Biodiversity and Fisheries Management Opportunities in the Mekong River Basin

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Abstract

Due, in part, to extreme ecosystem complexity, relatively un-regulated tropical rivers support a high biodiversity, rivalling that of marine systems. Such rivers, the Mekong Basin being perhaps one of the greatest, traditionally support very important and under-valued fisheries. High diversity of resources, in close proximity to large human rural communities, leads to a high degree of participation in resource exploitation. In essentially agro-fishery livelihoods setting such as this, large commercial fisheries do occur, but part-time fisheries using smaller gears are, generally, the norm. The linkages between biodiversity and exploitation are immediately obvious. Reduced biodiversity will lead to decreased participation, shifts in fishing effort and generally unfavourable socio-economic impacts.

Caution needs to be exercised when applying conclusions drawn from marine fisheries to river fisheries. Marine and river fisheries function differently in several notable respects.

Some threats to biodiversity, including over-exploitation and the use of destructive gears, arise from within the fisheries sector. One solution involves a shift to co-management approaches, which are already widespread, and, in places, locally effective. The use of resource allocation systems (fishing lots), highly developed in the Mekong basin, enables the control of open access and is, potentially, a very important tool in biodiversity conservation, but requires more research before being promoted more widely. Aquaculture, certainly not a universal remedy for the problems of capture fisheries, involves its own set of biodiversity impacts. Chief among these are habitat losses and the widespread introduction of exotic species and strains. An effective solution for the problem of introduced of species is the development and application of codes of practice for pre-introduction assessments.

The greatest threat to biodiversity arises from other sectors, where activities can promote extensive loss of habitat, ecosystem simplification and reduced water quality and quantity. The current socio-economic benefits arising from the river fishery provide the major economic and social argument for improving integrated natural resources management to address the problem of general ecosystem decay. Recently, this consideration is demonstrably influencing development policies. Overly negative attitudes toward the impacts of fisheries on biodiversity in rivers will undermine biodiversity conservation, especially in the Mekong.

Introduction

The theme ‘managing global fisheries for biodiversity’ begs the question whether the fisheries sector is to be perceived as the villain or ally in the quest for sustaining biodiversity. The answer is complex but is of significant strategic importance. This paper explores this question in relation to tropical river fisheries, using the Mekong River as its example.

Large tropical rivers represent ecosystems of historically immense value, in terms of both the high biodiversity they support and the number of people whose livelihoods depend upon that biodiversity. They also, unfortunately, represent perhaps the best examples of the erosion of

these natural assets by inappropriate development, driven primarily by conflicting demands upon water, and other resources caused by growing populations. This is particularly true for areas where fast-track economic development has been favoured.

The general global trend of degradation of river environments has been depressing. Ecosystem integrity has often been undermined to such an extent that systems fail to support decent levels of aquatic life. As a result the livelihoods of people, previously supported by this aquatic life, are seriously compromised (Coates 1995a). The perilous state of the world's freshwater resources has been summarised by Armanatrout (1995), Arthington and Welcomme (1995) and FAO (1998) and for Asian rivers by Dudgeon (1992). Holcík (1990) notes that some rivers have been modified to a level where they almost cease to be recognisable as rivers.

There is, however, room for guarded optimism regarding freshwater ecosystems (Coates 1995a). While the historical correlation between economic prosperity and degraded freshwaters is clear for all to see, there is a growing awareness of sustainability options for freshwater biological resources, where these resources are still significant. Serious efforts are also beginning to be taken towards rehabilitating degraded systems, with considerable success (Cowx and Welcomme 1998). Central to this, in developing countries, is the growing appreciation of the importance of living freshwater resources to rural livelihoods; that is, primarily to fisheries.

Of the world's tropical river floodplain ecosystems, this paper argues that the Mekong, whilst by no means the largest, is perhaps the greatest. Central to this claim is the extremely rich biodiversity the river supports but, more so, the perhaps unsurpassed inter-relationships between the people and those resources. The river is integral part of the everyday life for almost the entire population of the basin (currently of about 70 million people from amongst China, Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam). Political and economic history, including a long period of military conflict, has shielded large areas of the river system from fast-track development. These attributes, coupled with the very high demand for fisheries products, and Asian enterprise, result in what remains as perhaps the most productive freshwater fishery in the world.

Kottelat and Whitten (1996) summarized freshwater biodiversity issues in Asia, in general, and although they identified the Mekong as a "hot spot" of biodiversity, they seriously underestimated its extent. This paper takes the opportunity to focus on specific issues in relation to biodiversity and fisheries in the Mekong, emphasizing its problems and practical solutions. It is the author's belief, reflecting a bias towards an environmental approach, that it is at the level of regional/transboundary aspects of resources management in international rivers where the important issues and opportunities lie and where the most significant progress can be made.

Any consideration of practical approaches to sustaining biodiversity in rivers must consider:

- the reasons such biodiversity occurs in the first place,
- its regional and international significance,

- the way it is exploited in the fishery,
- the various threats to that biodiversity, and
- the subsequent theoretical and practical options for mitigating those threats.

Natural river habitat diversity, both spatially and temporally, and the diversity of aquatic life are intimately linked. Therefore, the major threat to biodiversity is the undermining of environmental integrity (Armanatrout 1995, Coates 1995a, FAO 1998, Welcomme 1995a, 1997). The case is presented that biodiversity and fisheries are also intimately linked through the diverse ways this complex system of resource can be exploited. Recognition of the linkages between rural livelihoods and biodiversity, through fisheries, is of paramount importance. Without the fisheries, managers across sectors have limited incentive to sustain the aquatic habitats upon which fisheries, and hence biodiversity, depend.

Some fundamental differences between inland and marine fisheries must also be highlighted because, all too often, conclusions drawn from the latter sector can be counterproductive when all too eagerly applied to rivers. A comparison of listings on the IUCN Red List © of bony fishes from freshwater *versus* marine biomes amply illustrates the relative plight of fishes living in the two environments (Figure 1). The fact that 96 freshwater species are listed as extinct, while no marine species are, along with differences in other categories, confirms the much higher threats to loss of diversity in the freshwater environment. If expressed in proportion of total species (much higher for marine) these differences are even more pronounced. Interestingly, about one in five marine records lists excessive exploitation as a threat, but only about one in twenty freshwater records does. These data raises the question of the disproportionate worldwide attention paid to marine conservation, as compared to freshwater conservation.

This paper must also attack some dangerous assumptions about the potential role of aquaculture in alleviating threats to biodiversity. However, I do not intend to promote a saintly picture of the capture fisheries sector in the Mekong and will endeavor to highlight the adverse impacts of capture fisheries where they occur.

Biodiversity in the Mekong

Fish species diversity in the basin is current estimated at 1200 species, and could be as high as 1700 species. In addition, the Mekong fish fauna, as in other large rivers, is probably characterised by a high degree of within species diversity. This, in part, is brought about by the zoogeographic history of the region, whereby different sections of the basin have been isolated and re-united over time. The dynamic nature of floodplain ecosystems also drives fish to migrate, often over long distances, contributing to both genetic mixing and isolation of populations. Although only a fraction of migratory species have been studied, in only modest detail, to date, a high proportion of these are thought to have distinct populations within the Mekong basin (Coates *et al.* 2000, Poulsen *et al.* 2001, and Table 1).

Although comparisons of biodiversity between regions and ecosystems depend greatly on the criteria used, it is worth noting that the fish species diversity of the Mekong, per unit area of catchment, is roughly three times that found in the Amazon River basin. Furthermore, this is well in excess of that which is normally associated with coral reefs, which are popularly expounded as highly diverse aquatic ecosystems. Although poorly documented, invertebrate diversity is likely also higher, at least for crustaceans, molluscs, insects and especially nematodes (not to mention plants which are generally absent from the sea), in tropical freshwater ecosystems than in marine ecosystems. The inclusion of the biodiversity of semi-terrestrial/aquatic ecosystems, such as riparian vegetation and flooded tropical forest, which are part of and dependent upon the river aquatic ecosystem, crystallizes the relative worth of these environments.

Factors effecting biodiversity

Ecological

This high degree of diversity is also due to a number of ecological factors, the most important of which is ecosystem complexity, or diversity (Chevey 1933, Guégan *et al.* 1998, Rodriguez and Lewis 1997). Rivers originate primarily in mountainous areas and their shapes and forms change, blend, merge and re-emerge as they wind their way to the sea. Local climate, geology, terrain and riparian conditions shape riverine habitats into an almost un-quantifiable variety of types. Ecological barriers can biologically separate even adjacent equivalent habit types. For example, aquatic organisms adapted to life at higher altitudes (e.g., in faster flowing cooler streams) may be isolated from their neighbours if unable to survive in lowland environments, especially in rivers such as the Mekong subject to monsoon climates.

