

## 5.2 Case studies

The project case studies cover a range of culture fisheries systems in different stages of development, summarised in Table 1 -

Table 1 Overview of the culture fisheries case studies conducted under the project.

	China (Zhejiang Province)	India (Karnataka State)	Thailand (Udon Thani Province)
Water bodies	Dongfeng and Siming reservoirs	Vanivilas Sagar reservoir	Village ponds/reservoirs
Area [ha]	100 and 760	2000	0.5-10
Production [kg/ha/year]	480 and 200	50 (uncertain)	100-2000
Culture-based %	> 90	< 40	> 90
Stocking density [fish/ha] (size in brackets)	1800-2300 (13 cm)	< 400 (3-5 cm)	3000-20000 (2-3 cm)
Use rights	Corporate	Common (licensed)	Communal
FAO classification	Aquaculture	Fishery	Fishery
Users	Full-time commercial	Full-time and part-time commercial and subsistence	Part-time subsistence
Characteristics	Highly developed extensive culture system	Artisanal fishery with limited enhancement	Culture system managed for community income
Key issues studied	Technical and economic efficiency	Potential for large-scale enhancement, access regulation	Management for community revenue, use rights issues, social costs

The Chinese case studies were concerned with highly developed extensive aquaculture systems. Detailed and long-term data sets on these systems were made available by the collaborating institute. This allowed the testing of population models on long-term data series, and an assessment of the production potential of culture fisheries under good management. The economic performance an extensive culture system has been analysed in detail, focusing on changes in management that may be required to maintain the viability of the system in the face of economic reforms.

The Indian case study was concerned with an artisanal fishery, based predominantly on natural stocks and exploited by a large number local and migrant fishermen. The contribution of ongoing enhancement to the catch was limited and not precisely known. The study focused on the appraisal of different stocking and effort control options, based on a technical and bio-economic analysis of the present fishery.

The Thailand case study was concerned with village ponds (small reservoirs), managed primarily for community income. The analysis focused on the relationship between technical management and community income, and the social costs and benefits arising from the conversion of open-access swamps to culture fisheries with restricted access.

### 5.2.1 China

Two reservoirs were studied in China: Dongfeng, a medium-size reservoir of 100 ha, and Siming, large reservoir of 760 ha. The culture fisheries in both reservoirs are corporately owned by the respective reservoir bureaus, and are therefore extensive aquaculture systems according to the FAO definition.

Reservoir bureaus have overall responsibility for irrigation/flood control, electricity generation, agriculture and forestry on reservoir slopes, and all fishery uses

#### *Dongfeng reservoir*

The culture system in Dongfeng reservoir (100 ha) has been studied intensively by the collaborating institute over a period of five years, from 1974 to 1978. At the beginning of this period, an efficient new fishing method known as the "combined technology" was introduced to the reservoir. The combined technology involves sequentially closing off parts of the reservoir with blocking nets, and the driving of fish with seines or electricity into large set "filter nets". Stocking density in the reservoir was increased two-fold during the period of the study. Hence the population biomass in the reservoir changed significantly over the study period, allowing the estimation of density-dependent responses. The data on bighead carp, the dominant species in the culture system, were analysed in detail using the transparent modelling approach described above. Virtual population analysis indicated that the fully selected size groups of fish were subject to a very high fishing mortality of 2.0/year. Gear selectivity was well described by a weight-dependent logistic model with a mean selection weight of  $W_c=880$  g. The natural mortality rate of bighead carp at reference weight 1000 g was estimated as 0.19-0.32/year, depending on the degree of size-dependence in mortality which had to be inferred from comparative studies (see Section 5.1.1 and Appendix II).

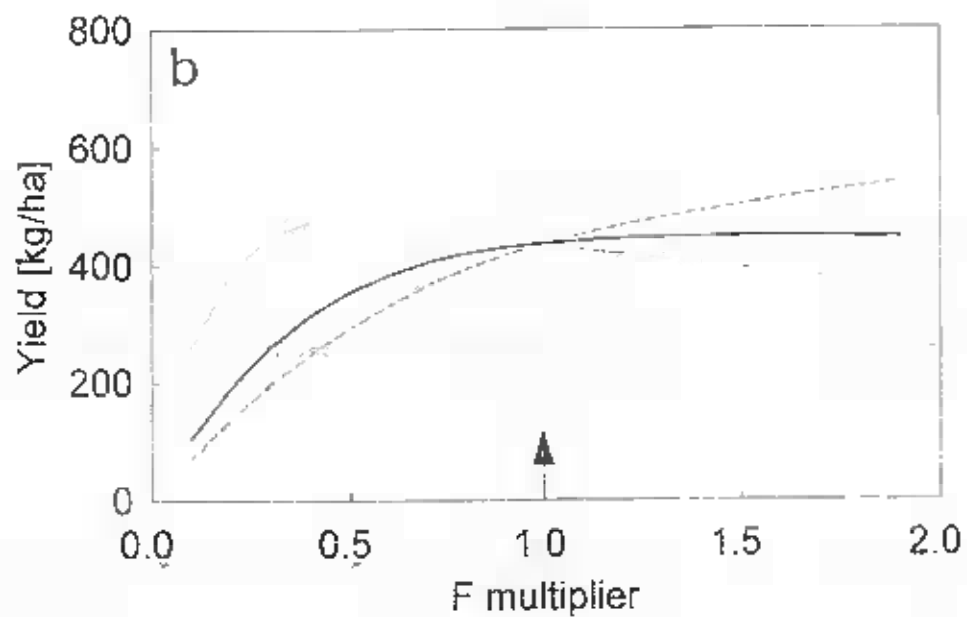
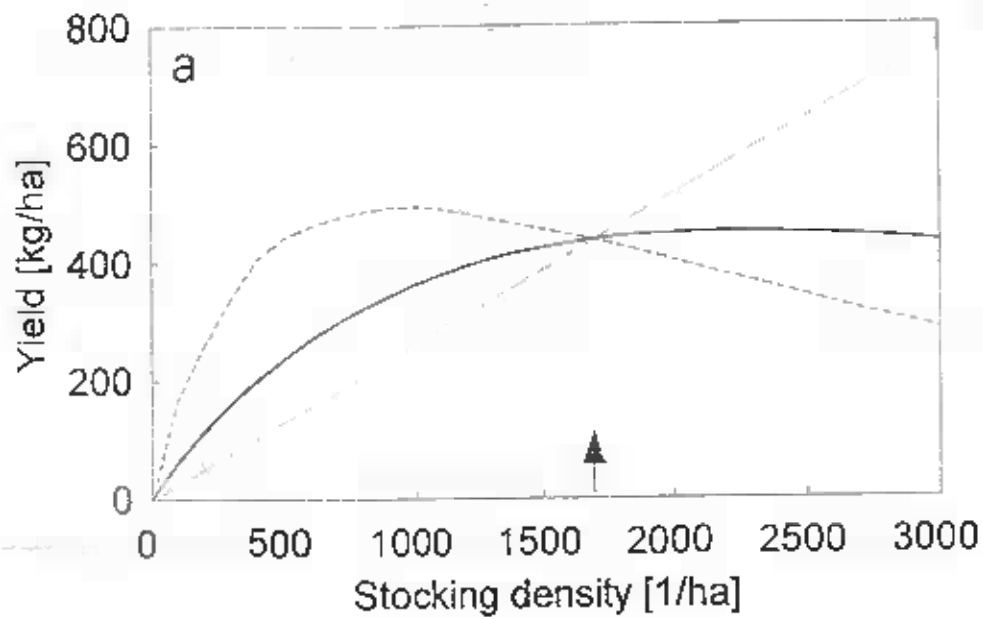
The reconstructed population biomass increased from 600 to 900 kg/ha from 1974 to 1978. Hence a 100% increase in stocking density has resulted in a 50% increase in biomass, clearly indicating the action of density-dependent processes. The density-dependent growth model was fitted to body weight data and the reconstructed total biomass. The uncertainty in all parameter estimates was assessed by the estimation of approximate confidence limits, or other measures where confidence limits could not be calculated. The single-most uncertain parameter was the competition coefficient, which indicates the degree of density dependence in growth.

