increases in fish catches in areas adjacent to FCZs, as well as other indicators (Baird 2005). However, the fish species that benefit differ, depending on the type of riverine habitat protected within the boundaries of individual FCZs (Baird and others 1998a).

An important advantage of CBFC systems is their ability to make use of LEK regarding fish stock dynamics and ecology. However, it is important to collect additional evidence, whenever possible, on the specific consequences of fishery management initiatives biologically and socially. The principal biological consequence is the extent to which resource stocks are affected. Social consequences include changes in the cohesion of rural communities, and prevailing attitudes towards compliance and enforcement of regulations. This paper deals mainly with the monitoring and assessment strategy associated with biological factors. It is based on a survey of local fishers from 53 villages in Khong regarding which fish species they believe have benefited from the FCZs. Because some villages jointly manage particular FCZs, in some cases two or three groups of fishers were interviewed regarding the same FCZ. The final tally was 63 individual village focus group interviews.

Village Survey

The initial monitoring activity took place between July 1997 and March 1998, and included interviewing fishers about aquatic resource management regulations and FCZs. All 60 villages with FCZs were included in the survey. Fishers were given the chance to assess, in groups, whether FCZs had benefited fish stocks, and what particular species had benefited from FCZs, and why. This participatory process was very useful for providing insights into the fishery for villager and local government officials (Baird and others 1998a).

The surveys were designed to elicit information about the LEK of fishers regarding Mekong fish and fisheries, and to document and assess the habitat requirements of economically important species. The overall goal was to produce a local pilot model that would allow for the effectiveness of FCZ compliance and protection measures to be compared with protected habitat types. One objective was to investigate the relationship between the physical and environmental characteristics of FCZs and the reported benefits of FCZs to different fish species stocks. These data facilitated an investigation of whether the reported increases are associated with environmental factors and the habitats protected by the FCZs. Data regarding the environmental parameters used to describe the FCZs were collected from villagers during the surveys.

One issue that arises in obtaining fisher assessments of fish stocks is the reliability of responses (Baird 2004a). The assumption underlying this study is that village fishers have a keen understanding of the status of local fish stocks and major changes that have occurred in them (Baird and others 1999a, 1998a, Roberts and Baird 1995, Roberts 1993c). However, subsistence fishers do not normally maintain written catch records. Answers to questions about what has happened to stocks over time, therefore, are based on the memory recall of individuals. After completing the initial survey of representatives from all the villages in Khong with FCZs, it was decided in 1998 to return to the 60 villages considered in the first study to validate the reports received of fish species benefiting from FCZs. Based on these validation interviews, the list of fish species that had reportedly benefited from FCZs was revised. Some species were added as FCZ beneficiaries, whereas others were removed. It was striking that few changes were required. More importantly, however, most changes made ''biological sense,'' based on known science about the fishes. Only data from villages known to be enforcing FCZ regulations were included in the analysis, so as to ensure the integrity of the data set.

Environmental Parameters

It is difficult to identify and measure characteristics of FCZs that might influence the size of fish stocks. Moreover, FCZs are by no means internally homogeneous. Owing to the lack of detailed environmental data, and the unique nature of each FCZ, original field measurements were made. Although significant variations in depth and other characteristics exist within a FCZ, single numbers were recorded for each of the variables, to represent the entire protected area. The set of environmental characteristics considered is presented in Table 1. The other variables are the age of FCZs, recorded by year; the sizes of FCZs, measured in square meters; the depths of FCZs, measured in meters; and the localized gradient or slope of individual FCZs. Velocity was recorded on an ordinal scale, as was the extent of wetland forests nearby FCZs.

