Impacts of irrigation and aquaculture development on small-scale aquatic resources

(R 7235)

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Final Report to the
Department for International Development
Environment Research Programme

Cover photograph:
Irrigation weir at Huay Xay, Namphou scheme, Savannakhet.

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Signature of the author of this final report

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Executive summary

(1) Small-scale aquatic resources play an important but poorly quantified role in the livelihoods of rural people in many developing countries, and are also important reservoirs of biological diversity. We conducted a field study in Southern Laos to quantify small-scale aquatic resource, and to assess the impacts of (small-to-medium scale) irrigation and aquaculture development on these resources.

(2) The main resource use and irrigation impact study has been designed as a paired comparison of household fishing effort and yield, and fish species richness between impacted and non-impacted sites for the three main types of irrigation schemes found in the project area. A total of 31 paired sites with 620 households were surveyed.

(3) Participation in natural aquatic resource use was near universal, with 83% of households fishing during the survey period. The estimated average annual household catch was 60 kg, with a market value of 90 US$. This represents about 15-20% of average household income. Household fishing effort and catch were strongly related to household size, but only weakly influenced by socio-economic status.

(4) Weir irrigation schemes were associated with a 40% (90%CI [5%, 67%]) reduction in household fish catches from a non-impacted mean of 30 kg/hh/year. This difference reflects a change in fishing effort as well as in resources abundance.

(5) Dam irrigation schemes were associated with no significant overall effect on household catches in villages in the vicinity of the newly created reservoir. However, catches from floodplain areas declined significantly by 58% (90%CI [2%, 90%]) from a non-impacted average of 78 kg/hh/year. This was largely but not fully compensated by increased catches from the reservoir. Again, differences reflect a change in fishing effort as well as in resources abundance.

(6) Reservoirs should not be regarded as adding to total aquatic habitat and productivity, but as (partial) compensation for downstream impacts. Net impacts may be spatially differentiated, and overall negative impacts may occur downstream of the dam where the reservoir is less accessible.

(7) Pump irrigation schemes abstracting from major rivers had no significant effect on catches from the irrigated areas.

(8) None of the irrigation schemes had significant effects on fish species diversity. Measured effects on species richness were as follows: weirs –3% (90%CI [-30%, +16%]), dams +8% (90%CI [-22%, + 30%]); pumps (irrigated area) –13 (90%CI [-31%, +4%]).

(9) It is concluded that the development of individual, small-to-medium scale irrigation schemes is associated with moderate, but significant negative impacts on local aquatic resources. However, these resources can remain productive and diverse and add substantial value to the use of water in irrigation.

(10) Aquatic resources impacts should be considered in cost-benefit analyses and environmental assessments of small and medium scale irrigation schemes.

(11) Proliferation of small-to-medium scale irrigation schemes may lead to cumulative impacts in excess of those established here. This should be assessed and managed on a catchment scale.

(12) The aquaculture impact study consisted of two surveys. One survey quantified the effects of successful adoption of aquaculture on natural aquatic resource use.

A separate survey was designed to compare fish species richness between small water bodies with and without established feral populations of Nile tilapia.

(13) Aquaculture has been adopted by 7% of households in the project area, and the estimated contribution to fish catches of aquaculture is 2-10%. In the survey periods, adopting households obtained 20% more fish while expending 18% less effort than non-fish farmers.

(14) Aquaculture adoption occurred across a wide range of socio-economic groups, but was dominated by households with high levels of asset ownership and cash income.

(15) Aquaculture adoption resulted in a significant reduction (-36%) of household fishing effort, but only small reduction in household catch from natural aquatic resources.

(16) The establishment of feral tilapia populations (as a result of escapement from fish ponds or deliberate stocking) had no significant effect on wild fish species richness.

(17) It is concluded that aquaculture expansion is unlikely to have a major effect on the use or diversity of natural, small-scale aquatic resources.

1 Background

Small-scale aquatic resources may be defined as the productivity and diversity of organisms associated with small water bodies (e.g small lakes and rivers/streams; reservoirs and canals; paddies etc.) and used or otherwise valued by humans.