Equilibrium yield predictions were obtained for different management options, always considering the key uncertainty about the degree of density-dependence. Results indicate that at the end of the study in 1978, the evolved stocking and harvesting regime was optimal with respect to production. This regime has been maintained to the present day, but no further detailed studies have been conducted. Yield levels are relatively insensitive to changes in stocking density, or fishing mortality from the end-of-study regime (Figure 8).

The lack of sensitivity is a consequence of density-dependence, which compensates for variation in management up to a degree. In practical terms this indicates a certain robustness of the culture system to sub-optimal stocking and harvesting regimes. Low sensitivity of yield to the management regime also implies that substantial reductions in inputs (stocking density, fishing effort) are possible without affecting yield to a great extent. In other words, the end-of-study regime may be optimal with respect to yield, but it is not efficient in its use of inputs. Considerations of efficiency and profitability are now replacing the previous focus on production in the Chinese economy, and the analysis suggests that substantial increases in efficiency are possible in the reservoir culture system.

#### *Siming reservoir*

Siming is a large reservoir (760 ha) in the Chinese classification, and like Dongfeng it is managed for a variety of purposes by a single corporate body, the reservoir bureau. In recent years, the reservoir fishery has been divided into two operational units: the extensive culture system in the reservoir itself, and the hatchery/nursery unit of the bureau, located some 20 miles from the reservoir. Stocking and total catch records have been maintained by the reservoir bureau since the impoundment in 1959. Catch composition and weight at age data were collected in 1981, 1993 and 1995. The fishing method in the reservoir has changed from gill net fishing (1959-1964) to the combined technology with seine net driving (1965-1981), and combined technology with electric driving (1982-1990). Since 1990, the combined fishing technology with electric driving has been supplemented with passive use of the "filter net" for one or several months of the year. While harvesting was previously limited to December and January, it is now spread over 4 to 5 months, from September to January. A bioeconomic analysis of the culture system in Siming reservoir was conducted in several steps. A population model for the extensive culture system was fitted to the mixed set of data available (i.e. long-term stocking, total catch and effort data, as well as detailed catch data for certain years). The seasonal activities, inputs and outputs in the seed production unit were analysed using rapid rural appraisal methods. Costs of all inputs to the extensive culture and the seed production



**Figure 8** Predicted effect of changes in stocking density and fishing effort on the yield of bighead carp from Dongfeng reservoir, China. Predictions are shown for the best estimate of density dependence in growth (solid line), and for extreme assumptions of no density dependence (dotted line) and very high density dependence (dashed line)(from Lorenzen, Xu, Cao, Ye & Hu *subm*)

operations were quantified, together with marked prices of all outputs. The integrated bio-economic analysis suggests that similar to Dongfeng, the extensive culture system in Siming was well managed with respect to production during the 1980s. Since 1991, fishing mortality has increased due to the extended use of the fixed "filter net", and the system is now technically overfished. In economic terms, fishing accounts for two thirds of production costs, and a reduction in fishing effort would substantially improve the profitability of the operation. At lower fishing effort, seed numbers could also be reduced but this would have a less dramatic effect on profitability. The seed production unit is presently tied to sell silver and bighead carp seed to the extensive culture unit at a below-cost price, and compensates for the loss through the highly profitable production of grass carp seed for farmer aquaculture. In the longer run, the prices for silver and bighead carp seed must increase to make their production sustainable, and consequently seed costs for the extensive unit will rise. At present, silver and bighead fingerlings are nursed at the seed unit to a large size of 11-13 cm. Nursing to a large size is preferred by the seed unit, because the carp can only be spawned during a short period of the year, and a long nursing period extends the time during which the farm provides gainful employment. The cost of nursing are considerable, however, and feed accounts for almost half of the total production costs in the seed farm. Analysis of the likely effect of changing seed size in the extensive culture unit, together with the established need to reduce seed production costs (or increase prices) suggests that a reduction in seed size is likely to improve the profitability the seed unit without jeopardizing the extensive culture unit. With respect to long-term development, the reservoir bureau could pursue two different strategies: the seed unit could be integrated more closely with the extensive culture unit to benefit from synergies, or it could be given complete autonomy. In the case of increased integration, substantial savings in labour would be possible because the seasonal labour requirements of both units are complementary. The nursing period could be shortened, liberating more labour for the fishery and substantially reducing feed costs. If the two units were given complete autonomy, the seed unit is likely to concentrate production on the most profitable species at the hatchery/nursery level (e.g. grass carp and popular high-value species like mandarin fish, California perch). Production of silver and bighead seed would be maintained only if these species commanded substantially higher prices than at present.

### *Conclusions*

The analysed reservoir culture fisheries are highly developed, and are managed efficiently to maximise production. The present economic reforms in China have shifted the emphasis from production to profitability, and pose a challenge to the established reservoir culture systems. In order to remain viable, changes in production technology may be necessary at both the extensive culture and the seed production level. The greatest increases in profitability are likely to result from reductions in fishing effort (in particular labour) in extensive culture operations, and from changes in the species composition and nursing periods in seed production. The integration of seed production and extensive on-growing may enhance the viability of the reservoir culture systems. Substantial increases in profitability are possible only at the expense of employment and, to a lesser extent, output. Established culture units are most likely pursue an intermediate strategy, maintaining the highest possible level of employment while increasing profitability to remain viable.