Table 1. Characteristics of fish conservation zones

Area	Square meters
Age	Number of years since establishment (1 = 1997, 2 = 1996, 3 = 1995, 4 = 1994)
Depth	Meters
Velocity	1 = standing/slow, 2 = moderate, 3 = fast
Gradient	Degrees
Wetlands	0 = none, 1 = some, 2 = large area

Originally, data on several other environmental features of FCZs were collected, including riverbed substrate within FCZs, as well as objects found in FCZs such as logs, large rocks, and caves. However, the classifications developed for these variables resulted in very sparse data matrices, due to a large variety of mixes of different substrate types and combinations of objects. They were, therefore, not considered in the analysis, even though fishers believe that they are important factors affecting the biological success of FCZs for particular fish species.

The selection of the environmental factors was based on what is known about the habitat preferences of fish species in the Mekong River, both by villagers and by scientists. Unfortunately, the pioneering nature of this study resulted in some important variables being measured rather crudely. For example, quantities of wetland forests were measured as ''very abundant,'' ''moderately abundant,'' and ''rare or absent.'' River velocity was also measured on an ordinal scale. River substrate was difficult to measure because so many different substrate types can be found inside a single FCZ. Quantifying the amount of each type present was simply not possible. This was also the case when considering objects in FCZs. The occurrence of 1 log was included in the same category as 10 logs, even though there may be differences in their effects on habitat suitability.

Results

The existence of possible relationships between reported increases in fish stocks and environmental parameters is investigated using nonparametric measures of association, because several variables are measured at nominal or ordinal scales. The use of nonparametric tests also enables us to avoid the distributional assumption that the random variables of interest are normally distributed, which is a very strong assumption in the present context. The key assumptions for the application of nonparametric statistical tests are randomness and independence.

The species that were reported to have increased in the FCZs are presented in Table 2. Overall, 51 species were identified by villagers as direct beneficiaries of FCZs. The most commonly reported species were the carps *Morulius* spp., the featherback *Chitala blanci*, the seven-striped carp *Probabus jullieni*, and the pangasid catfish *Pangasius pleurotaenia*. The fishes reported to have benefited most often from FCZs were carps in the family Cyprinidae, with 18 of 51, followed by catfishes in the family Pangasiidae, with 8 or 51, and then catfishes in the family Siluridae, with 7 of 51. Villagers reported an increase in species from 15 fish families, as well as one family of soft-shelled turtles.

The association between fish stock increases and the ratio level variables (age, area, depth, and gradient of the FCZs) is reported in Table 4. Only the top 25 species reported as increasing because of FCZs are considered. The others are characterized by very low frequency counts, and do not lend themselves to statistical analysis.

The data presented in Tables 3 and 4 indicate that there are no statistically significant correlations between the numbers or types of fish species reported as increasing because of FCZs and the ages or area sizes of FCZs. Other factors are probably the main determinants of the numbers and types of species increasing in FCZs.

Villagers believe that dry season water depth is the single most important factor affecting dry season habitat use by different Mekong River fish species (Baird and others 1998a), and this is borne out in Table 4. Six species—*Micronema micronema, M. apogon, Hemisiluris mekongensis, Pangasius conchophilus, Boesemania microlepis,* and *Cyclocheilichthys enoplos*—are all significantly associated with deep water FCZs. This is not unexpected, considering what is known about their biology (Baird and others 2001b, 1999a, Rainboth 1996). In contrast, *Morulius* spp. were both significantly associated with shallower waters, which also fits with their algae eating habits. Other species, such as *Chitala blanci* and *Hypsibarbus malcolmi*, also have negative signs, as might be expected, but the associations are not strong or statistically significant for either. Virtually all the other signs for the coefficients are in the directions that might be expected, although associations are generally weak. Some of the most interesting and

Table 2. Fish species reported to have increased in fish conservation zones (FCZs)