Hydrological

Gross seasonal changes add an important temporal dimension to habitat diversity. Of these, the seasonal changes that occur on the floodplain are the most marked. The huge expansion of Mekong floodwaters, as in most tropical rivers (Welcomme 1985), is responsible for the majority of aquatic biological production in the basin (Junk 1982, Junk *et al.* 1989, Payne *et al.* 1993, Welcomme and Hagborg 1977). The fact that most of this aquatic habitat does not even exist (in its aquatic phase) for over half of the year is perhaps the greatest of all possible seasonal/temporal influences in aquatic ecosystems. Similar changes, although less spectacular, occur in most of the main and tributary channels, being most marked in the upper reaches (where streams may also periodically dry out). Not only is this temporal effect on habitat diversity evident within any one annual season, but there are also significant natural differences between the timing, extent and duration of the seasonal flooding events between years. These factors, differing both within and between years, result in a large proportion of the fish fauna being opportunistic, further enhancing ecosystem diversity.

The “flood pulse” nature of most tropical river fisheries and its significance for river fisheries ecology is becoming reasonably well documented (Junk *et al.* 1989, Welcomme 1995a), but the importance of hydrological cycles to sustaining biodiversity are not widely appreciated. It is not enough simply to maintain a flood regime, but timing, duration and extent of flooding

must be considered, along with the discrete natural hydrological variations that exist within and between years.

Social

Understanding the natural basis for the high biodiversity of the Mekong is important. Development activities in the basin almost universally result in the simplification, or obliteration, of this ecosystem diversity, again, both spatially and temporally. These disturbances are later argued to be by far the greatest threat to sustaining riverine biological resources (Coates 1995a, FAO 1998, Welcomme 1995a, 1995b, 1997). The relevance of this, to a supposedly focussed discussion of biodiversity and fisheries, is that only by considering fisheries is there any realistic hope that these impacts can be moderated.

Considering the importance of tropical rivers, and their current status, the relative lack of attention paid to sustaining them is puzzling; except, of course, when one considers, and my personal experience confirms, that working in freshwaters is much more difficult and inordinately less glamorous (Coates 1995a).

Some Important Comparisons Between Inland and Marine Fisheries

The fisheries sector, its popular opinions, problems and potential solutions and, to a large degree, its actual scientific advice, is heavily influenced by experiences in its most prominent and studied sub-sector, marine fisheries. Coates (1995a) argued that this is a major constraint to sustaining inland resources and advocated the better application and development of scientific approaches recognising the special characteristics of tropical river fisheries.

Gear types

Although important small-scale and "subsistence" fisheries do occur in the marine sub-sector, highly efficient industrial/commercial gears obtain the vast bulk of the total catch, and the catch per participant is generally very high. Few dispute that the major problem facing marine fisheries is one of over-exploitation, even with smaller scale operations (FAO 2000). The situation is exacerbated by the dominance of capital intensive gears and vessels and the somewhat ludicrous government subsidies which promote exploitation well beyond that which is economically viable, let alone biologically sustainable (FAO 1998).

In contrast, although impressive commercial/industrial gears do occur in river fisheries, they are less capital intensive and small-scale operators, and in particular, family-based operations (Examples for the Mekong are given later) take the majority of the catch. Part-time fishing is the norm and is invariably mixed with agricultural activities. Average catches per fisher tend to be low, but participation is very high. Coates (1995a) concluded that the extent of participation in the fishery was perhaps the greatest sectoral advantage of river fisheries. There are no known direct or indirect economic government subsidies provided for the Mekong fishery, and probably none for the whole river fisheries sector.

Social aspects

Coastal communities live adjacent to the sea, not within it and high seas fisheries, which dominate world catches, are even more divorced from the land. By contrast, river basin communities and their traditional livelihoods are intimately linked to seasonal cycle and the mixture of terrestrial and aquatic phases created by them. They do not, generally, live "adjacent" to their fishery resources they live amongst them.

These characteristics of river fisheries have some important implications. River fisheries are exploited largely by local communities and true "open access" fisheries rarely occur. Traditional systems for managing access and effort are widespread. Consequently, community-based management systems are better developed for inland fisheries. The low capital inputs for most gears, together with the part-time nature of most of the fishing effort, promotes flexibility in the fishery. Effort can therefore respond very rapidly to variations in fish availability, both natural and otherwise, and both within and between years (see also Welcomme 1985).

Fish communities

However, perhaps the most important difference between floodplain river fisheries and marine fisheries is due to the nature of the fish community being exploited. The huge changes in ecology occurring seasonally has resulted in tropical river fish communities, by the large, being adapted to very high natural adult mortality (Lowe-McConnell 1987, Bayley 1988, Bayley and Li 1992, Junk *et al*. 1997). Many species are naturally capable of quite rapid population explosions in response to opportunities that arise with either seasonal or exceptional floods. Welcomme (1985) has suggested that for this reason river fish communities are perhaps better adapted to cope with fishing mortality than for more stable marine or lacustrine ecosystems. This, coupled with the rapid way in which local communities are able to adjust fishing effort, has resulted in a fishery that can sustain efforts unthinkable in many marine fisheries. On first witnessing the intensity of fishing in some areas of the Mekong, many fisheries scientists, including myself, have been baffled as to how it can possibly be sustained, but, so far, it has been.

The Fishery Resource and its Exploitation

Official government statistics still significantly undervalue the fishery. Unofficial survey-based estimates of production in the lower Mekong basin fisheries sector (excluding Myanmar and China) are currently being revised to at least 1,500,000 tons per annum, a figure which excludes the very important estuarine/inshore fishery off the river mouth (MRCS IN press). Scattered, but reasonably representative, datasets suggest that fish consumption in the lower basin is about 2.5 million tons, part of which is supplied by the marine fishery. This marine contribution is likely balanced by a substantial, but currently unquantified, export of inland fish from the basin (MRCS in press). Of this consumption, less than 10% arises from aquaculture.

Although finfish dominate the overall catch, other taxonomic groups are also important, especially in small-scale fisheries. Of the aquatic animal products consumed in Lao PDR, for example, approximately 30% are composed of a high diversity of taxa other than finfish, including molluscs, crustaceans, amphibians and reptiles (Sjorslev 2001). The region also has a dried "seaweed" (algae gleaned from rocks in clearer mountain streams) cottage industry and a rice field fisheries based upon non-fish resources (Gregory 1997, Gregory *et al.* 1996, Guttman 1999, Shams and Hong 1998), particularly diverse unless impacted by excessive pesticide use. This part of the fishery represents a very important biological resource. Invariably, researchers, in part due to a bias towards fish, but also due to taxonomic constraints, aggregate catches into quite meaningless groups such as "other animals". There is much need for further research on the biodiversity aspects of these fisheries.

Regional fisheries

The fisheries vary greatly from region to region, according, largely, to local resource availability and market access. In areas with more abundant resources and access to larger markets, usually areas of higher population density (e.g., the Thai Mekong and central and southern Cambodia), larger commercial gears are more prominent. The Delta area of Viet Nam has the highest population density and, in its upper sections, the fishery is at perhaps its most productive. In some areas the fishery takes on industrial proportions, especially in the Tonle Sap (Thuok and Sina 1998).

Dias fishery

The "dai" fishery, prominent in Cambodia and Viet Nam, is based essentially on a form of static trawl fixed by stakes in the river. Mesh size is small (to less than 25 mm) and is determined more by current speed than conservation goals (Lieng *et al.* 1995). During peak times a single gears in these "bagnet" fisheries can land up to 0.5 tons of fish per 15-minute haul. Although catches are highly seasonal and influenced greatly by the lunar cycle, scenes here are reminiscent of the days of plenty in the high seas fisheries (Lieng *et al.* 1995). There are up to 70 rows of gears located along the Tonle Sap River alone and over 30 species are regularly caught in a single haul.

Barrage fishery

Other spectacular gears include the large barrage systems, in which fish are directed, using fences, towards various forms of capture devices, normally some form of trap or holding pen. Barrage fences in the Grand Lac, for example, can be over 60 km long; with a mesh size of less than 10 mm. Fences are made of local materials and are often erected within less than 48 hours of the start of the legal fishing season. They are moved regularly throughout the season as waters recede (Chevey and Poulain 1939, D'Aubenton 1963, van Zalinge *et al.* 2000).

Lot system

Participation in activities associated with the fishery, such as gear making, transportation, fish processing and marketing, is significant. In Cambodia a prominent fishing "lot" system operates whereby most of the best fishing grounds are allocated through a bi-annual auction.