Quantitative bio-economic analyses can make a crucial contribution to maintaining the viability of extensive culture systems. Without such analyses, culture units may respond inappropriately to the challenges of economic reform (for example by further increasing instead of reducing fishing effort), and may go out of business although they would be sustainable under appropriate management. Quantitative analyses are particularly important because the production cycle in the reservoirs is two to three years, and the effects of inappropriate management actions may be evident only years after the actions have been taken.

### These studies are reported in:

Lorenzen, K., Xu, G., Cau, F., Ye, J., & Hu, T. (subm.) Extensive fish culture in Chinese reservoirs: analysis of management options by transparent population modelling. Submitted to *Aquaculture Research*. (Appendix III)

Lorenzen, K., Xu, G., Cau, F., Ye, J., & Hu, T. (in prep.) Bioeconomic analysis of extensive fish culture in Chinese reservoirs: a case study of Siming reservoir, Zhejiang. To be submitted to *Aquaculture*

## 5.2.2 India

### *The fishery*

Vanivilas Sagar is a large irrigation reservoir in the Chithradurga District of Karnataka, India. The area of the reservoir is officially listed as 8700 ha, but the actual mean water spread area is only about 2000 ha. The reservoir was completed in 1911, and has been fished since the beginning. Fishing was initially the domain of migrant fishermen from the Shillekyathas (Burdé Bestha) community. Local villagers developed an interest in the fishery from the 1960s onwards, and learned the necessary skills from the migrant fishermen. Only over the last 10 years have local villagers taken up fishing on a large scale, in response to rapid population growth and limited employment opportunities. The dominant fishing unit is a coracle with 3-5 gill nets, operated by two persons. Virtually all fishing units are indebted to particular merchants or commission agents, and are tied to sell their catch to these merchants or agents. The amount borrowed by fishing units is reflected in the prices paid by the merchants, who do not formally charge interest. Three classes of fishing units can be distinguished on the basis of socio-economic criteria: migrant units, and local units from "poor" and "rich" villages. Migrant units are operated on a family basis, usually by husband and wife. These units migrate between reservoirs in the region, in response to catch information which is relayed through market traders. Their migratory lifestyle enables these units to maintain high catch rates throughout the year, and limits both their need and their opportunities to borrow money. Consequently, migrant units achieve above-average catches and prices, and represent the most profitable sector of the fishery. Local units from "poor" villages (i.e. those located on marginal land) are also run on a family basis. These units do not leave the reservoir during the low season, become highly indebted to traders or agents, and consequently receive a low price for their catch. These are the least profitable units, kept in the fishery by an almost complete lack of alternative employment. Local units from "rich" villages (i.e. those located on better agricultural land) are jointly owned by two households (neighbours, friends or family), and operated only by men. The cooperating households also receive income from farming, and may reduce their fishing effort in the low season which coincides with a peak in labour demand for agriculture. Fishing units from "rich" villages are only mildly indebted, receive better prices, and are of intermediate profitability. The fishing community therefore comprises both a highly mobile and economically efficient fleet, and a very immobile fleet which is unable to leave the fishery in spite of low economic returns. These fleets are defined solely in socio-economic terms, and are not distinguishable in terms of gear use or other technical characteristics.

The reservoir fish resources are divided by their users into "local" fish, comprising mainly predators, and "government" fish, i.e. major carps which are stocked by the government but may also reproduce naturally. The two groups form distinct fisheries, with the "local" fish caught near the shore with small mesh nets, and the major carps caught further offshore with large mesh nets. Direct observation and interviews indicate that there is little technical interaction between the fisheries, i.e. major carps are rarely caught in the small mesh nets and vice versa. On average, "local" fish (dominated by *Notopterus* sp., *Mystus* sp. and *Ompok bimaculatus*) account for about 60 % of total yield, while the major carps *Catla catla*, *Cyprinus carpio*, and *Labeo rohita* contribute about 40 %.

### *Quantitative analysis*

Quantitative analysis concentrated on the major carp fishery, as the target for potential further enhancement measures. The apparent lack of technical interaction between the major carp and the "local" fisheries allowed the analysis of the local fishery to be restricted to aggregate statistics. Growth and mortality estimates for the major carp species were obtained by analysis of length frequency data collected at a local fish market. The catches were pooled from a large number of gill nets, covering a range of mesh sizes. Each pooled sample covered a wide range of sizes above a minimum length of about 30 cm, and consistent modes were observed over the sampling period. This indicates that the fishery provided sufficient coverage of population length structure to allow the use of length-frequency methods for growth and mortality estimation. A sensitivity analysis of the assessments and predictions was carried out to allow for the possible effects of non-uniform gear selectivity. The determination of gill net selectivity would have required a formidable sampling effort, with widely dispersed landing sites served by a few coracles each, and catches averaging less than one major carp per mesh size per day.

Growth of the three stocked major carp species (*Catla catla*, *Cyprinus carpio*, and *Labeo rohita*) was extremely good, with estimated asymptotic lengths ranging from 115 to 130 cm. The average gear selection length was 38 cm, corresponding to a weight of about 800 g. The bulk of the catch comprised individuals

of 40 to 80 cm length, estimated to be in their second and third year of life. Total mortality rates were estimated to be 1.2 to 1.6 /year. Using empirical models for natural mortality (Pauly 1980, Trenkel 1993), natural mortality was estimated to be 0.38-0.54 /year, which indicates a fishing mortality rate of about 1.0/year.

Length frequency data clearly indicated the recruitment of new cohorts to the fishery in all major carp species. Stocking in the year of origin of the cohorts was limited to common carp, and this suggests that all major carp species reproduce naturally in the reservoir. Fishermen consistently reported observing the successful breeding of common carp. Some fishermen also reported spawning of Indian major carp, but were not sure about the breeding success.

A yield per recruit analysis using the estimated growth and mortality parameters suggests that the major carp fishery is overfished. The maximum yield would be achieved at a fishing effort (or mortality) of only one third of the present level. However, due to the restriction of harvesting to larger individuals, the effect of overfishing on the total yield is moderate. Yield at optimal fishing effort would be only 10 % higher than at present. Catches per unit of effort would, of course, be more than three times higher at the optimal effort level. This illustrates the tradeoff between employment and profitability in the fishery.

#### *Potential for large-scale enhancement*

The length-structured population model (Lorenzen 1995), extended to include natural recruitment and a dynamic response of fishing effort to catch per unit of effort, has been used to evaluate enhancement options. Overall, the technical prospects for enhancement are very good, owing to the good growth of major carp at the present population density. While the growth response to increasing density could not be estimated for this particular fishery, comparative information suggest that substantial increases in stocking density are possible even under a high degree of density dependence.