Fish ID	Latin name	Local Lao Name	No. of FCZs with reported population increases
1	*Morulius barbatula*	pa phia itou	48
2	*Chitala blanci*	pa tong kai	47
3	*Morulius chrysophekadion*	pa phia khi kam	40
4	*Probarbus jullieni*/spp.	pa eun	32
5	*Pangasius pleurotaenia*	pa gnone thong khom	30
6	*Hemibagrus wyckioides*	pa kheung	29
7	*Cosmochilus harmandi*	pa mak ban	28
8	*Micronema micronema*	pa nang khao	27
9	*Hemisiluris mekongensis*	pa nang deng	25
10	*Hypsibarbus malcolmi*	pa pak kom	21
11	*Labeo erythropterus*	pa va souang	20
12	*Chitala ornata*	pa tong khouay	19
13	*Pangasius conchophilus*	pa pho/pa ke	18
14	*Hemibagrus nemurus*	pa kot leuang	17
15	*Helicophagus waandersi*	pa na nou	16
16	*Belodontichthys dinema*	pa khop	16
17	*Amphotistius laosensis*	pa fa lai	15
18	*Notopterus notopterus*	pa tong na	15
19	*Boesemania microlepis*	pa kouang	14
20	*Pangasius bocourti*	pa houa mouam	12
21	*Bagarius yarrelli*	pa khe	12
22	*Cyclocheilichthys enoplos*	pa chok/pa choke	12
23	*Gyrinocheilus pennocki*	pa ko	12
24	*Hemibagrus wycki*	pa kot mo	11
25	*Micronema apogon*	pa sa-ngoua	11
Cut off for statistical analysis			
26	*Hypsibarbus wetmorei*	pa pak thong leuang	9
27	*Bangana behri*	pa va na no	8
28	*Cyprinus carpio/*	pa nai	8
29	*Cirrhinus microlepis*	pa phone	6
30	*Micronema bleekeri*	pa nang ngeun	6
31	*Wallago attu*	pa khao	5
32	*Coius undecimradiatus*	pa seua	5
33	*Osphronemus exodon*	pa men	5
34	*Amyda cartilaginea*/spp.	pa fa ong	5
35	*Hampala macrolepidota*	pa sout	5
36	*Pangasius hypophthalmus*	pa souay kheo	4
37	*Pristolepis fasciata*	pa ka	4
38	*Wallago leeri*	pa khoun	3
39	*Mastacemblus Armatus*/spp.	pa lat	3
40	*Hampala dispar*	pa sout	3
41	*Mekongina erythrospila*	pa sa-i	3
42	*Pangasius larnaudii*	pa peung	2
43	*Pangasius sanitwongsei*	pa leum	2
44	*Channa micropeltes*	pa meng phou	2
45	*Catlocarpio siamensis*	pa kaho	2
46	*Hypsibarbus lagleri*	pa pak pe	2
47	*Pangasius polyuranodon*	pa gnone hang hian	1
48	*Channa marulius*/spp.	pa kouan	1
49	*Barbodes altus*	pa vian fai	1
50	*Labiobarbus leptocheilus*	pa lang khon	1
51	*Poropunitus deauratus*	pa chat	1

informative results are related to the water depth of FCZs. This may be because the data collected for this variable were quite accurate and/or because this variable is particularly important for Mekong River fish species. We believe both of the above to be true, but especially the latter.

Table 4 also shows that there are few strong correlations between the benthic localized gradient or riv-

Table 3. Reported increases in fish species by fish conservation zone (FCZ)

FCZ ID	Year FCZ established	No. of species reported as increasing
52	1996	23
47	1995	20
55	1994	20
7	1995	18
53	1996	18
10	1995	17
22	1996	17
56	1994	17
34	1994	16
62	1994	16
4	1994	15
20	1995	15
44	1996	15
57	1994	15
21	1995	14
35	1996	14
37	1996	14
43	1996	14
48	1995	14
54	1996	14
1	1994	13
3	1994	13
19	1996	13
25	1994	13
12	1996	12
40	1995	12
16	1995	11
58	1995	11
59	1994	11
15	1995	10
17	1996	10
39	1995	10
9	1995	9
27	1995	9
45	1996	9
36	1995	8
60	1994	8
13	1995	7
24	1996	7
29	1995	7
41	1997	7
49	1995	7
2	1994	6
14	1996	6
18	1995	6
23	1996	6
28	1995	6
30	1995	6
33	1995	6
42	1997	6
46	1997	6
61	1994	6
5	1995	5
11	1995	5
31	1995	5
32	1995	5
6	1994	4
8	1996	4
50	1995	4
63	1997	4
38	1994	2
26	1995	1
51	1994	1