Such systems of resource allocation are not uncommon in inland fisheries (Welcomme 1985), and also occur in the Mekong in Thailand. Lot "owners" possess, not only the fishing rights to their area, but also act as stewards for the environment surrounding and supporting their lot. The owners invariably protect their lots and enforced their regulations by the use of small local armies. This has interesting repercussions for resources management, some of which are mentioned later, and has resulted in the Fisheries Department in Cambodia, through the revenue generating lot auctions and other activities, being one of the most prominent agencies in the country. This is almost unique amongst countries dominated by the inland fisheries sector.

Factors effecting the fishery

Hydrological

Much of the industrial/commercial fishery, throughout the entire Mekong, is based upon exploitation of fishes migrating in response to receding floodplain waters, not least the dais and all barrage systems. In addition to these mass fish movements providing easily targeted concentrations of fishes, the receding waters are also used to operate many of the gear systems, such as the dais fishery. Many of the other smaller gears capitalise on similar opportunities.

The flood pulse nature of the river is responsible for the marked seasonality of biological production and, as a result, the fishery. Peak catch periods near floodplains occur when river water levels are receding and huge quantities of fish are retreating to their dry season habitats. During this time catches greatly exceed the local fresh fish demand. This has enabled the development of a low technology, yet very effective, fish processing and marketing systems based essentially on the production of fish paste and fish sauce (Thuok and Sina 1998, van Zalinge *et al.* 2000). This huge processing industry has not only greatly increased participation and employment in the fishery, it has also spread the benefits of the seasonal production over the full year by catering to off season demand. Remarkably, fishing can actually cease along the Tonle Sap river when, during peak periods, catches become too high and local prices becoming too depressed (van Zalinge *et al.* 2000). This is possibly the last remaining example of over supply in a fishery.

Social

The Mekong fishery is still largely dominated by the much more dispersed use of smaller gears operated by individuals (men, women and children). The relative contribution of the larger, commercial, gears to that of the smaller units varies from region to region but smaller, family based, fishing operations always dominate the fishery (Table 2).

The net result is a very high participation in the fishery, with recorded involvement ranging from 64 to 93% of households (Table 2). Survey findings indicate that, contrary to the common myth, the fishery can not be easily divided into its "commercial" and "subsistence" elements. Almost universally, catches, especially of the higher value fish, will be sold in preference to being consumed. The fishery is best categorised by scale and should considered a matter of opportunities rather than motivation. This is not to say that fish is not important in

the local diet of rural households in all sections of the socio-economic spectrum. Fish, and other aquatic animal products, form the major component of the animal protein intake of rural communities (Sjorslev 2001a), emphasizing how crucially important fishery products are to local and regional food security. This is especially true, since the majority of rural populations represent the poorest socio-economic classes. The significant importance of inland fisheries to food security, globally, was reviewed by Coates (1995a).

Gear Types

The diversity of the ecosystem and its components, the general accessibility of aquatic resources to local communities, and the high participation in exploitation and utilisation of aquatic resources are intimately linked. One result of this is the evolution of perhaps the most diverse array of fishing gears known in any fishery. At least 80 categories of gear have been identified in Cambodia alone (Management of Freshwater Capture Fisheries of Cambodia Project, unpublished) and are equally diverse in Lao PDR (Claridge *et al.* 1997). These lists are far from complete and have yet to be compiled systematically for the other countries. Each gear category can be further sub-divided by dimensions, mesh size and construction material, not to mention the mode, location and timing of deployment.

Many of the gears are habitat specific and their use can be highly seasonal. Some gears are unspecialised (e.g., barrage fences, dais) and catch a wide variety of species, while others are species specific. The result is that almost every conceivable, and sometimes inconceivable, fishing opportunity is utilized. Some fishers specialize in the use of one gear type, particularly in the professional/commercial sector, but normally a range of gears are used. A complex set of factors, including seasonal, gender, ethnical, social, economic and environmental aspects, determines the gear utilized.

Aquaculture

Although it is more prominent in some areas than others, aquaculture is currently dwarfed by the capture fisheries sector. Commercial aquaculture, including industrial production for the luxury and export markets, is increasing and cage culture of snakeheads (*Channa* spp) and pangasiid catfish in the Delta are becoming notable industries (Thuok and Sina 1998).

Much of the production of luxury, higher value, fish is based upon inputs of lower grade fish from the capture fishery (Sjorslev 2001b). Culture and capture fisheries are further linked by the use of wild fish stocks in industrial aquaculture (Thuok and Sina 1998). Shrimp culture, as elsewhere, has exploded along the coastal areas causing the usual negative environmental impacts, most notably mangrove destruction. The motivation for aquaculture, as with the fishery, tends to be profit rather than food.

Small-scale aquaculture, particularly prominent in the Thai part of the Mekong basin and the Viet Nam Delta, tends to be combined with farming. Not surprisingly, small-scale aquaculture is best developed in areas away from the main fishery and major floodplains. Rice-fish "culture", a very significant resource (Guttman 1999, Gregory *et al.* 1996), is based upon the recruitment of wild fish and animals stocks to rice areas, which they treat as natural floodplains (which historically were). Rice farmers have complex traditional methods for

managing this fishery with elaborate systems of allowing recruitment and continuous cropping, primarily through trapping. Only more recently is rice filed aquaculture production being enhanced through stocking.

Threats to Aquatic Biodiversity in the Mekong

Since the fishery, by and large, exploits most of the available aquatic biodiversity, threats to fisheries and biodiversity are largely inseparable. Threats can roughly be divided into those arising from within or without ("outside") the fisheries sector.

The direct impacts of the fisheries sector on biodiversity

Destructive and unsustainable fishing activities

These include, the use of destructive fishing gears (explosives, poisons and electric fishers), exploitation of vulnerable life history stages and fishing activities in sensitive areas, e.g., spawning grounds, or at sensitive times, e.g., spawning periods (Claridge *et al*. 1997, Van Zalinge *et al.* 2000).

Coates *et al.* (2000) noted that the more migratory elements of the fish fauna, in particular the highly migratory "white-fish" stocks are in theory more vulnerable to over harvest. They are characterised by movements of large populations of fish, often within a discreet period of time, making them vulnerable to specialist and seasonally intensive fishing operations (e.g., Singanouvong 1996a, 1996b, Baird and Phylavong 2000). This can promote larger-scale, industrialised or capital intensive fisheries (for example, the Dai operations on the Tonle Sap River in Cambodia). The requirements for returns on capital investment, therefore, can exacerbate problems with over-exploitation, although in no way as significantly as with high seas fisheries (FAO 1998). Many of the migrations tend to be associated with breeding phenomena, especially the concentration of breeding populations at localised spawning sites. This further increases the vulnerability of the resource to over-fishing.

Introductions and transfers of living aquatic organisms

Introductions/transfers to or within the basin occur through two major activities:

1) *Transfers primarily through aquaculture related activities (including ornamental fishes/aquaria)* - This is the most common source, and is one of the best documented impacts of fisheries related activities on biodiversity (e.g., Kottelat and Whitten 1996). These problems largely arise from the fisheries sector itself although development policies can have an influence on the extent of potential problems.

2) *Inter and intra-drainage transfers of water* - The Mekong River basin is characterised by a high degree of endemicity, or biodiversity, particularly between its upper catchments (Annex 1). Where water resources are diverted between one catchment, or sub-catchment, and another, the organisms living in that water are also, normally, transferred (and in some cases the organisms in the receiving catchment are provided

with a route to invade the donor catchment). Although strikingly obvious, this is very rarely, if ever, considered in impact assessments of water diversion projects.

The introduction of exotic species has been identified as a major threat to biodiversity in many regions (e.g., Kottelat and Whitten 1996). This is very much a transboundary issue, as aquatic organisms do not respect political boundaries. Fishes introduced in the Mekong basin in China are now appearing in Thailand (Vidthayanon and Kottelat 1995). The status of, and management options for, exotic species in the Mekong was reviewed by Welcomme and Vidthayanon (2000).