Small-scale aquatic resources make an important contribution to rural livelihoods in many developing countries, a fact that is not always fully appreciated (Kottelat & Whitten 1996). Fish account for the bulk of animal protein consumed in countries such as Laos or Bangladesh, and much of this obtained locally by part-time subsistence fishing. The importance of small-scale aquatic resources stems from their accessibility to all sections of the population and the fact that diverse natural stocks, including many small species eaten whole, provide high levels of micro-nutrients and vitamins (Haraksigh-Thilsted *et al.* 1997). Small-scale aquatic resources may also, collectively, be significant reservoirs of biological diversity (Gibbs 1993).

Small scale aquatic resources are under threat from a variety of sources, in particular habitat modifications, the introduction of exotic species, and overexploitation. However, habitat modifications and species introductions may also have positive impacts on aquatic resource productivity. In rural areas of the developing world, the interventions most commonly associated with impacts on small-scale aquatic resources are water resources development for irrigation, and the development of aquaculture (i.e. intensification of aquatic resource management). In addition to their direct effects on the ecology of aquatic resources, these interventions may precipitate changes in exploitation patterns, which in turn may impact on resource abundance and diversity (e.g. Lorenzen *et al.* 1998a).

Impacts of irrigation development on small-scale aquatic resources may result from:

- reduction/modification of stream/river flows;
- obstruction of migratory pathways (loss of habitat connectivity);
- destruction of old (e.g floodplain) and creation of new (e.g. reservoirs, irrigation canals, ponds) aquatic habitats;
- increased use of agrochemicals associated with irrigated crops;
- changes in access rights to aquatic resources and the opportunity costs of fishing.

(ICID 1993; Roggeri 1995; Claridge 1996; exploratory studies by project team)

Impacts of inland aquaculture development on natural aquatic resources may occur due to:

- pond effluent loadings with various pollutants,
- the intentional eradication of wild fish in the course of intensification of the use of existing water bodies
- feral animals, in particular of exotic species, that may establish breeding populations
- spread of diseases between farmed and wild fish, and
- restrictions of access to various resources including wild fish.

(Beveridge *et al*. 1994; FAO/NACA 1995; exploratory studies by project team)

The importance of large-scale aquatic resources associated with major rivers and lakes is widely appreciated, and water engineering projects and other activities affecting them have been subjected to extensive impact studies (e.g. FAP 17, 1995; Halls *et al.*, 1998). Small-scale aquatic resources, however, are much less appreciated even though collectively they are likely to match or exceed the socio-economic and ecological importance of the large-scale resources. Small-scale resources are frequently impacted by developments on an equally small scale, such as small-to-medium irrigation schemes. Impacts of such developments are rarely assessed, although they may be significant both locally, and cumulatively on a larger scale.

Ignorance of small-scale aquatic resources, their role in the livelihoods of rural people, and the impacts of development on them may have significant negative consequences for the resources themselves and the livelihoods of people who rely on them most, often the poor. A quantitative assessment of the role of small-scale aquatic resources, impacts from irrigation development, and the role of aquaculture is therefore crucial to ensure that these issues are appropriately considered in policy and planning decisions.

2 Project purpose

The project purpose is defined in the project document as follows:

Impact of irrigation and aquaculture development on small-scale aquatic resource abundance, diversity and use assessed and recommendations for conservation developed.

3 Research activities

3.1 General overview

A large-scale, collaborative field study was carried out in Laos to address the project purpose.

3.1.1 Project partners and key staff.

The project was implemented jointly by Imperial College and the Regional Development Committee for Livestock and Fisheries in Southern Laos (RDC). Specialist input in fish taxonomy was provided by The Natural History Museum.