erbed slope within FCZs. This may be because localized gradient is not particularly important for most Mekong fish. However, it may also be because the data regarding this parameter contained considerable measurement error. There are two problems with information collected regarding gradient. The first is that only qualitative data were used to indicate the degree of slope of the riverbed within a certain FCZ. The other is that slope may vary within an FCZ, but a single number is used to represent the entire protected area.

Table 5 presents the associations found between the reported increases in fish stocks and the ordinal scaled environmental variables (velocity of water flow and the presence of wetland forests near the FCZs). Many deep FCZs are partially surrounded by areas of seasonally inundated shrubs and trees, and many fish species are believed to rely on flooded forests for food and shelter during certain parts of their life cycles (Baird and Phylavanh 1999, Roberts and Baird 1995, Roberts 1993c). For example, some fish inhabit flooded forest areas in the rainy season before retreating to deep-water areas during the dry season. The data in Table 5 indicate that several fish species are significantly associated with the existence of large tracts of flooded forests: *Hypsibarbus malcolmi, Gyrinocheilus pennocki, Labeo erythropterus, Pangasius conchophilus, Hemibagrus nemurus* and *Bagarius yarrelli.* This is consistent with what is known about the biology of these species. *H. malcolmi* and *P. conchophilus* are both known to be important consumers of flooded forest plant material and fruits (Baird and Phylavanh 1999). *L. erythropterus* is an algae eater that may rely on the rocky habitat where flooded forests are often established (Baird and Phylavanh 1999). The same is true for *G. pennocki. B. yarrelli,* on the other hand, is a carnivorous fish species, which is especially common in rocky areas in close proximity to flooded forests, and is generally found in the same areas as *G. pennocki. H. nemurus* is another carnivorous fish species that is often found in rocky areas suitable for supporting substantial tracts of seasonally inundated forests. Most deep-water carnivorous fish species have weak associations with the occurrence of wetland forests. It must be noted, however, that the

Table 4. Biserial point correlation coefficients

Fish ID		Area m^2	Age	Depth	Gradient
1	*M. barbatula*	−.243	.004	−.376**	.131
2	*C. blanci*	.036	−.001	−.145	−.145
3	*M. chrysophekadion*	−.246	.041	−.305*	−.305*
4	*Probarbus* spp.	−.174	−.034	.133	.306*
5	*P. pleurotaenia*	.158	−.228	.049	−.034
6	*H. wyckioides*	−.140	.210	.136	.144
7	*C. harmandi*	.046	−.090	.225	−.069
8	*M. micronema*	.331**	.202	.414**	.056
9	*H. mekongensis*	.062	.119	.274*	.053
10	*H. malcolmi*	−.292*	−.091	−.229	−.141
11	*L. erythropterus*	−.302*	−.176	−.014	−.009
12	*C. ornata*	.059	.217	.173	.149
13	*P. conchophilus*	.094	.174	.516**	.150
14	*H. nemurus*	.267*	−.118	.025	.008
15	*H. waandersi*	.229	.001	.170	.236
16	*B. dinema*	.025	.170	.215	−.260*
17	*A. laosensis*	.019	.082	.192	.054
18	*N. notopterus*	.223	−.004	.100	.091
19	*B. microlepis*	.494**	.079	.420**	.231
20	*P. bocourti*	.039	−.022	.147	.146
21	*B. yarrelli*	−.284*	−.022	−.007	.026
22	*C. enoplos*	.201	−.069	.360**	.079
23	*G. pennocki*	−.157	−.163	−.072	−.122
24	*H. wycki*	−.199	−.174	−.122	−.004
25	*M. apogon*	.397**	.261*	.456**	.052

*Significant at = 0.05.
**Significant at = 0.01.

data used in the analysis are rough estimates of the amount of wetland forest in close proximity to individual FCZs.