Recently attention has also been given to the consequences on biodiversity of the transfer of species within the their natural ranges. Wild stocks in the Mekong have a high degree of genetic diversity (Coates *et al.* 2000; Hogan *et al.* 2000, MRCS/FAO 2001, McConnell *et al* 2001). Where the movements involve native species, interbreeding (hybridisation) between released and local stocks is probable (Waples 1991, FAO 1993). Most, if not all, released native organisms represent a genetically modified stock, e.g., a domesticated strain (Hirdar *et al.* 1991, FAO 1993, Pullin 1995). The genetic effects of inappropriate transfers of native species are some of the best documented examples of problems with the introduction and transfers of living aquatic organisms (Bartley and Coates 1995). The most convincingly documented example of the adverse impacts upon biodiversity of the release of live fishes in the Mekong refer to the transfers of native species undertaken for aquaculture (e.g., McConnell *et al* 2001). The hybridisation, deliberate or otherwise, of species or strains, invariably followed by release (intentional or otherwise) into the environment only exacerbates the potential problems. The risks are particularly marked with stocks of riverine species because inappropriate transfers can adversely affect migratory behaviour (Gausen and Moehn 1991). If not appropriately managed, the accelerating transfer of native Mekong species is a major threat to biodiversity in the Mekong River (Welcomme and Vidthayanon 2000). Considering that a reasonably comprehensive suite of exotic species already occurs in the Mekong basin, the majority of future movements will involve exotic strains (Welcomme and Vidthayanon 2000). This activity, driven primarily by aquaculture interests, is considered to be perhaps the major threat to biodiversity in the Mekong originating within the fisheries sector.

Other impacts from outside the fisheries sector

Changes in the environment and habitat in rivers, brought about by the impacts of development in sectors other than fisheries can be many and varied and have significant direct and indirect impacts upon biodiversity. Some of these include:

1) destruction of local spawning grounds or dry season refuges by habitat alteration (e.g., streambed dredging, removal or alteration of aquatic, emergent and riparian vegetation cover etc.),

2) local changes in the quality (e.g. pollution) and quantity of water available in sensitive habitats and the timing of local hydrologic events (through local water management/utilisation), and

3) the construction of barriers (dams, weirs, diversions etc.) which, apart from local environmental disturbances they might cause (as above), can additionally act as a physical barrier to migrations.

Essentially, these influences undermine ecosystem integrity by promoting a simplification of the riverine ecosystem, often in conjunction with changes in water quality. Due to the limited extent of industrialisation and urbanisation, in general, water quality considerations are likely more of longer-term concern (excepting for problems with increased sediment load due to deforestation, MRCS 1997); although some severe local impacts are already evident. Even so, the linkages between water quality, biodiversity, poverty reduction and sustainable development are unclear. Certainly in the Mekong, the pressing problem is one of water quantity. Major interferences with natural hydrological regimes, through water management and utilisation, are having gross impacts upon the integrity of the ecosystem (MRCS 1997). A second major concern is the gross changes occurring with riparian vegetation cover, and in particularly the rapid loss flooded forest, which is crucial habitat (Chevey 1932, Bryant and Sedell 1995, Degen *et al.* 2000, Lamberts and Sarath 1997, Woodsworth 1995).

For management purposes it is useful to divide these environmental disturbances into local and transboundary impacts (that is, those impacts traversing international borders). The situation is complex because a large proportion of the species on which the fishery is based are transboundary stocks (migrating from one country to another). Therefore, local impacts on habitat can have transboundary impacts on fishery resources (Coates *et al*. 2000). In the context of river basin management, the key transboundary environmental area is water resources management whereby changes in the quantity and quality of water, and the timing of hydrological events, can have an impact beyond the country responsible for those changes (normally, but not always, downstream). For example, fishery resources (biodiversity) in the coastal region of the Mekong Delta are extremely vulnerable to the water resources management activities of upstream countries (Quang 1996).

It is useful to compare the relative threats to aquatic biodiversity in the Mekong. MRCS (1997) list the impacts of fishing on biodiversity as “slight” but “high” for the activities of most other sectors (through impacts on the environment). Likewise, although Whitten and Kottelat (1996) recognise overfishing as a problem, it is only one amongst many others. Most reviews conclude that the major threat to sustaining biodiversity, and river fisheries, is environmental degradation (Arthington and Welcomme 1995, Coates 1995a, FAO 2000, Welcomme 1995b, 1997, Kottelat and Whitten 1996).

Summary of Status and Trends of Target Species

The common perception of the Mekong fishery is certainly one of decline (e.g., Claridge *et al.* 1997, van Zalinge *et al.* 2000). But is this view justified, and if so what does it mean? Or is it a convenient assumption based upon trends in capture fisheries in general?

Practically all species are targeted in the Mekong fishery. Species can be broken down only in terms of their importance to the various sub-sectors (e.g., commercial/industrial catches, family catches etc.). Species composition of catches can also change between years due to

natural variations (Singanouvong *et al.* 1996, Warren *et al.* 1998, Loeung *et al.* 1998). Overall, the species composition of the gross catch likely reflects resource availability. No stocks are known that are not already extensively exploited, excepting in areas with low population densities. Useful fishery statistics for gross production are generally unavailable and data for individual species even more so. Limited time series data for the better documented parts of the fishery (Barran *et al*. 2001, van Zalinge *et al*. 2000) do not even extend beyond the known interval of longer-term natural cycles. Establishing trends in the species is therefore extremely speculative, but a number of useful observations can be made.

The first, and most important, is that there is no evidence to support the widely held view that the fisheries, in terms of gross production, are actually declining. Individual fishing units may well report declines in catches, and they likely know best (Claridge 1997), but does their interpretation of the situation take into account longer-term natural cycles in production? Moreover, where participation in fisheries is increasing (through population growth), reduced average catches per unit can occur whilst total catches are maintained, or are even increasing. Hence, a recent survey in N. E. Thailand (AMFC) showed that most community leaders reported greatly increasing fishing pressure over the past five years (as a response to the Asian economic crisis, that is, population increases due to reverse urban drift) as a major problem – but it is not known if total catches subsequently declined.

The limited data available, in fact, support the view that total catches have been maintained and quite possibly are increasing. Baran *et al*. (2001) analysed historical data for the Tonle Sap ecosystem in Cambodia with some interesting conclusions:

- Recent catch data over a six-year period (to 2000) show no evidence of a decline but the expected correlation between catches and variations in hydrological levels is evident.

- Various sources of historical data from 1907 (when certain assumptions are made regarding historical population statistics) show a significant increase in catches much in-line with population growth.

- Fish catches per person have possibly declined from an average of 347 kg/person/annum for the 1940's, to 190 in the mid-1970's and remained at that level in the mid 1990's (the 1940's and 1990's dataset are the most comprehensive, with that for the 1970's possibly less reliable).

Further indications as to the state of the resources can be obtained by making comparisons of the response of resources under similar environmental conditions but with differing degrees of effort – based on contemporary data. Where resources are under significant stress catches per caput would be expected to decline with increasing population density. Again data are limited but preliminary analyses suggest that catches per caput from floodplains in central Cambodia (Ahmed *et al.* 1998, AMFC 2001) are in close agreement to those obtained in the same resource system in the much more densely populated area in the adjacent northern part of the Mekong Delta in Viet Nam (Sjorslev 2001b). This does not indicate a fishery in decline. More importantly, the observation dispels another common myth – that there is limited potential for increases in fish production (because although it is not known whether

heavily fished areas have reached their limit, more lightly populated areas, which are still extensive, have not). The latter point is important because it has implications for investment policies for the fisheries sector, and, therefore, for biodiversity considerations (see later).

But this analysis refers to gross production. What is probably more generally accepted is that there are likely some serious declines in the stocks of certain species. Welcomme (1985) notes that rivers cannot be fished at any degree of intensity without the loss of the larger elements of the fish community. The Mekong appears to be at the beginning of this trend in terms of the simplification of its fishery resources. There are signs that this is already happening to the Tonle Sap fishery (Van Zalinge *et al*. 2000) where the larger migratory species have declined significantly but the smaller migratory and the non-migratory species are possibly still being sustained. Even so, piscivores (such as *Channa* spp) still account for 38% of the catches from the relatively unselective fishing lots around the Great Lake. Welcomme (1995b) has already noted that one difference between tropical river and other fisheries is possibly that as the fishery comes under stress the diversity of the catch decreases (because it already starts at the highest level), as opposed to generally increasing in marine fisheries (as effort shifts to new resources as target species decline and selectivity of gears diminishes) (Figure 2). The fishes most obviously affected by this process are the larger, presumably slower growing, elements of the fauna. These are almost exclusively highly migratory "white fish" species which, as already noted, are more vulnerable to excessive fishing effort. Included in these are all of the "Giant" Mekong fishes - *Pangasius sanitwongsei*, *Probarbus jullieni, Catlacarpio siamensis* and the endemic *Pangasiandon gigas*. However, Rainboth (1996) notes that for at least *Pr. jullieni,* and likely the others also, the decline in much of the range, especially throughout Thailand, is due to river impoundments, that is, not effort. Two of these, *Pa. gigas* and *Pr. jullieni*, are on the IUCN red list, both as endangered; neither owing specifically to over-exploitation and the latter for habitat loss.