A key process determining the outcome of increased stocking is the dynamics of fishing effort. If effort remains constant, an increase in stocking density would result in a substantial increase in catch per boat, and a consequent increase in profitability. The costs of stocking per boat would increase linearly with stocking density. The increased density and reduced growth would move the fishery from its present overfished state to a state of optimal exploitation, or even underexploitation. A more likely scenario is that effort increases in response to stocking density and the consequent increase in catch per boat. In the most extreme case, effort would increase in a manner such that the catch per boat remains constant, and consequently the benefit of stocking to the individual fisher is insignificant. The fishery as a whole would, of course, provide more food and employment than in the absence of stocking. It would, however, be very difficult to recover the costs of stocking through license fees as there is no benefit to the individual fisher. The fishery would remain in an overfished state. In theory, it may be best to follow an intermediate strategy with license fees or taxes at a level sufficient to recover stocking costs, and a consequent limitation of effort. In practice, this would force the least efficient "poor" local units to leave the fishery, and deny access to the resource to those people who need it most. A restriction of licenses to local fishermen only would be equally problematic as the migrants constitute the traditional fishing community of the reservoirs and face social barriers to entering other employment. Past experience at Vanivilas Sagar has shown that restrictive access regulations or expensive fees are virtually impossible to enforce, as the reservoir is widely perceived as a public resource. Fishers are in favour of licenses because of the official status they confer, but insist that licenses should be freely available at a moderate fee. The issues of effort regulation and recovery of seed costs may well be the most crucial problems in creating a sustainable enhanced fishery in Vanivilas Sagar.

Stocking in the reservoir has increased in the past year, following the implementation of a new scheme to promote the development of private seed production capacity. Under the scheme, the Fisheries Department is obliged to purchase part of the seed output of each supported nursery, and the contingent is often stocked in Vanivilas Sagar or other reservoirs. An increase in major carp yield is expected to be visible within the present year. The issues of effort control and cost recovery, however, have not yet been addressed.

## Conclusions

The technical potential for culture-enhancement to increase the yield from Vanivilas Sagar is likely to be good. The economic sustainability of enhancement, and the type and level of benefits are crucially dependent on the regulation of access to the reservoir.

This study is being finalized and written up as:

Lorenzen, K., Mohan, C.V. & Bhatta, R. (in prep.) Assessing the potential for culture-based fisheries development: a case study of Vanivilas Sagar reservoir, India. To be submitted to *Fisheries Research*.

### 5.2.3 Thailand

Communal pond fisheries have been promoted in Northeast Thailand (Esan) since the mid-1980s, through a variety of government programmes. These include the village fishpond (VFP) programme of the Department of Fisheries, the broader green Esan (Esan Keauw) programme of the Ministry of Agriculture and Cooperatives, and a reservoir construction programme by the Irrigation Department. Equally varied are the objectives of these programmes: production of food from village resources, extension of aquaculture technology, generation of community income, and most importantly perhaps, strengthening the cohesion of the village community. In the present project, the communal pond fisheries were analysed with respect to their efficiency as fish production systems, managed primarily for community income. No attempt was made to evaluate their contribution to the wider goals of the above government programmes.

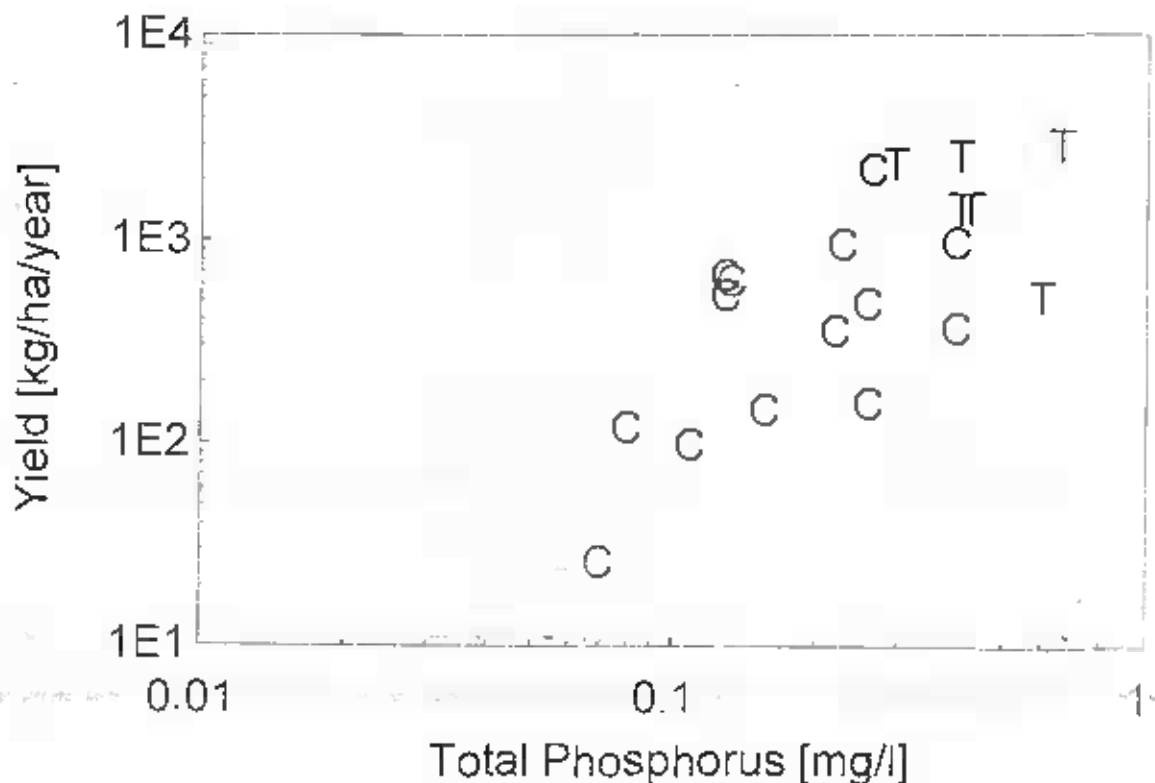
#### *Baseline survey*

A baseline survey of community fisheries in the Nong Wuua Sor District of Udon Thani Province covered a total of 16 water bodies, comprising 12 ponds close to villages, and 4 small reservoirs in the more remote, upper region of the watershed. Of the 12 ponds near villages, all had been stocked recently and 11 were managed as communal fisheries with restricted access. All 4 reservoirs had also been stocked recently, but no access restrictions were in place. All communal ponds had been constructed under one of the government programmes, usually by deepening an existing swamp but occasionally on formerly dry land. Most ponds had been excavated repeatedly, and the time since the last excavation ranged from 0 to 12 years (average 5 years). All except for one villages with communal fisheries maintained at least one other permanent water body as an open access resource, although this water body was usually further away from the village. All communal fisheries were stocked regularly, most (70 %) with seed purchased from private traders and only 30 % with partly or wholly subsidised seed from the Department of Fisheries. Harvesting in all ponds was conducted in the form of fishing days, where tickets are sold to individuals from within and from outside of the village.