Water velocity is an important factor affecting riverine fishes (Rainboth 1996). Unfortunately, one of the more important constraints for investigating the relationships between water velocity in FCZs and species benefiting from FCZs is that there are no detailed water velocity data available for the areas. Simple ordinal measures (''fast'', ''moderate,'' and ''slow'') were used to indicate water velocity at individual FCZs. There were also difficulties in determining how to classify areas where water flowed quickly in a circular pattern rather than quickly in a linear manner, even though both types of fast flowing waters may affect fish species differently. Table 5 shows that *Morulius chrysophekadion, Boesemania microlepis, Micronema micronema, Pangasius bocourti, Cyclocheilichthys enoplos*, and *Gyrinocheilus pennocki*, for example, are significantly associated with faster flowing waters. Not all of these relationships were expected, which suggests that there is a great deal more to learn about the habitat preferences of particular fish species. However, the species with the highest association with fast flowing waters, *Gyrinocheilus pennocki*, is a well-known inhabitant of rocky fast flowing rapids (Baird and others 1999a).

Table 6 presents the degree of association between the 25 fish species most commonly reported as increasing. The species considered were reported as increasing in 11 to 48 of the 63 cases. The analysis assessed the extent to which the reported increase in one species' stock is associated with the reported increase of another fish's, one that may have similar habitat requirements. Again, the nature of the relationship (positive or inverse) and the strength of association need to be considered.

Although the r-values obtained are generally low, this is to be expected because the habitat requirements of two species are never exactly the same. It is interesting, however, that almost all of the associations are in the direction that might be expected based on what is known about the behaviors of different species. Several species are significantly associated with one another, probably because of similar habitat requirements and life-cycle patterns.

The carps *Morulius chrysophekadion* and *Morulius barbatula* have only recently been recognized by ichthyologists as being distinct species (Baird and others 1999a). Because they have similar morphologies and probably life cycles as well, it stands to reason that the association between them is higher than for any others (r = 0.66). Another example is the association between

Table 5. Values of Cramer's V

Fish ID		Velocity	Wetland forests
1	*M. barbatula*	.418**	.109
2	*C. blanci*	.177	.135
3	*M. chrysophekadion*	.289	.118
4	*Probarbus* spp.	.211	.160
5	*P. pleurotaenia*	.325	.097
6	*H. wyckioides*	.255	.093
7	*C. harmandi*	.261	.103
8	*M. micronema*	.393*	.170
9	*H. mekongensis*	.309	.100
10	*H. malcolmi*	.280	.414**
11	*L. erythropterus*	.209	.343*
12	*C. ornata*	.376	.351*
13	*P. conchophilus*	.146	.309*
14	*H. nemurus*	.309	.365*
15	*H. waandersi*	.318	.169
16	*B. dinema*	.253	.102
17	*A. laosensis*	.326	.175
18	*N. notopterus*	.260	.038
19	*B. microlepis*	.459**	.223
20	*P. bocourti*	.400*	.285
21	*B. yarrelli*	.351	.391**
22	*C. enoplos*	.360**	.079
23	*G. pennocki*	.460**	.393**
24	*H. wycki*	.148	.257
25	*M. apogon*	.307	.211

*Significant at = 0.05.
**Significant at = 0.01

Micronema micronema and *Micronema apogon*, two large silurid catfish that are often found in deep-water areas. Increases in *Micronema apogon* are highly associated with other deep-water pool inhabitants like the pangasid catfish *Pangasius conchophilus*, but are not closely associated with relatively shallow water inhabitants like both *Morulius* spp. and the featherback *Chitala blanci*. Some species, like *Hypsibarbus malcolmi* and *Helicophagus waandersi*, have not previously been recognized as having similar habitat requirements, but this study indicates that there is a significant association between them.