Key staff were:

Imperial College
Dr Kai Lorenzen (principal investigator)
Ms Sophie Nguyen Khoa (project officer and field manager, Savannakhet-based)
Dr Caroline Garaway (social and institutional research specialist)
Mr Robert Arthur (PhD candidate)
Dr Geoff Kirkwood (biometrics advisor)

RDC
Mr Doungchith Litdamlong (coordinator)
Mr Bounthanom Chamsingh (project officer)
Mr Nick Innes-Taylor (senior advisor)
25 provincial and district level officers

The Natural History Museum
Dr Darrell Siebert (Southeast Asian fish specialist)

3.1.2 Research philosophy and approach

The research philosophy of the project was guided by the following principles:

- Direct developmental relevance through focus on household aquatic resource use and related use of biological diversity by villagers
- Rigorous experimental design with sufficient replication to allow generalisations impacts
- Close integration of ecological and socio-economic analysis
- A two-stage project design with exploratory research informing the design of a quantitative impact survey
- Use and further development of local government capacity to carry out aquatic resources research and integrate results into development decision making.

3.1.3 Overview of activities

Project activities were divided into two steps:
- Exploratory studies to aid the design of the main impacts surveys
- Quantitative assessments of impacts on fishing effort, catch and fish diversity

Exploratory studies

Project activities in Laos started with the establishment of a Memorandum of Understanding between Imperial College and the RDC in September 1998.

A planning workshop attended by provincial level livestock and irrigation staff from Khammuane, Savannakhet and Champasak provinces was held in October 1998. This led to the identification of a list of potential project sites.

A site survey programme aimed at providing baseline data on aquatic habitats in potential project sites was designed and pre-tested in October. In November, site survey training courses for district staff were prepared and delivered in all three provinces by the RDC Training Unit and project staff. About 100 sites across the three provinces were surveyed between November 1998 and January 1999, and preliminary results were collated at a workshop in February 1999.

An initial rapid rural appraisal to identify potential impacts of irrigation and aquaculture development on aquatic resource use was carried out in January 1999. At the same time, household fishing survey methods were devised and pre-tested. Biodiversity survey methods and procedures were pre-tested in March 1999.

The design of the impact studies was completed in March 1999, in the light of results from exploratory investigations as well as previous household and biodiversity surveys. A report detailing preliminary studies and survey design was submitted to DFID in April 1999.

Impact surveys

The main impact surveys were carried out between April and November 1999. All surveys were preceded by training workshops and followed by analysis workshops with district and provincial level government staff.

Data checking and entry took place from December 1999 to March 2000 in Savannakhet. The fish samples obtained in the biodiversity survey were transported to The Natural History Museum in London and identified by Dr Siebert and RDC staff in February 2000.

All planned activities have been completed. Slight delays occurred in data entry and the processing of biodiversity samples, and a two months extension of the project (without financial implications) was sought by the project team and granted by DFID.

<u>3.2 The study area</u>

3.2.1 Rationale for choosing Laos as a study area

Laos was chosen as a study area because

- aquatic resources are known to play an important role in the livelihoods of the rural poor
- the degree of irrigation development in the country is moderate and there are sufficient non-impacted control sites for a quantitative impact assessment
- an established good working relationship between the UK team and the in-country collaborators made it possible to carry out a field study of the required magnitude while relying on and developing local capacity

3.2.2 Laos

The climate in Laos is tropical with an average daily temperature of 31► C and an average annual precipitation of 1500 mm, about 75% of which occurs in the monsoon season (May to October).

Rice is the single most important crop in Lao agriculture, accounting for 72% of the cultivated area. More than 85% of rice produced is of traditional varieties of the glutinous type, and annual yields are in the range of 1.5 to 2.8 t/ha.

Only 3% of the paddy area is irrigated, and the dependence on rainfed systems is seen as the major constraint to the expansion of rice production (SUAN 1989; IRRI 1999). Agricultural production in the rainfed areas tends to be subsistence-oriented. The net value of the rainfed rice crop has been estimated at about 100 US$/ha, not costing family labour (AIT 1992, ELC 1993). However, only a small fraction of the crop is usually sold, and farming in rainfed areas tends to generate little cash income.

3.2.3 Study area in southern Laos

Field studies were carried out in three provinces in southern Laos: Khammuane, Savannakhet and Champasak (see map, Fig. 1). The lowlands of Savannakhet and Champasak provinces are among the major rice producing areas in Laos, together accounting for over a third of rice production in the countries'17 provinces. Much of Khammuane is mountainous, making the province a less important, but still significant area for rice production.