#### *Impact of trophic status and species composition on yield*

Yield data were analysed in relation to limnological conditions, stocking density and harvesting effort. Yields ranged from 25 to 2800 kg/ha/year, and were correlated with the trophic status of the water body measured by parameters such as nutrient or chlorophyll concentrations. The highest correlation was found between yield and total phosphorus concentration, which may therefore be used to predict the potential yield of newly established communal fisheries.

A cluster analysis of catch composition identified two distinct species assemblages in the community fisheries: tilapia-dominated and carp-dominated systems. Tilapia-dominated systems were found exclusively in the most fertile ponds, while carp-dominated systems occurred over a wide range of trophic conditions (Figure 9). Yields from tilapia-dominated systems are not different from those observed or predicted for carp-dominated systems of similar trophic status (i.e. concentration of total phosphorus). This indicates that tilapia systems tend to occur in the more productive water bodies, but are not inherently more productive than carp systems. All ponds have been stocked with a mix of carp species and tilapia (although the details are often unreliable). The observed pattern of group dominance in the catches suggests that the stocked carp outcompete tilapia in ponds of low to moderate productivity, while tilapia outcompete carp and form prolific breeding populations in ponds of high productivity. In tilapia-dominated systems, tilapia



**Figure 9** Relationship between fish production and total phosphorus concentration in communal fish ponds in Northeast Thailand. Letters indicate the species combination of the catches: tilapia-dominated (T) or carp-dominated (C) (from Lorenzen, Juntana & Bundit *in prep.*).

account on average for 63 % of total yield, followed by mrigal (12%) and around 5 % each for the remaining species. Carp-dominated systems show a slightly more even distribution of species, with Chinese (mainly silver) carp accounting for 41 %, mrigal for 20 %, and rohu, tilapia and silver barb for about 10% each of total yield. Wild fish (mainly snakehead, climbing perch and marble goby) contribute about 5% on average in both systems.

Yields per stocked fingerling were evaluated for ponds with a reliable stocking history. In carp-dominated systems, the highest average yields were obtained from Chinese carp (390 g per fingerling), followed after a large gap by mrigal (73 g/fingerling) and rohu (37 g/fingerling). The lowest yield per fingerling in carp-dominated systems is given by tilapia, with just 8 g/fingerling. In tilapia-dominated systems on the other hand, tilapia yield 1100 g/fingerling. This high yield is attributable to the prolific natural reproduction of tilapia in these systems, and is not therefore directly linked to the stocked fingerling as in the case of the non-breeding carp species. In fact, continued stocking of tilapia at the usual rates is unlikely to have a significant effect where a breeding population has been established. Of the carp species stocked in tilapia-dominated systems, rohu (200 g/fingerling) and mrigal (140 g/fingerling) provide the best returns, followed by Chinese carp (70 g/fingerling).

These average yields per stocked fingerling are based on a very limited sample, but nevertheless provide some useful indications for stocking strategies. Tilapia should be included in the species mix stocked in newly established community fisheries, and will either form a dominant breeding population, or else remain a minor species in a carp-dominated culture fishery. In either case, continued stocking of tilapia is unlikely to be of great benefit. Of the carp species, Chinese carp, mrigal and rohu are likely to yield reasonable returns in both carp and tilapia-dominated systems. Common carp and silver barb are unlikely to provide returns above 20 g/fingerling in either system, hence these species are the least worthwhile to stock. At present, silver barb often account for the largest proportion of seed fish, owing to the fact that they are easy



to breed and popular with villagers. Their contribution to production and their return per fingerling, however, tend to be the lowest of all stocked species.

The analysis of catch and stocking data, with or without additional limnological information, provides useful guidance on the stocking of community fisheries. The processes underlying phenomena such as the observed dominance of tilapia in highly productive water bodies, however, remain poorly understood. Whether or not a better understanding of these processes would result in better management of the communal pond system is an open question. In the short term, the best option seems to devise a stocking strategy that is robust, i.e. likely to provide good returns regardless of the limnological characteristics of the water body. The results from the present study give some indication towards such a robust strategy, which need to be confirmed on the basis of more comprehensive empirical evidence. Simple rules may also be devised for the adaptive improvement of stocking strategies in particular fisheries. However, the relative robustness of yield with respect to stocking patterns and the weak link between yield and community income (see next paragraph) suggests that the potential benefits of an adaptive strategy may not exceed the costs of even a simple sampling programme.

#### *Community income*

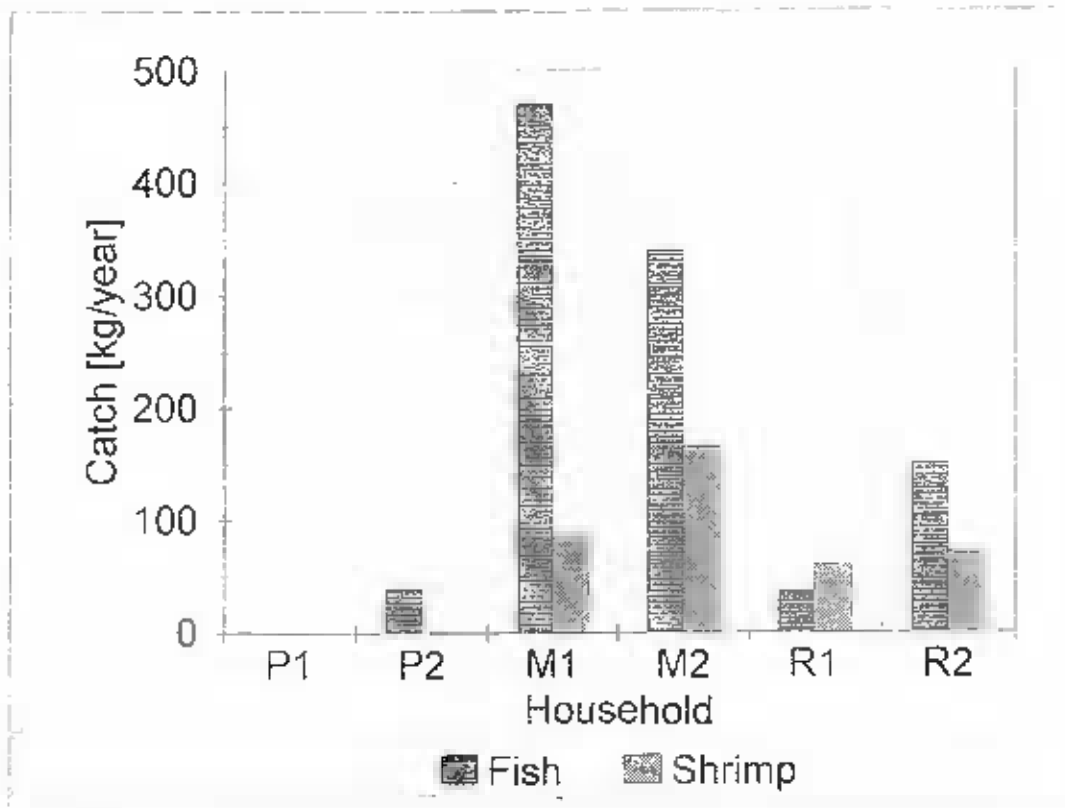
The economics of community fisheries were analysed briefly, focussing on their efficiency as a means of generating village income. The villages surveyed in Nong Wua Sor district obtained an average revenue of 7600 Baht/ha from their ponds, invested an average of 1000 Baht/ha in seed fish, and therefore obtained a gross profit of 6600 Baht/ha. This simple calculation ignores all secondary costs and benefits associated with the fishery, the quantification of which was outside the scope of this project. The value of the catch averaged at 22000 Baht/ha, which shows that on average only a third of the catch value was retained as community income. Village revenue is determined by the number and price of tickets issued, and both are influenced by expectations of catch (based on past experience and the number of seed stocked), as well as accessibility of the village and fishing conditions in the pond (Chantarawarathit 1989). In Nong Wua Sor District, fisheries with catches below 5 kg/ticket attracted between 100 and 700 fishers, all fisheries with higher catches attracted a stable 600 to 800 fishers. This shows firstly, that fishers have a realistic expectation of catches and avoid poor fisheries and secondly, that there is a limit to the number of fishers that may be attracted to even the most productive fisheries. This ultimately limits the income that can be obtained from communal fisheries to a level substantially lower than the catch value in productive ponds. Hence there is little incentive to intensify fish production, and in fact all surveyed ponds were managed extensively. Stocking densities on the other hand were often much higher than required from a production point of view, possibly because the known stocking densities have a direct influence on catching day participation and income.