The results presented in Table 6 indicate that fish species with the narrowest range of habitat requirements tend to be closely associated with other fish species. For example, the silurid catfishes *Micronema micronema* and *Hemisiluris mekongensis* are known to have very specific habitat requirements, and are rarely found outside of deep-water areas in the dry season (Baird and others 1999a). Species with more generalized habitat requirements, such as the carps *Morulius chrysophekadion* and *Cosmochilus harmandi*, have lower associations with other fish species. This is probably because the degree of difference and/or similarity with other species is not as great.

Discussion

The amount of protection obviously has a direct bearing on the effectiveness of FCZs. Ascertaining the degree of protection provided by different communities to FCZs throughout Khong District, however, is problematic. Almost all the villages report full or close to full compliance with regulations. This high level of compliance, however, may in part be attributable to different interpretations of the rules. In some villages, for example, people may consider a particular activity to be legitimate, or perhaps turn a blind eye to it, whereas in other villages it is seen as a violation. Nevertheless, local reports and field observations made by the first author and Lao colleagues over a number of years indicate that the majority of the FCZs are well protected, and that villager compliance is generally high (Baird 2001b, 1999b). Some difficulties, however, have arisen with the implementation of FCZs, such as conflicts within and between villages. As noted earlier, villages that were not successful in establishing effective FCZs have been excluded from this analysis.

Assuming that the FCZ protection provided by the villages included in the analysis is relatively even, it is reasonable to conclude that habitat parameters and other unique environmental factors are the main determinants of the number of reported beneficiaries of FCZs. Our hypothesis is that the microhabitats protected within FCZs are critical in determining the success of FCZs in benefiting certain fish species. Our understanding of the niche requirements of most Mekong fish species is still incomplete, however, because research on Mekong fish is still in an exploratory stage (Roberts 1993c). Nevertheless, this study provides valuable biological information about the habitat preferences of particular species, the degree to which changes in species stocks are associated with changes in the stocks of others, and the importance of properly sighting FCZs to ensure that suitable habitats are protected.

The migratory behavior of individual fish species is an important factor affecting the degree to which they benefit from relatively small and discontiguous protected areas. Fish that spend most of their lives, especially critical parts of their life cycles (spawning, nursing, and other vulnerable periods) within relatively small areas are more likely to benefit than fish that migrate long distances, or which are absent from protected areas during critical parts of their life cycles. Nevertheless, it is possible that the stocks of some highly migratory species that visit FCZs for short periods also benefit if their stays coincide with critical parts of their life cycles. Moreover, the establishment of large