Notwithstanding these observations, a reduction in catch-per-unit of effort does normally indicate a fish fauna under stress (Welcomme 1985) but the level at which this becomes critical in rivers is not known. If the fauna supporting the Mekong fishery is about to collapse under excessive fishing pressure, it is certainly taking its time. By comparison, for example, the fishery in the Brahmaputra and Ganges Rivers in Bangladesh are conspicuous for the absence of the migratory white fish elements and catches are totally dominated by very small individuals (MRAG 1994, Hoggarth 1999a, 1999b). In these terms, the Mekong is notable for the fact that species like the giant fishes are still fairly regularly caught. This suggests that the fishery is still in reasonably good shape, and, rather than suggesting there is room for complacency, shows it is still worth investing in its proper management. In biodiversity terms, it is also necessary to distinguish between losses of species as conspicuous elements from the fishery and total losses as genetic entities. Although no extinction of species from the basin are reported, a number of species are reportedly locally extinct (Rainboth 1996); although not necessarily due to fishing. It has been argued that fishing pressure has an impact on biodiversity by reducing effective population size, irrespective of fishing to extinction. This aspect cannot be explored further for the Mekong due to the lack of data.

The traditional diversity of the market for catches from the Mekong, by comparison to some other fisheries, moderates the tendency for prices for individual species to escalate in

response to reductions in catches. That is, the flexibility in effort enables rapid shifts to other species to supply demand. A notable exception to this, however, is in the fishery for ornamental species whereby rarity significantly increases value and can promote exploitation well beyond the limits of sustainability. The ornamental fishery is little studied in the Mekong but it is significant and likely to increase in response to increasing regional and international demand. The industry is also the most significant source of introductions of exotic species (Welcomme and Vidthayanon 2000) and as the sub-sector develops will be a major source of potential transfers of native species stocks/strains.

That adverse changes in biodiversity of fishery resources are occurring or imminent is undeniable. The underlying cause, however, is far from clear. Fishing pressure is certainly increasing but environmental changes are occurring even more rapidly. Thus, it is often not possible to identify the root cause of decline for individual species. Even where the potential effects of fishing are more obvious, it is not known if the situation is critical due to effort alone or because other factors have exacerbated the effects of fishing. But whatever the theoretical limits of fishing pressure, it is obvious that the resource cannot withstand both the current exploitation levels and environmental degradation combined. It is also unwise to assume all the elements of the fishery resource are equally resistant to fishing pressure. A sensible approach is to identify the elements of the fauna most vulnerable to threats from fisheries activities and promote appropriate management of the fishing effort (see later). But this should not be pursued at the expense of attention to the major threat to the biodiversity – environmental degradation.

Importance of Biodiversity in the Fishery

The most significant aspect of biodiversity in the Mekong is not its extent but how clearly it is linked to, indeed inseparable from, the socio-economic value of the fishery. The diversity of the environment, the fishery resource, and its accessibility, promote the high degree of diversity in exploitation. This leads to high levels of participation in the fishery, further enhanced by the highly seasonal nature of catches (which promotes the need for huge downstream efforts in processing and marketing). This provides a resource system of immense value, especially within a rural livelihood context. Irrespective of trends in total production, any significant reduction in diversity of the resource translates into reductions in participation and consequently to negative impacts on livelihoods. Equally, the trend in environmental changes, leading towards both a reduction in productive capacity and a simplification of the ecosystem components, will seriously undermine biodiversity and hence socio-economic values of the resources.

The objective of "sustaining biodiversity" is often seen narrowly and can lead to potential conflicts in policy, not least in poor nations desperate for rapid economic development. That biodiversity is an important issue both locally and globally is often clouded by the better known fact that the most productive natural resource systems are those with the simplest ecosystem components (e.g., a wheat field or the pelagic fisheries in West Africa). The Mekong fishery demonstrates that it is not necessary to bring into play more elaborate hypothetical arguments for sustaining biodiversity (e.g., ecosystem collapse or the

biodiversity is of some future hypothetical benefit). It is demonstrably of immense immediate and tangible importance.

Non-target Biodiversity Concerns (e.g., impacts upon other species)

In general, the entire catch, from any gear, is utilised. Gears themselves rarely impact the environment (excepting the destructive gears already mentioned) and bottom trawls (which can destroy benthic non-target organisms) are not used extensively in rivers, although more common in the Mekong delta. There are only two known examples of recorded problems with non-target biota in the fishery. First, accidental by-catches of freshwater dolphin (*Orcaella brevirostris*) in gillnets from below Khone Falls (Baird and Mounsouphom 1997). Second, by-catches from the dai fishery for juvenile pangasiid catfishes primarily operating in southern Cambodia and the northern part of the Delta in Viet Nam. Less than 15% of the individuals in these catches are target species, the remainder (composed of the larvae of at least 160 species) due to their very small size, are discarded. However, it is unlikely that this fishery takes a significant part of the stock available.

The discards of larvae from the aforementioned dai fishery represent the only notable example of a discard in the entire fishery – even so the level of discard is likely not significant. Incidental discards can include species with more limited utility, such as pipefishes (Syngnathidae) which nevertheless are often used as ornaments and to make toys for children, and in some areas rare catches of toxic puffers (Tetraodontidae) may be discarded although where opportune they will be utilized in the ornamental fish trade (Rainboth 1996). Inland fisheries world-wide are notable for their extremely low levels, almost absence, of both discards and wastage (Coates 1995a).

How Biodiversity has been Incorporated in Fisheries Management (national, regional, or individual project level)

In general, individuals, communities, and government agencies in the fisheries sector in the Mekong do not distinguish between the management of biodiversity and fisheries. A notable exception is the promotion of community based management approaches to mitigate the impacts of fishing on freshwater dolphin (Baird and Moungsouphom 1997). There are, however, a number of examples where fisheries management is essentially aimed at biodiversity concerns (or in a fisheries context - at the decline of certain fishery resources). These include:

- The recent official ban on the use of dais for juvenile catfishes by Viet Nam (imposed over fears of the impacts of the by-catch on other fisheries).
- Widespread official bans on the use of destructive gears – such as electrofishing equipment (Cambodia and Viet Nam), poisons and explosives (all countries).
- Widespread restrictions on fishing effort usually by gear type, location, season, method of deployment etc., but sometimes by access.

- Rarely, restrictions on harvesting certain species, notably for giant catfish.

- Cambodia is currently considering closing down one of the dais in the Tonle Sap River which is responsible for catching most of the giant fishes (especially giant catfish) migrating from the Great Lake (and the hesitation is due to consideration of the usefulness of the catch for research, e.g., genetic samples and tag-release programmes).

By and large, experiences with these government imposed restrictions, as with many fisheries, suggest they do not work effectively, except for the larger, easily monitored gears such as stationary dais (Vuthy *et al* 1998, Thuok *et al.* 1999, van Zalinge and Thuok 1999). There is widespread abuse of the regulations and little effective enforcement. For example, the recent official ban on dais for juvenile catfishes is thought to have had limited impact as many operations continue illicitly but data for research is now more difficult to obtain. A notable exception is the fishing lot system in Cambodia (Degen and Thuok 2000). Here the regulations are aimed mainly at controlling access within clearly demarcated boundaries and seasons. Regulations are very effectively enforced and almost exclusively by lot "owners" themselves, sometimes perhaps over-zealously (XX PHOTO). Lot owners, because of their investments, are encouraged to protect the resources, including habitat (Degen and Thuok 2000). A major objective of such a management system is to extract resource rent for the government. But it has been argued that the management system contributes significantly to resource protection as it inhibits open access. This is likely so, but the down side is that it is seen as socially unjust, being dominated by more wealthy individuals and results in the poor being further marginalized (Thuok and Nouv 2000, van Zalinge *et al*. 2000). Conflicts are exacerbated by the auction system for lots being less than transparent.

It is encouraging that examples of community based management initiatives are relatively widespread in the Mekong (Hartmann 2000). Most of these have beneficial implications for sustaining biodiversity. Some of these include:

- The aforementioned efforts with dolphins.

- Community-based management systems in southern Lao PDR (Ahmed and Hirsch 2000, Roberts and Warren 1994, Roberts and Baird 1995, Baird *et al.* 1999, Lorenzen *et al.* 1998).

- In a recent survey in northern Lao PDR (Sjorslev 2001) 52% of villages reported that they had effective traditional management systems in operation which include: conservation zones (where fishing is limited to certain times, usually of local religious significance, these especially include deep pools in rivers), restricted seasons (especially at spawning times), gear restrictions (not only for known destructive gears such as poisons and dynamite, but also for other gears used to obtain what are considered to be excessive catches especially of vulnerable migrating schools), and more occasionally restrictions on species (which can be imposed by restricting species specific gears or their mode or timing of deployment).