Fig. 1: Map of Laos indicating the study area

3.2.4 Irrigation development

The project was concerned mainly with irrigation schemes that involve a significant local re-distribution of water and/or modification of aquatic habitats. Such schemes are constructed and maintained under the auspices of the Department of Irrigation and Micro-Hydropower in Laos. In addition to these formal schemes there are traditional, informal schemes, usually on a very small scale. Also, in recent years many farmers have acquired private diesel pumps, mostly through the Department of Agriculture.

Three types of formal irrigation systems are common in southern Laos:

(1) *Dams.* Dams involve the storage of substantial volumes of water. Usually this water is distributed to paddies through canal systems, either by gravity or by pumps (the latter is quite common in lowland Laos). Some shallow reservoirs in southern Laos have no associated distribution systems, and are used exclusively for rice growing in the reservoir itself. Only reservoirs with associated distribution systems were considered in this study.
(2) *Weirs.* Weirs serve to abstract water from streams or small rivers. Weir structures do not in themselves lead to significant storage of water, although substantial amounts of water may be retained in the irrigated areas. Distribution of water from weirs is almost exclusively by gravity.
(3) *Pump* schemes. Large pumps are used to abstract water from the Mekong mainstream and its major tributaries.

The total number of irrigation schemes operational in the project area in 1998 is shown in Table 1, broken down by type and province. Overall, pump schemes are by far the most common type of irrigation, followed by weirs and dams. While pumps and weirs are quite evenly distributed among the three provinces, dams are concentrated in Savannakhet.

Table 1: Total number of formal irrigation schemes by type and province

Type	Savannakhet	Khammouane	Champasak
Dam	31	4	1
Weir	37	20	18
Pump	125	131	109

Most irrigation schemes in the project area are small. Schemes with a realised command area of more than 500 ha are rare, and most schemes irrigate less than 100 ha. The realised command area is often substantially smaller than the design command area.

The age distribution of irrigation schemes is shown in Fig. 2. Dam schemes have been built at a more or less constant rate over the past eight years, and about half of the operational schemes are more than eight years old. Weirs have also been built at a fairly constant rate, but not many are older than eight years. There has been a striking increase in the construction of pump schemes in recent years, with two thirds of schemes being less than two years old. Pump irrigation schemes on major rivers are favoured by planners because of their potential for secure dry season irrigation (less dependent on annual rainfall), and low initial infrastructure costs compared to dams.

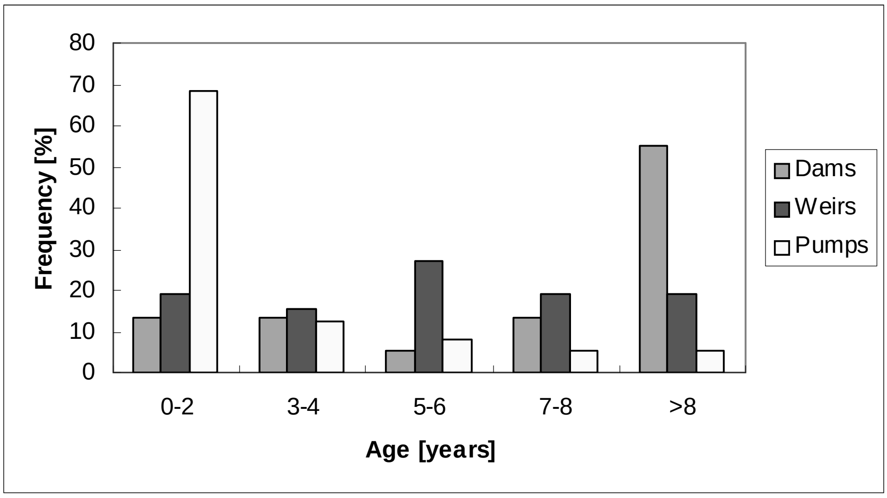


Fig. 2. Age distribution of irrigation schemes in the study area

3.2.5 Aquaculture development

Aquaculture implies both a technical intervention in the rearing cycle of aquatic organisms, and the private or corporate ownership of the stock being cultured. Aquaculture systems found in southern Laos range from traditional "trap ponds" to various semi-intensive systems involving the stocking of exotic species and the provision of other inputs such as feed or fertilisers. Systems of the latter type are being promoted by the Lao government and various development projects.