Table 6. Values of phi coefficient

Fish ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	–																								
2	.102	–																							
3	660++	.239	–																						
4	.195	.228	.111	–																					
5	.085	.118	.261*	.303*	–																				
6	.007	.027	−.093	.145	−.115	–																			
7	−.025	−.065	.147	−.014	.171	.199	–																		
8	−.344+	−.011	−.209	.147	−.055	.230	−.065	–																	
9	−.308+	.250*	.009	.084	.266*	.292*	.254*	.347+	–																
10	.079	.180	.187	.022	.135	.158	−.090	−.136	.115	–															
11	−.019	−.072	.021	−.215	−.172	.328+	.145	−.177	−.135	.386+	–														
12	−.039	.383+	.067	.232	.204	.295*	.108	.060	.245*	.342+	.072	–													
13	−.141	−.196	−.104	.131	.101	.121	.424	.304*	.277*	-.149	.022	.044	–												
14	.172	.026	.164	−.045	.208	.228	.320+	−.165	.238	.405++	.200	.224	.090	–											
15	−.102	.055	−.012	−.009	.028	−.100	−.102	.453+	.049	.405++	−.085	.014	.277*	−.108	–										
16	-.359+	.089	−.088	.064	.101	.193	.139	.379+	.347+	−.258*	−.085	.173	.115	−.190	-.005	–									
17	−.125	.241	−.118	.177	.139	.306+	.250*	.043	.308+	−.026	.019	.526++	.059	.164	.016	.188	–								
18	−.125	.241	−.041	.177	.213	.007	.250*	.118	.232	.079	−.141	.363+	.141	.080	−.155	.016	.388+	-							
19	−.329+	.049	−.150	.068	.178	−.034	.137	.231	.191	.237	−.118	.231	.169	.019	.214	.127	.149	.329+	–						
20	−.014	.097	−.116	−.008	.104	.120	.217	.070	.185	.086	.277*	.298*	.320+	-.022	.274*	−.004	.203	−.176	.032	–					
21	−.108	.004	−.052	−.089	−.058	.282*	.054	−.012	.102	.343+	.451++	.210	−.038	.252*	−.097	.088	.203	.014	−.065	.176	–				
22	−.203	.097	−.052	.073	.266*	.282*	.217	.152	.102	.171	.190	.298*	.051	.160	−.097	.181	.108	.298*	.421++	.176	.176	–			
23	.081	.004	.200	−.169	.104	−.124	.136	−.257*	.102	.257*	.103	.034	−.307+	.252*	−.283*	−.097	.108	.108	−.065	.074	.176	−.029	–		
24	.061	.076	.001	−.216	−.020	.079	.178	−.060	.140	.207	−.044	−.029	.079	.474++	−.076	−.076	−.159	.037	.056	−.132	−.010	−.010	−.010	–	
25	−.430++	−.308*	−.346+	.118	.064	.079	.262*	.447++	.225	−.237	−.134	.062	.357+	.003*	.212	.212	.234	.234	.458++	−.117	−.010	.096	−.117	−.101	–

*Significant at = 0.05.
+Significant at = 0.01.
++Significant at = .001.

numbers of FCZs in river systems could have positive synergistic effects on species that migrate to and from or through networks of several FCZs (Baird and others 1998a, see also William and others 2003, Friedlander and others 2003). Although our understanding of these complex processes is quite limited, these factors may help to explain why some migratory species are reported to have benefited from FCZs. Moreover, some long-distance migrators may actually move shorter distances than previously believed. Nevertheless, villagers did not report increases for many species known to be long distance migrators, such as *Henicorhynchus* spp., *Paralaubuca typus, Tenualosa thibaudeaui,* and *Scaphognathops bandanensis.* Other known migratory species such as *Mekongina erythrospila* and *Labiobarbus leptocheilus* were reported, but only in a few villages (see Baird and others 2003, and Baird and others 1999a for information about the migratory patterns of the above species).

Overall, there is some association between the reported increases in fish stocks and the selected environmental variables. The relationships are generally in the directions that might be expected, considering what is known about the habitat preferences of the Mekong fish species under consideration. The strength of the relationships between different species and single habitat parameters is generally weak. This is not surprising given the highly complex ecological system involving hundreds of fish species and other aquatic organisms, which are influenced by a multitude of interrelated riverine habitats and environmental factors. No one factor is likely to exclusively account for variations in fish stocks; rather, it is the interaction between numerous factors that has the largest impact on stocks. These complex and dynamic interactions, however, are poorly understood by fisheries scientists, and lie beyond the scope of this study. They are, however, suited for holistic and broad ecosystem-based approaches to viewing natural resources.