- Many of the species have significant cultural value, especially the giant fishes. For example, MRCS (1997) reports that, in celebrations of the 50th anniversary of the ascension to the throne of the King of Thailand, Thai fishermen unilaterally decided to send all the Mekong giant catfish caught during the season (April-May 1996) to the Thai Department of Fisheries for breeding, instead of selling them to restaurants as in previous years.

The existence of such widespread community-based management systems is of significant relevance regionally (Coates *et al.* 2000). A considerable portion of the management initiatives are aimed at migratory species. Therefore, sound local management initiatives will have benefits beyond the local area including, in the case of transboundary stocks, in other countries. However, for this management to be successful it must be supported by reciprocal management measures in the other areas to which the species migrate. Regional co-ordination of management systems is therefore an area of considerable importance (Coates *et al.* 2000).

However, there are few case studies enabling any definitive analysis of whether these community-based initiatives, some of which are certainly successfully implemented, actually succeed in sustaining biodiversity. This question requires a very long-term view and relevant data are not available. Currently, their existence, and scope for potential improvement, is regarded positively in terms of biodiversity considerations. An interesting question is whether co-management approaches, in general, can be more effective with tropical river fisheries than in other areas because of the stronger associations between users and resources in a rural mixed agro-fishery livelihoods setting on river floodplains.

Conversely, there are examples of where biodiversity considerations are lacking from or not explicitly mentioned, in management or development initiatives and some of these are most obvious at the national and regional levels. Coates *et al.* (2000), for example, recently reviewed management opportunities for transboundary (migratory) stocks pointing to the need for international co-operation. Several international agreements already exist as a framework to promote such activities. These include: The code of conduct on responsible fisheries (FAO 1995), the Convention on the Conservation of Migrating Species of Wild Animals (CMS), and the Convention on Biological Diversity (all of which have considerable relevance as management guidelines and/or instruments in many other circumstances). The aforementioned citation, however, is the only one known (regionally) that mentions such instruments specifically in the context of fisheries in the Mekong. The situation is perhaps more alarming with aquaculture, and especially so for the use of exotic species or strains. Kottelat and Whitten (1996) note that despite the long existence of informal or formal codes of practice, Coates (1995b) remains the single example of an agency effectively evaluating the introductions of fish using pre-introduction assessment. Anywhere near adequate pre-release assessments of introductions sponsored through the aquaculture sector (including stocking) are almost unheard of world-wide.

In terms of fisheries regulations and legislation, the picture in the Mekong is much the same as elsewhere. Top-down, government centred approaches, generally fail to be effective – especially so for the majority of the fishing effort (smaller gears). Community based management systems are implemented much more competently. Obviously, the co-

management approach between government and users is to be preferred. This is consistent with moves in most fisheries. This approach is being promoted in the Mekong with variable success but progress is apparent (Hartmann 2000). Even so, biodiversity as such is still not firmly on the agenda of most fisheries management agencies. There are, for example, opportunities to redirect some of the management efforts more directly towards those species, areas and communities where the biodiversity concerns are the greatest.

Management approaches in the fisheries sector in the Mekong, in general, have failed to take on the greatest need of all - to manage environments. This problem occurs generally throughout the sector. For example, all of the community based management systems reported by Sjorslev (2001) focus solely on the management of problems arising within the fishery (i.e., managing fishing effort etc.) but villages were almost unanimous in their assertions that major threats to their fishery resources arise from "outside" influences and especially environmental degradation. Although there are local initiatives to address problems in other sectors, cross-sectoral approaches to environmental management for benefiting fisheries is likely a weak point. Therefore, unless these communities can manage influences from other sectors, these important fisheries can be considered as highly vulnerable, if not doomed (Coates *et al*. 2000). The problem is even more marked where major transboundary environmental impacts are concerned where local communities, and sometimes even national governments, can have no influence at all. Complacency by fisheries managers in adopting the concept that, in rivers, environmental management is a fundamental part of fisheries management, and, therefore, directly their business, is a significant constraint to sustaining the resources (Coates 1995a).

At the level of environmental management, historically, activities in the basin are conspicuous for their absence rather than a source of examples of good practice. This is especially so historically for the larger aid funded schemes, but degradation from small local sources should not be underestimated and cumulatively is likely larger. The current reasonable state of some of the Mekong environment can be attributed more to the slowing of development through regional conflicts than to rational resources management (Annex 1). More recently, however, attitudes and policies are showing verifiable signs of significant change (Annex 1). Fundamental to successes in this arena will be the effectiveness of the region's river basin organisation, not least because of the transboundary nature of the major environmental threats. In common with most such organisations, the early history of the Mekong River Commission (under its various previous guises) was very much one of promoting fast-track development and especially large dams. But in 1995 the four countries of the lower Mekong Basin (Cambodia, Lao PDR, Thailand and Viet Nam) signed a comprehensive water and related resources sharing agreement based solidly on the principles of sustainable development (MRC 1995). MRCS (2001) consolidates the principle of environmental integrity as being fundamental to sustainable development, poverty alleviation and sustaining livelihoods. Conserving biodiversity as such is not explicitly mentioned but is implicit within the concepts adopted. This paper highlights these linkages. The 1995 Mekong Agreement has significant relevance to the topic of this paper, especially as the majority of the inhabitants of the region lead rural livelihoods and are largely dependent upon living aquatic resources for food, income and employment. It is also possibly unique for such an agreement to exist in a river basin where the environment (and biodiversity) is still in reasonable shape (Annex 1) and for it not being promoted through an existing or previous

major conflict over water resource use. The Commission has a large fisheries programme. In addition to its internal initiatives, Coates *et al*. (2000) noted that the 1995 Agreement (and Commission) present an opportunity to implement regionally several existing international agreements, guidelines or codes including the Convention on Biological Diversity, Convention on Migratory Species and the FAO Guidelines for Fisheries.

A highly relevant point here is the extent to which recent shifts in policy approaches towards sustainable development in rivers has been stimulated by fisheries considerations. Major observations on the negative impacts of dams by the World Commission on Dams (2000), for example, centre on the absence, from project evaluations, of adequate consideration of the downstream impacts upon fisheries. One of the study sites was in the Thai part of the Mekong where impacts of the dam upon local fisheries were particularly apparent (Roberts 1993, 1995). Recommendations of the commission included development approaches centring more on a sustainable livelihoods approach, as opposed to the more usual formal economic "cost-benefit analysis" criteria applied to investment decisions. This is considered to be a major leap forward in natural resources management - especially as the report is endorsed by the World Bank. The fisheries sector is also playing a major role in motivating the significant shift towards river restoration that essentially aims to reinstate ecosystem diversity and complexity (Coates 1995a, Zalewski 1995, Cowx and Welcomme 1998).

The Role of Aquaculture

Aquaculture is widely regarded as a means of increasing fish production as capture fisheries reach, or in some cases, exceed their production limits (FAO 2000). Currently, aquaculture accounts for less than 10% of total fish production in the Mekong River Basin (MRC In press). Clearly aquaculture will play an increasingly important role in the Mekong. However, the extent to which it will sustain or increase total fish production in the loner-term is debatable, and will depend primarily upon the extent to which capture fisheries are sustained. The aquaculture sector itself is very diverse in the Mekong (MRCS In press) but is exhibiting the usual characteristics of agricultural development of ecosystem simplification due to increasing control of production. A significant proportion of the production also arises from the consumption of low-grade fish from the inland capture fishery (Sjorslev 2001b). Neither is the activity necessarily more environmentally friendly than fishing. Aquaculture can cause major environmental disturbances (FAO 2000). In the Mekong, major impacts of aquaculture include habitat alteration (especially so for coastal shrimp farming), the aforementioned impacts of fishing for wild stock for seed and the widespread use of exotic species and strains. Appropriate aquaculture development can be very beneficial and of course has much potential to offer. Such development should, however, be based upon the same principles as for fisheries development and management which essentially relate to sustaining livelihoods, reducing poverty and sustaining ecosystem integrity (and hence biodiversity). A major danger is that aquaculture is often regarded as a panacea for solving all the problems of the fisheries sector – often at the expense of often more appropriate investments in inland capture fisheries (Coates 1995a).

Examples of Best Practice , Results and Lessons Learned, Guidelines, Policies or Legislation that have Resulted from this Experience

Management of "within" fisheries problems

By far the best examples of management systems being effectively implemented in the Mekong are the community-based initiatives. Where human communities are stable, and able, the resource users tend to have traditional, sometimes contemporary, management systems that will contribute towards improved resource (biodiversity) sustainability. The problem is, of course, the extent to which such management systems can cope with the pressures of development, especially increasing population pressures. Additional considerations include the extent to which the practices adequately manage problems arising from outside the sector (or community) and address requirements for sustaining transboundary resources. Utilising such community based systems, together with government in a co-management approach, is the only real option for managing exploitation of the resources (Hartmann 2000); excepting for the lot-system – below.