#### *Access restrictions and their social costs*

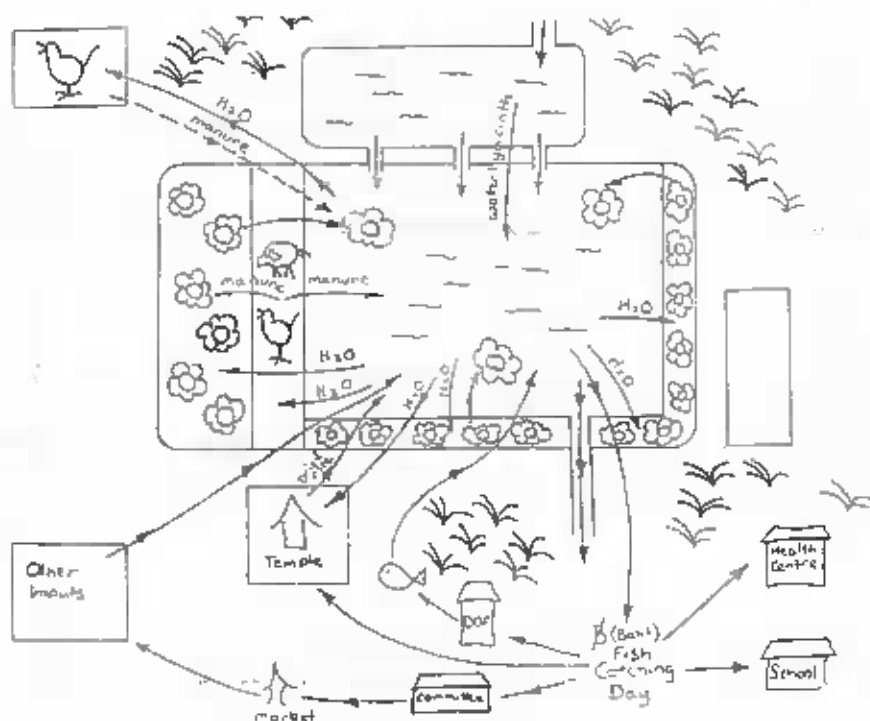
The development of community fisheries involves restricting access to water bodies that were previously open access resources. This has raised concerns that substantial benefits from open access water bodies are foregone, and that this affects primarily the poorest sections of the village community. To investigate this issue, participatory appraisals were conducted of two small reservoirs under different management regimes. An open access fishery operated on one of the reservoirs (Ang Namrod), supported by natural stocks of indigenous species and introduced tilapia. In the other reservoir (Huaywangben), harvesting was limited to one fishing day per year, and the fishery was based on regular stocking. Both ponds were of similar trophic status as shown by limnological analyses.

In the open access reservoir, benefits in the form food accrued directly to individuals, in relation to their individual use of the resources. The main users of the fish resource were middle income households (Figure 10). Poor households could not afford the investment in time and gear required for fishing, and often spent the main fishing season away from the village in paid employment. Rich households preferred to buy fish. Invertebrates and vegetables are easily collected in sufficient quantities, and were utilized to a similar degree by all socio-economic groups. The produce harvested from open access water bodies contributed significantly to the diet in most households using such resources.

In the stocked reservoir where fishing was restricted to one day per year, the major perceived benefit was community income raised by ticket sales. This is illustrated in a systems diagram drawn by villagers and reproduced in Figure 11, where the output from the pond is shown as money, not fish. The pond was also used to provide water for vegetable plots. The inputs shown in the diagram (apart from seed fish) were



**Figure 10** Impact of socio-economic status on the utilisation of aquatic resources from an open-access small reservoir in Northeast Thailand. Total annual quantities of fish and shrimp harvested by six households from different socio-economic groups, estimated on the basis of interviews and matrix scores. The households were selected at random from three socio-economic groups identified in a wealth-ranking exercise: P1/P2 are poor, M1/M2 middle and R1/R2 rich households (from Garaway 1995).



**Figure 11** Systems diagram of a communal pond with a culture fishery and restricted access, showing inputs and outputs of the pond and its connection with other activities (from Garaway 1995).

insignificant in quantity, and the pond is therefore managed as an extensive system. The magnitude of the community income benefit was related primarily to the effectiveness of the communal administration. Benefits to individuals and the contribution of the catch to the diet of villagers were insignificant. The development of community culture fisheries can have a profound influence on the magnitude, kind, and distribution of benefits from a fishery. The development of appropriate access rights regimes is thus a central consideration if the promotion of culture fisheries is to serve wider objectives of rural development. The access restrictions imposed on this (and most other) stocked reservoirs in NE Thailand exceed what is technically necessary to protect the stocked fish. Less restrictive access regimes, however, may be too complex and too difficult to enforce in a marginal resource such as the community fishery.