Careful examination of the results of this study provides some interesting clues as to which habitat parameters are likely to be more important for particular species. Consider, for example, *Micronema micronema, Micronema apogon,* and *Boesemania microlepis.* They are known to inhabit deep-water areas in the dry season (Baird and others 2001b, 1999a). These species are all significantly associated with large FCZs, which tend to be the deepest ones. Similarly, *Hypsibarbus malcolmi, Labeo erythropterus,* and *Hemibagrus nemurus* are all known to mainly inhabit relatively shallow to moderately deep waters (Baird and others 1999a). These species were found to be inversely associated with large FCZs.

The species with the most specific habitat requirements are probably more threatened by habitat degradation than species with more generalized requirements. The information presented here can, therefore, help resource managers, including local people, prioritize the types of habitats that require the most protection, and to identify the species that require the most attention due to their vulnerability to loss of habitat. There are other ways these results can benefit management too. For example, if certain species were targeted for protection by a habitat conservation initiative, we could estimate other associated species that might also benefit. It might also be possible to monitor single species, and then make inferences about populations of others. However, because the statistical associations found are generally low, considerable margin for error exists. This error could be reduced as the amount and accuracy of habitat documentation improves, and as the assessments provided by villagers become more accurate as the assessors gain experience in monitoring fish stocks. There is considerable scope for improving the quantity and quality of the data collected so as to improve our understanding of fish ecology, and to use this information in the development of more effective strategies for managing fisheries resources.

Baird and others (1999b) found that the results of CPUE fisheries data collected in eight pilot villages with FCZs in Khong generally did not contradict villager reports regarding the species of fish benefiting from FCZs. Those species reported as increasing because of FCZs were, for the most part, the same ones found in significant quantities in villager catches. Although only 1 year of CPUE data were collected, and no other records of fish catches are available for comparison, these data at least show that the species reported as increasing are present in fish catches in relatively large quantities. If they had been reported as increasing, but were not found in catches, one would be much less confident in the villagers' assessments, since catch is the main indicator they use to determine whether fish species benefit from FCZs (Baird 2005, Baird and others 1999b). Villagers in Khong have often demonstrated their skills in assessing natural systems and processes (Baird 2005). All these factors lead us to believe that although some error in the ability of villagers to assess changes in fish stocks cannot be avoided, the LEK of villagers in Khong is extremely useful for providing researchers with insights into fish stock changes. However, fisheries scientists have rarely used LEK to assess fish stocks, even though it has considerable potential for improving the management of local fisheries, and reducing the cost of managing fisheries by governments. There is much to be gained, and very little to be lost, by developing management regimes that are based on the integration of fisheries science with long-practiced local ways of viewing resources.

Conclusion

Fisheries research is often characterized by a distinct dichotomy. Biologists concentrate mainly on the biological resources, whereas social scientists are largely concerned with social, economic, and cultural issues related to the resource users. It is our view that it is now time to devote greater effort into merging the insights provided by these two research perspectives, so as to increase our common pool of knowledge. Because local fishers in Khong District are continuing to build on their LEK about Mekong fishes through various monitoring activities (Baird and others 1999b), there is a good possibility that fisher LEK could become increasingly important to management, provided that it is taken seriously and promoted by scientists and governments.

We believe that the framework presented here has considerable potential for improving management decisions regarding particular fish species and habitats, be it in southern Laos, other parts of the Mekong River Basin, or elsewhere. LEK can play an important role in the assessment of fish stocks targeted by artisinal fisheries. The use of LEK to assess and monitor fish stocks may be especially important in tropical aquatic ecosystems with high degrees of biodiversity, because the human and financial resources required to conduct detailed scientific studies are especially scarce in nonindustrialized countries such as Laos. It is likely to be especially important in areas characterized by small artisinal fisheries that are not commercially valuable enough to justify large research budgets for detailed stock assessment activities. The use of LEK provides a cost-effective and pragmatic alternative that has the extremely important added benefit of being participatory and having the ability to draw resource users directly into management decision-making processes. This paper has hopefully provided the reader with a glimpse of what is possible when LEK is combined with tools more commonly associated with scientific fisheries management.

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