Perhaps the most interesting and relevant example of "best practice" in the Mekong is the fishing lot system of Cambodia (and Thailand). There is no doubt that this system is very effective in galvanising the interest of resource users in resource protection. It is very effective in controlling problems of "open access". The system (at least in principle) also contributes significantly to government revenue by being an effective means of "rent extraction" for natural resources. Not only does this maintain government interest in the resource, but it presents at least the opportunity for the distribution of benefits from resource exploitation. The significant feature of the system is that it is not simply the allocation of rights over resource exploitation but also the right to exclude others, and in part also an element of environmental control. That such a method of resource management occurs in inland fisheries in the Mekong also signifies three important points: (i) that access can be controlled, (ii) the resource has significant value, and (iii) that governments actually recognise that value. It also creates a relatively wealthy "elite" of resource users that can be very influential (including in a positive way). In practice, the extent to which a lot of "owners" manage their operations for sustainability is debatable, but a move towards longer-term, perhaps transferable, leases should promote moves in that direction. The social problems that the system may cause need to be addressed, particularly the question of whether communities (as opposed to individuals) can effectively operate lots (either directly or through corporate ownership). But if open access is thought of as leading to over-exploitation, and that that is bad for biodiversity, then the lot system has much to offer. One question, however, still remains – are the potential benefits for biodiversity justified by the social costs of the exclusion of the poor from resource use (and are the two necessarily mutually exclusive)?

A good example of progress in management approaches in the Mekong is afforded by the relatively successful application of the use of local ecological knowledge in research and policy formulation (Valbo-Jorgensen and Poulsen In press, Poulsen *et al.* 2001). This has led not only to cost-effective means of obtaining information but also a much greater general recognition of the value, extent and relevance of the local knowledge of natural resources

held by rural communities. This includes not only knowledge regarding livelihood related information, but of natural history and biodiversity in a more general sense. Although the approaches have yet to lead to actual improved management, they are certainly making a significant contribution to management information. Perhaps more importantly, the approach is also laying better foundations for participation of resource users in future resource management systems.

In relation to managing the potential impacts of exotic species, and strains and/or varieties of native species, the only documented successful approach is that of developing and implementing an appropriate, effective and practical code of practice (Coates 1995b). Such guidelines should be based on consideration of the potential impacts of introductions/transfers at the genetic level, that is, upon genetic diversity (Bartley and Coates 1995, Bartley *et al*. 1996). It is essential, however, that such codes be developed with the participation of the relevant stakeholders, at regional and local levels, as appropriate, and are workable (Bartley *et al.* 1995).

Cross-sectoral best practice (management of environmental factors)

A detailed consideration of best practice for managing the impacts of other sectors upon aquatic biodiversity (and hence fisheries) is beyond the scope of this paper. The subject is however relevant because: (i) these impacts are far greater than arising from within the fisheries sector, and (ii) the fisheries sector can influence how those impacts are managed. The important role that the fisheries sector has played in promoting the recognition of the need to undertake better environmental management has already been noted. Improved cross-sectoral management of natural resources at the local level needs to be promoted much along the same lines as for fisheries, that is, with a co-management approach based upon participation of resource users and stakeholders. However, perhaps the most important need is that to adequately manage the transboundary (international) nature of the water resources of the Mekong River. The most valuable natural resource in the Mekong, and that to be targeted for major development, is the water itself. Sustainable development of the Mekong River Basin, encompassing sustaining aquatic habitats and the biodiversity they support, will depend ultimately upon the ability of the relevant riparian countries to co-operatively manage this resource under a common vision and objective. At the technical level, this requires sound policies on water resources utilisation and development planning within a basin-wide context. There are encouraging signs, and documented verification, that these not insignificant political and technical objectives are actually starting to be effectively achieved (MRCS 2001). Again, adequate consideration of the needs of the fisheries sector (and the biodiversity upon which it is based) is contributing significantly towards achieving these larger goals. Significantly, the fisheries sector, through the need to adequately manage transboundary fish stocks, has also much to contribute to improved water resources management at the international level (Coates *et al.* 2000).

Conclusions and Recommendations

1) Capture fisheries are not the major threat to biodiversity in rivers, environmental degradation is.

2) The important role that river fisheries play in maintaining aquatic biodiversity must be promoted more widely. This needs to result in increased interest in supporting, and funding for, river fisheries management and research as part of strategies for biodiversity conservation.

The promotion of the concept that fisheries are, generally, damaging to biodiversity will be seriously counterproductive in that it will reduce motivation to support the very sector that provides the clearest and most significant justification on economic and social grounds for improved management of the aquatic environment.

3) Fisheries activities can have negative impacts upon biodiversity. Improved management of over-exploitation, including the use of destructive gears, should centre on the promotion of co-management approaches.

4) The use of local ecological knowledge as both a research tool and mechanism for improving participation in management should be promoted more widely. There should be increased recognition of the importance of this knowledge base on biodiversity-related subjects.

5) Management measures for the introduction/transfer of exotic species or strains should include consideration of genetic diversity and, in particular, that of wild resources. The development, and more importantly implementation, of practical codes of practice regarding pre-introduction/transfer assessments of the movement of exotic species or strains should be promoted as a management tool with demonstrated benefits.

6) Aquaculture is not a panacea for reducing perceived problems capture fisheries create and can itself have significant negative impacts upon biodiversity.

7) Care should be exercised when applying conclusions essentially derived from marine capture fisheries to river fisheries.

8) The linkages between biodiversity and fisheries need to be more clearly and widely promoted.

9) A global review should be undertaken, including if necessary further research, to evaluate the fishing "lot" system as an effective tool for sustaining biodiversity with the objective of addressing whether the system should be promoted more widely.

10) There should be more widespread recognition and use of existing instruments for the promotion of improved approaches to the management of fisheries for sustainability, including attention to biodiversity needs. These include:

- the Code of Conduct for Responsible Fisheries (FAO 1995),
- the Convention on Biological Diversity (in particular promotion of its implications for fisheries management), and
- the Convention on Migratory Species.

11) Consideration should be given to producing a review of the implications of the Convention on Biological Diversity for fisheries management practices.

12) Reviews, guidelines and promotional materials should, where necessary and appropriate, be written and disseminated in a technical language (and medium) that can be understood easily by target audiences (including resource users). This includes references to what biodiversity is, why it is important and how it can be affected (both negatively and positively) by management actions.