Apart from permanent water bodies, significant fish harvests were taken from paddies and other temporary water bodies. Snakehead (*Channa striata*) are perhaps the most important fishery resource in NE Thai villages, and villagers expend considerable effort on catching them in various habitats throughout the year. A PRA study of the snakehead fishery was conducted to assess the relative importance of the community fishery relative to other aquatic resource uses, and to gain further insight into impact of community fisheries development on traditional resource uses. The study showed that farmers spent much more effort on the snakehead fishery and obtained far greater catches than from the community fishery. The bulk of these catches were taken during the wet season from temporary water bodies, and were not directly affected by the access restrictions to the communal pond. Snakeheads rely on permanent water bodies for dry season habitat, and may be affected by the conversion of swamps into community fish ponds.

The socio-economic analyses indicate that open-access aquatic resources are used intensively in NE Thai villages. The main users of such resources are middle income farming households. Access restrictions therefore affect primarily middle income households, rather than the poor as has often been assumed. Alternative open access water bodies are available in most villages, mitigating the effects of restrictions. Furthermore, the snakehead study indicates that a large part of the wild fish catch is taken from water bodies other than the village pond or reservoir even when access to the latter is unrestricted. Hence the overall impact of community fisheries development on aquatic resource use in the villages appears to be limited.

#### *Conclusions*

Community fisheries were initiated by government programmes, but have been sustained independently in many villages. All community fisheries are managed extensively, but can reach production levels of 2-3 t/ha/year in fertile water bodies. Community fisheries are managed primarily for village income, and contribute only marginally to the diet of villagers. The level of community income is limited by demand for fishing day tickets, and is only weakly related to production. The development of community culture fisheries affects both the nature and distribution of benefits from aquatic resource use. Access restrictions to community fisheries affect primarily middle income households not the poor as has often been assumed.

Community culture fisheries in Thailand are of marginal importance to villagers, and this limits the scope for more intensive management. The stocking regime could be improved by changing the species composition and reducing overall density. Results of the present study indicate the possibility of developing a robust stocking strategy that is likely to yield satisfactory results in a wide range of ponds. Community income is strongly related to factors other than production, and increased attention to these factors is most likely to raise income. Extension for community fisheries should pay increased attention to these non-technical aspects of management.

#### These studies are reported in:

Cowan, V.J. (1995) A participatory rural appraisal of the exploitation and ecology of snakehead (*Channa striata*) in Kumpawapee District, Northeast Thailand. MRAG/AIT Aquaculture Outreach Research Report.

Garaway, C.J. (1995) Communal ponds in NE Thailand under different use-rights systems: a participatory rural appraisal of their differing roles in peoples' livelihoods. MRAG/AIT Aquaculture Outreach Research Report. (Appendix VI)

Lorenzen, K., Juntana, J. & Bundit, J. (in prep.) Communal pond fisheries in Northeast Thailand: status and management options. Research Report.

## 6. Contribution of Outputs

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The project has developed methodology for the biological/technical, bio-economic and socio-economic assessment of culture fisheries. Application to a range of case studies has shown that the methodology is flexible, practical, and relevant to the management and development needs of the fisheries. The project has therefore achieved its purpose

This Section describes the contribution of project outputs to the achievement of ODA's developmental goals, and the steps that are required to ensure the contribution of outputs to the achievement of development goals.

### 6.1 Contribution to ODA's developmental goals

ODA's developmental goal in the widest sense is to promote sustainable economic and social development. The Renewable Natural Resources Research Strategy (RNRRS) recognizes that "the sustainable use and exploitation of renewable natural resources requires an adequate knowledge of the location, extent, nature, tenure, and best management practices for their exploitation.." and concludes that these global concepts are significantly diverse in ecological, economic and social context, and that location-specific approaches are essential (RTG 1994). The present project epitomises this philosophy, providing general methodology for the location-specific assessment of culture fisheries. In particular, the project provides

- A framework for the rapid identification of key management and development issues in particular culture fisheries, and
- Transparent and practical methods for the quantitative assessment of management and development options in particular culture fisheries.

Locally appropriate management regimes are crucial for culture fisheries to realise their potential to increase yields. The application of project outputs will make a significant contribution to the achievement of the ODA Fisheries Management Science Programme Purpose 2: yields from enhanced fisheries increased by optimising strategies for stocking and harvesting. At the same time, outputs contributes to Purpose 2 of the Aquaculture Research Programme: Sustainable yields from small-scale, semi-intensive and extensive aquaculture systems increased through improved management.

### 6.2 Identified promotion pathways

Uptake of results has been promoted in a variety of ways including publications and reports, presentations at conferences and seminars, and the organisation of workshops and training courses.

#### 6.2.1 Publications and reports

Chevalier, C. (1995) Culture fisheries: Programme and user's guide. DAA Agro-informatique, INP-ENSA Toulouse, and MRAG Ltd.

Cowan, V.J. (1995) A participatory rural appraisal of the exploitation and ecology of snakehead (*Channa striata*) in Kumpawapee District, Northeast Thailand. MRAG/AIT Aquaculture Outreach Research Report

Garaway, C.J. (1995) Communal ponds in NE Thailand under different use-rights systems: a participatory rural appraisal of their differing roles in peoples' livelihoods. MRAG/AIT Aquaculture Outreach Research Report.

Lorenzen, K. (1994) Dynamics and management of Asian culture-based reservoir fisheries. *Aquaculture News* 18, 20.

Lorenzen, K. (in press a) The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. *Journal of Fish Biology*.

Lorenzen, K. (in press b) Culture-based fisheries in Asian reservoirs and lakes: Key issues for sustainability. In: *Network of Aquaculture Centers in Asia-Pacific (Ed.) Aquaculture Sustainability and the Environment*. Bangkok/Manila: ADB/NACA.

Lorenzen, K. (1996) A framework for the appraisal of culture fisheries development. Discussion Paper.

Lorenzen, K., Juntana, J. & Bundit, J. (in prep.) Communal pond fisheries in Northeast Thailand: status and management options. Research Report.

Lorenzen, K., Mohan, C.V. & Bhatta, R. (in prep.) Assessing the potential for culture-based fisheries development: a case study of Vanivilas Sagar reservoir, India. To be submitted to *Fisheries Research*.

Lorenzen, K., Xu, G., Cau, F., Ye, J. & Hu, T. (subm.) Extensive fish culture in Chinese reservoirs: analysis of management options by transparent population modelling. Submitted to *Aquaculture Research*.

Lorenzen, K., Xu, G., Cau, F., Ye, J. & Hu, T. (in prep.) Bioeconomic analysis of extensive fish culture in Chinese reservoirs: a case study of Siming reservoir, Zhejiang. To be submitted to *Aquaculture*.

Zhang, S. (1995) Knowledge-based decision making support system for culture-based fisheries management. MSc Thesis (Knowledge Engineering), University of Westminster.