Quantitative information on the status of aquaculture development on Laos is somewhat more limited than that on irrigation. The total numbers of fish ponds reported to the provincial livestock and fisheries offices in Savannakhet and Khammouane are 3200 and 1200, respectively. However, these figures include traditional trap ponds as well as semi-intensive aquaculture operations. Exploratory fieldwork indicated that the prevalence of semi-intensive systems is still fairly low. The size of private fish ponds covered in the site survey ranges from 0.01 to 0.5 ha, with an average of 0.12 ha.

The main biodiversity concern relating to aquaculture is the widespread stocking of exotic species, in particular the Nile tilapia but also common, Chinese and Indian major carps (Claridge 1996).

<u>3.3 Irrigation impact study</u>

The potential impacts of irrigation development to be quantified in the survey have been identified as:

- Impacts on aquatic habitat abundance and diversity
- Impacts on fishing effort and yields (including distribution between habitat types and household members), at the household and local area level
- Impacts on wild fish diversity

While negative impacts may be expected from reductions in stream/river flows and the disruption of migratory pathways linked to dams, weirs and excessive abstraction by pumps, positive impacts may result from the creation of new aquatic habitat in or around the irrigated area itself. In general, both types of impacts will occur within each scheme and only the net result will be measurable in impact surveys. It should be noted, however, that any impacts on river/floodplain productivity may still occur some distance downstream from the irrigation scheme where the reservoir and irrigated paddy would be less accessible. It is therefore important to separate effects on existing river/floodplain fishing from those related to the newly created habitats. The project aimed to achieve this in two ways. Effort and catch data were recorded by water body type, allowing separation of effects within sites. In addition, an impact survey of small-scale pump schemes abstracting water from major rivers such as the Mekong mainstream. Such schemes are unlikely to have a significant impact on the river itself, but should impact on aquatic resource ecology and use in the irrigated area.

The irrigation impact study was designed as a paired comparison between impacted and control sites, with replication at the irrigation scheme level. Separate sub-studies have been designed for dams, weirs and pumps; with foci on Savannakhet, Champasak and Khammuane respectively.

Three different surveys have been carried out in the sites selected for the irrigation impact study:

(1) A site survey aimed at identifying impacts on aquatic habitat abundance and diversity at the village level. This survey has been largely completed during the first phase.
(2) A fishing survey aimed at evaluating impacts on fishing effort and yields, including distribution between habitat types and household members. This survey will be conducted at the household level and scaled up to the village level using site survey data.
(3) A biodiversity survey aimed at identifying impacts on the diversity of locally exploited fish stocks.

3.3.1 Selection and characterisation of sites

Site selection for the irrigation study was carried out in three steps.

(1) Possible impacted and control sites were identified in a workshop with Livestock/Fisheries and Irrigation section staff from the three provinces. This has led to a list of approximately 16 paired sites per type of irrigation scheme.
(2) A site survey was carried out for potential sites from this list.
(3) Site survey and auxiliary information on all sites were reviewed in order to identify those sites that best meet the criteria for pairing (e.g. similar order stream from the same watershed, and similar topography and land use). This led to the selection of ten dam, ten weir, and eleven pump sites, each paired with a suitable control.

Impacted sites were selected to be close to the main irrigation structure (weir or dam), and sharing a significant part of the irrigated area. Hence sites were expected to be affected by both, possible negative impacts on river/floodplain fishing resulting from water abstraction obstruction of fish migration, and possible positive impacts resulting from reservoir creation and irrigated rice fields. Recording of effort and catch information by water body type allowed to separate such impacts aIt should be

3.3.2 Site survey

The site survey is designed to provide a quantitative characterisation of habitat abundance and diversity.

The first step in the survey was the drawing of a water body map by local villagers. Villagers were asked to draw all water bodies in the village area, and indicate any others that are used by them for fishing (it is not uncommon for villagers to travel for several miles to fish in water bodies outside the village area). An example of a water body map is shown in Fig. 3. All water bodies were then visited by the survey team and some local villagers to obtain a range of baseline information such as area, depth, sinuosity, flow velocity, macrophyte cover, etc.