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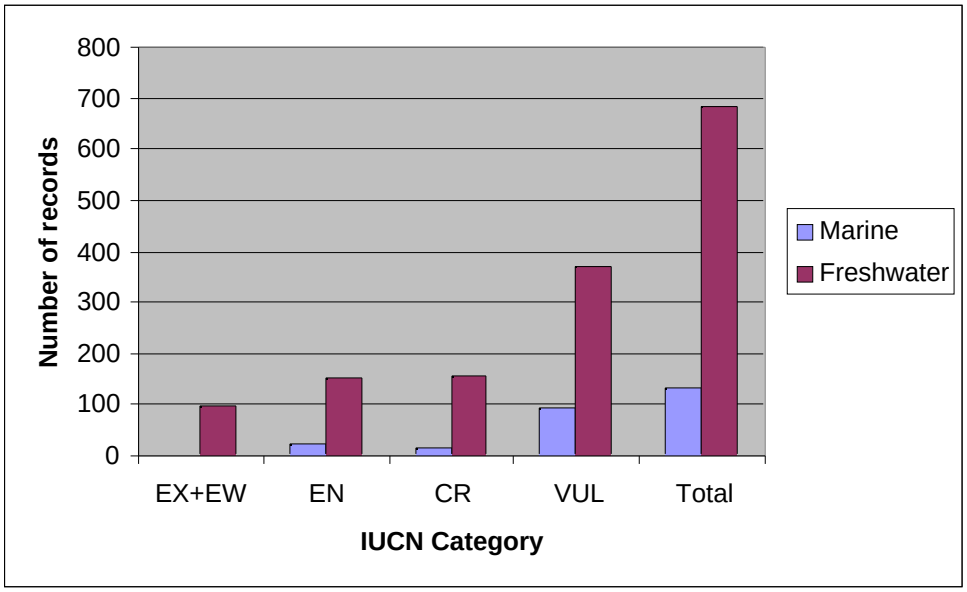
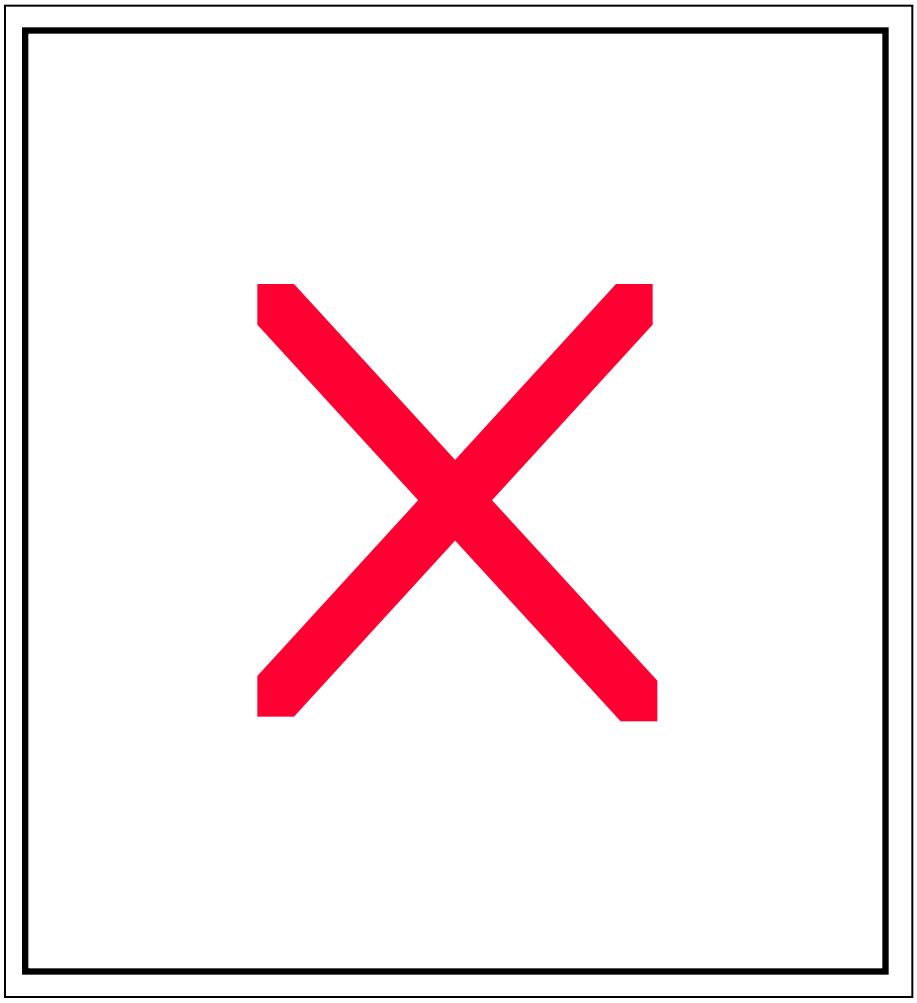
Figures and Tables

Figure 1. Summary of records (species or distinct populations of species) from the IUCN Red List of Threatened Species ä for bony fishes (Actinopterygii) for marine versus freshwater biomes. EX- extinct; EW – extinct in the wild; EN – endangered; CR – critically endangered; VUL – vulnerable.[1]



[1] Some adjustments to the raw data were made by shifting freshwater species of marine genera and those species from inland seas to the category freshwater – mainly sturgeons and freshwater salmonids (www.redlist.org).

Figure 2. Illustration of the theoretical effects of increasing fishing effort on fish catches and fish assemblages in tropical river fisheries.[2]



[2] With low effort a high diversity of species is still caught but total catches are dominated by larger slower growing species. With increasing effort these species are lost as major elements in the fishery and catches become dominated by smaller slower growing species. The trend is one of decreasing overall diversity in catches but of increasing diversity of species contributing to the bulk of the catch (the "Bangladesh effect"). However, throughout, total catches are maintained, presumably until a theoretical crash is reached (at an unknown point, but the fishery is likely undermined well before that stage by environmental degradation). From Welcomme, unpublished.

Table 1. List of currently known trans-boundary species and stocks in the Mekong River Basin.[3]

axon	Species	Stock #	Countries						Comments
			Viet Nam	Cambodia	Lao PDR	Thailand	Myanmar	China	
ammals	*Orcaella brevirostris* (freshwater dolphin)			X	X				
ustaceans	*Macrobrachium rosenbergi*	?	X	X	?	?	?	?	
sh	*Aaptosyax grypus*	?	?	X	X	X			Very rare, little documented
	Bangana behri	?	?	X	X	X			Juveniles may enter Vietnam
	Catlocarpio siamensis	1	X	X	?	?	?	?	
		2	?	?	X	X	?	?	likely several stocks
		3			X	X	?	?	
	Cirrhinus microlepis	1	X	X	X	X			
		2		?	X	X	?	?	likely several stocks
		3			X	X	?	?	
	Cyclocheilichthys enoplos	1	X	X	X	?			
		2		?	X	X	?	?	likely several stocks
		3			X	X	?	?	
	Henicorhynchus lobatus	1	X	X	X	?			likely several stocks
	Henicorhynchus siamensis	1	X	X	X	?			
		2		?	X	X			likely several stocks
		3			X	X	?	?	
	Mekongina erythrospila	1		X	X	X			
		2			X	X	?	?	may be distinct species
	Morulius chrysophekadion	1	X	X	?	?			
		2		?	X	X			likely several stocks
		3			X	X	?	?	
	Paralaubuca typus	1	X	X	X	?			
		2		?	X	X	?	?	likely several stocks
		3			X	X	?	?	
	Probarbus jullieni	1	X	X	X	?			
		2		?	X	X	?	?	likely several stocks
	Probarbus labeamajor	1	X	X	X	?			
		2		?	X	X	?	?	likely several stocks
	Probarbus labeaminor	?	?	?	X	X	?	?	Rare, little known
	Puntioplites falcifer	1	X	X	X				
		2			X	X	?	?	likely several stocks
	Thynnichthys thynnoides	1	X	X	X	?			
		2		?	?	?	?	?	likely several stocks?
	Tenualosa thibeaudeaui	1	?	X	X	?			
		2		?	X	X	?	?	
	Botia modesta	1	X	X	X	?			
		2		?	X	X	?	?	likely several stocks
	Heligophagus waandersii	1	?	X	X	?			
		2		?	X	X	?	?	likely several stocks
	Pangasianodon gigas	1	X	X	?	?	?	?	
		2	?	?	X	X	?	?	
	Pangasianodon hypophthalmus	1	X	X	X	?			
		2		?	X	X	?	?	
	Pangasius bocourti	1	X	X	X	?			

[3] The list is not exhaustive and the status of the various stocks is subject to further confirmation (From Coates et al. 2000).

	2		?	X	X	?	?	likely several stocks
Pangasius conchophilus	1	X	X	X	?			
	2		?	X	X	?	?	likely several stocks

Table 1. Con't

axon	Species	Stock #	Countries						Comments
			Viet Nam	Cambodia	Lao PDR	Thailand	Myanmar	China	
	Pangasius djambal	1		X	?	?			
		2		?	X	X	?	?	likely several stocks
	Pangasius krempfi	1	X	X	X	?			
		2		?	X	X	?	?	
	Pangasius larnaudiei	1	X	X	X	?			
		2		?	X	X	?	?	likely several stocks
		3			X	X	?	?	Rare
	Pangasius macronema	1	?	X	X	?			
		2		?	X	X	?	?	likely several stocks
	Pangasius pleurotaenia	1	?	X	X	?			
		2		?	X	X	?	?	likely several stocks
		3			X	X	?	?	likely several stocks
	Pangasius polyuranodon	1	?	X	X	?			
		2		?	X	X	?	?	likely several stocks
	Pangasius sanitwongsei	1		?	X	X	?	?	likely more than one stock
	Bagarius yarelli	1		?	X	X	?	?	likely several stocks

Table 2. Some data on participation in fisheries and the proportion of total catches taken by smaller-scale (family operated) gears in the Mekong River Basin.

Location	% of households involved in fisheries	% of total catch taken by small-scale gears[4]	Reference
Cambodia – Tonle Sap	64.72	-	Ahmed *et al.* 1998
Cambodia – Tonle Sap	-	62.0	van Zalinge and Tana 1996
Lao PDR – Luangprabang Province	83.0	< 95.0	Sjorslev 2001a
Viet Nam – floodplains in An Giang Province, northern Delta	63.0	< 85.0	Sjorslev 2001b
Thailand – Songkhram River sub-catchment	93.0	< 90%	Suntornratana 2001

[4] family operated