#### 6.2.2 Presentations at conferences and workshops

The Seventh International Conference on Natural Resource Modelling and Analysis, London, August 1994 (Lorenzen)

Mekong River Commission Regional Workshop on Reservoir Fisheries Development, Ubon Ratchathani, Thailand, February 1995. (Garaway, Lorenzen presented by Garaway)

Seminar at the Institute of Aquaculture, Stirling University, November 1995. (Garaway, Lorenzen)

Fourth Asian Fisheries Forum, Beijing, China, October 1995 (Lorenzen)

Asian Development Bank/Network of Aquaculture Centers in Asia-Pacific Workshop on Aquaculture Sustainability and the Environment Beijing, China, October 1995. (Lorenzen)

World Fisheries Congress, Brisbane, Australia, July 1996. (Beddington)

#### 6.2.3 Workshops and training courses organised

Project workshop on the assessment of Chinese culture-based reservoir fisheries, London, February 1996.

Training course on "The Assessment of Culture-Based Reservoir Fisheries" for Biologists of the Thai Department of Fisheries, Udon Thani, Thailand, March 1995

Workshop on the biological and socio-economic assessment of culture-based reservoir fisheries, London, May 1995 (Workshop was organized on the occasion of the visit of Dr V.V. Sugunan, FAO Andre Mayer Research Fellow on small reservoir fisheries).

Workshop on management and development options for Vanivilas Sagar reservoir, Mangalore, Karnataka, June 1996

### 6.3 Uptake of project results

Significant uptake of results from this project and its predecessor (R5023) has occurred during the reporting period.

The Indo-German Reservoir Fisheries Project Malampuzha in Kerala, India, was the first external organisation to use project methodology for the evaluation of management options in culture-based fisheries (Taage & Reters 1994, 1995).

The Royal Thai Department of Fisheries (DOF) has started to implement project methodology following a training course held in March 1995. Several DOF stations have collected stocking and catch data which will be analysed in a second training course to be held in November 1996. The DOF has expressed an interest in further support for the implementation of project methodology, for the assessment of culture fisheries in larger reservoirs as well as in village ponds.

Dr V.V. Sugunan, FAO Andre Meyer Research Fellow and Senior Scientist at the Central Inland Capture Fisheries Research Institute in Barrackpore, India visited MRAG in May 1995. Dr Sugunan studied project methodology and results from the field studies, which will be incorporated in his forthcoming review on small water body fisheries (Sugunan in prep.).

A presentation on project outputs, focusing on quantitative analysis of culture fisheries, has been invited by FAO for their Expert Consultation on Fisheries Enhancements, to be held in Bangladesh in early 1997.

Dr Y.S. Yadava, Fisheries Development Commissioner of the Government of India, has expressed an interest in combining population models developed in the project with remote sensing data of reservoir size and productivity in order to estimate the potential for culture fisheries development on a state or national level.

A request from the Livestock and Veterinary Section of Savannakhet Province, Laos, to apply project methodology to the development of small reservoir fisheries in the province has been followed up with a proposal for adaptive research. The project is now in its second year.

### 6.4 Follow-up necessary to promote uptake

The assessment methodology developed in the project has met with considerable interest in many Asian countries, and has already been implemented in some projects and institutions. This experience has pointed to several factors that frequently limit uptake and must be addressed to realise the developmental benefits of the outputs.

Project outputs are targeted at governmental and non-governmental organisations involved in the promotion, management and development of culture fisheries. Target groups thus include inland fisheries research and extension officers, local or international NGO staff, development volunteers and consultants. In order to successfully apply the methodology, the target groups are required to

- Appreciate the contribution of inland capture fisheries to fish production, and to understand the ecological, technical and socio-economic context of these fisheries.
- Adopt a participatory approach to their investigations.
- Obtain data from and conduct adaptive experiments in operational fisheries.
- Develop skills in quantitative stock assessment.

The degree to which these requirements are met varies between target institutions, and merits further consideration. The appreciation and understanding of inland capture fisheries is often limited, with fisheries departments in particular concentrating their efforts almost exclusively on aquaculture. Non-governmental organisations may have a greater sense of appreciation, but not necessarily understanding of capture fisheries. Participatory approaches are still rare in practice, and the knowledge and management capabilities of fishers are often neglected. The systematic study of operational culture fisheries through stocking and catch monitoring and adaptive experimentation is rare, as fisheries officers prefer more familiar on-station experiments and basic limnological studies. Knowledge of fisheries stock assessment is often too limited to apply the quantitative methods developed in the project.

Hence the background, knowledge-base and culture of organisations involved in culture fisheries development may pose constraints to the adoption of project outputs. Policy changes and adequate training are required to overcome these constraints. Training must emphasise the philosophy behind the methodology (participation, adaptive management) and institutional aspects of its implementation as well as the dissemination of technical skills. Two general trends in recent years are conducive to the implementation of project outputs: participatory approaches are widely promoted at the higher levels of government agencies and slowly find their way into practice, and computer skills are becoming increasingly common. Specific training is required in the integrated appraisal of culture fisheries, using participatory methods and population modelling. Experience from training workshops held as part of this project and the adaptive project R6339CB has been very encouraging. Participatory appraisal methods can be taught in compact workshops, linked with field studies that can significantly enhance the appreciation and understanding of capture fisheries. Likewise, spreadsheet-based population models can be constructed in training courses and used to demonstrate the principles of adaptive management. In the medium term, specific training materials such as manuals with worked examples should be produced to facilitate wider adoption of project outputs.

#### 6.4 Needs for further strategic research

Needs for further strategic research have been identified in the following areas:

- (1) Design of adaptive management strategies for culture fisheries. This includes a meta-analysis of culture fisheries to assess the degree to which information on key technical parameters can be transferred between sites. A Bayesian framework for parameter estimation would provide the most rigorous way of combining heterogeneous sources of information and updating parameter estimates in the light of new information.
- (2) Analysis and design of institutions for culture fisheries management. Institutional constraints are possibly the most important factor limiting the expansion of culture fisheries. This research would analyse the design of resource user institutions to perform the key tasks of limiting access, recovering seed costs, and resolving conflicts. The role of external governmental and non-governmental organisations in facilitating the development of efficient resource user organisations is also crucial.
- (3) Development of geographic information systems combining remote sensing data on water body productivity with other information on accessibility, markets etc. to identify water bodies with a high potential for culture fisheries development. This would help governmental and non-governmental institutions to focus their support for culture fisheries development in areas with a high potential for success.
- (4) A comprehensive, quantitative analysis of the economic cost and benefits of culture fisheries development should be conducted where culture fisheries are promoted on a large scale, for example in India.
- (5) The integrated management of small water bodies for fish production is still poorly understood at a fundamental level. Fundamental research in this area, focusing on robust strategies (management measures that are likely to produce good results over a wide range of conditions) may generate substantial benefits for the fisheries utilisation of irrigation systems.

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