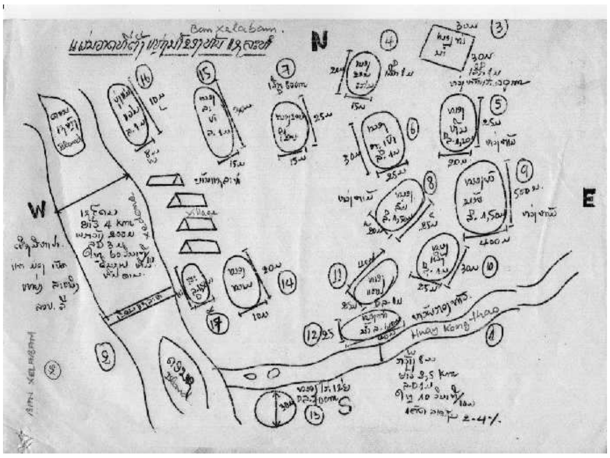


Fig. 3. Example of a water resources map drawn by villagers and recorded by a district officer. Xelabam village, Sanasomboune district, Champasak.

3.3.3 Fishing survey

At each site, a sample frame for the fishing survey was constructed from village lists or maps. Ten households were selected at random from the list. (In villages with significant adoption of aquaculture, the population was stratified into adopters and non-adopters. Ten non-adopters and five adopters were then selected at random from the respective strata).

Socio-economic baseline information was collected on each selected household. Interviews were carried out in each selected household in order to obtain detailed information on the last seven day's fishing events: person fishing, habitat type, gear type, time fished, and catch in weight.

The interview method was adapted from a previous survey (Garaway *et al.* 1997; Garaway 1999), and involves the use of aids such as bowls of different size and sticks of different length to aid recall of catches and obtain the best possible quantitative information.

The fishing survey was carried out twice, to capture the dry and late wet seasons.

3.3.4 Biodiversity survey

Sampling for fish biodiversity was carried out through participation of large groups of local villagers in a fishing event. Villagers (already acquainted with the project from the site survey) were asked to catch as many different species of fish as possible from the local water bodies. Emphasis was placed on the participation of women as well as men and children, the use of a wide range of gear (Fig. 4). This participatory approach was chosen for three reasons. Firstly, to provide the best possible coverage of local habitats and species with limited resources. Secondly, because the diversity of experimental catches is likely to reflect the diversity of fish commonly caught and utilised by villagers. Thirdly, it was felt that collection of the samples by villagers would promote local ownership of information and allow villagers to interpret results of the comparative study.

Diversity assessment requires the proper identification of specimens, and this was not possible under field conditions. Hence all samples were preserved and identified jointly with RDC staff at The Natural History Museum in London.

Fig. 4. Group of women participating in a fishing event as part of the biodiversity survey. The water body pictured is a new reservoir created inadvertently by the construction of a raised irrigation canal across a small watershed. Nanokyang village, Champhone distict, Savannakhet province.

The biodiversity survey has also been carried out twice, in the dry and wet seasons.

3.3.5 Quantitative aspects of survey design

A major issue in survey design was to ensure that the survey would allow the detection of impacts of the magnitude considered to be policy relevant, or to reject the hypothesis that impacts of this magnitude occur. Prior, indicative information on household fish catches and their market value, and on the cost and benefits of irrigation development suggested that a reduction in fish catches by 50% would be sufficient to offset the net benefits of many irrigation schemes. Hence the survey was designed to detect a 50% reduction in fish catches at a level of significance of ► = 0.1 and power of 1-► = 0.9.

A paired design was adopted in order to reduce the variances of treatment effects due to environmental factors.

A key question with respect to the household survey concerned the optimal allocation of sampling effort within and between sites. Results from the previous survey (Garaway 1999) indicated that the sampling effort should be distributed to maximise the number of sites (the primary unit of the study), whereas samples in excess of about ten households per village would have little benefit. It was therefore decided to sample ten households per site as a standard protocol. Power analysis suggested that ten paired sites would be sufficient to meet the design criterion of a detecting a 50% difference in catch or diversity between impacted and non-impacted sites. Details of design considerations are given in Lorenzen et al. (1999).

3.4 Aquaculture impact survey

The key potential impacts of aquaculture development to be quantified in the study have been identified as:

- Impacts of exotic species introductions on abundance and diversity of native stocks
- Impacts of adoption of aquaculture on aquatic resource use at the household and village level.

As mentioned before, the level of aquaculture development in the project area was still low. Hence impacts on aquatic resource ecology and use at the village level are unlikely to be significant at present. Such impacts may, however, occur in the future if aquaculture becomes widely adopted, and it is therefore important to obtain an indication of the type and magnitude of likely impacts.

The current major biodiversity concern relating to inland aquaculture development in Laos and elsewhere in Asia is the widespread stocking of exotic species. Impacts of the Nile tilapia *Oreochromis niloticus* in particular are controversial, and have not been rigorously assessed (Kottelat & Whitten (1996). An indication of potential impacts of the widespread introduction of exotic species into natural water bodies in Laos may be obtained by evaluating the effects of deliberate stocking of exotics in natural small water bodies. Impacts of aquaculture adoption on natural aquatic resource use can be quantified at the household level, and scaled up to village level.

Hence, two separate studies have been designed to quantify the potential impacts identified above:

(1) A comparative study of wild stock diversity in stocked and non-stocked small water bodies.
(2) A study of household level impacts of aquaculture adoption on aquatic resource use.

3.4.1 Impact of feral tilapias on fish species richness

A comparative test fishing experiment using multi-mesh gill nets was carried out in 54 small water bodies in Savannakhet province. This study was carried out jointly with a project on adaptive learning approaches in the enhancement of small water body fisheries, supported by the DFID Fisheries Management Science programme.

3.4.2 Impact of aquaculture adoption on natural aquatic resource use

This study has been integrated with the irrigation impact study. In sites with significant adoption of aquaculture, households were stratified into adopter and non-adopters, and five adopting households were surveyed in addition to the ten non-adopting households surveyed for the irrigation impact study. Affects of adoption were then assessed through a paired comparison within sites.

3.5 Processing and analysis of survey data

All survey data were stored in a relational database. Statistical analyses of the data included paired comparisons and regression models, as detailed in Section 4. Site-level catch and effort data and the differences between paired sites were found to be slightly skewed and highly leptokurtic. Square-root transformations of the site level data resulted in approximately normal distributions of original variables and differences, and all statistical analyses have been conducted on transformed data. Means and effects reported in the text have been back-transformed from the square-root scale.

3.6 Analysis of institutional arrangements

Research was conducted through a series of semi-structured interviews over a period of four weeks in November/December 1999. A list of villages identified from initial surveys as having been impacted by irrigation and/or aquaculture development was drawn up. Time constraints limited the number of villages that could be investigated and meant that some of the more remote districts, and remote villages within the relatively more accessible districts could not be selected for investigation. It was felt that comparisons between districts and Provinces were more important than getting more in-depth knowledge within any one district, and therefore sites were selected in a way that maximised the area covered. With the above constraints therefore, villages were randomly selected from the majority of districts in the project study area. Eighteen villages were investigated in total.

3.7 Development of policy recommendations

Specific policy recommendations for Laos were developed in a series of workshops with Lao government staff. In addition, overall conclusions and recommendations were developed by the project team in London.

3.7.1 Results and policy workshops

A series of workshops was held to discuss project results and implications district, provincial and national government level.

(1) A workshop with district level staff was held in Savannakhet on 15 May 2000 to review the data collection, relay comments on the process from villagers as well as district staff, and identify key implications.
(2) A provincial level workshop was held in Savannakhet on 16 May 2000. Building on the outputs of the first workshop, Livestock & Fisheries and Irrigation Section staff discussed results and their policy and planning implications.
(3) A national level workshop was held in Vientiane on 19 May 2000, attended by high-level representatives of the Livestock & Fisheries Department, Irrigation Department, Lao Aquatic Resources Research Centre, Science Technology and Environment Organisation, Mekong River Commission, and FAO. Project results and outputs from previous workshops were presented before discussing policy implications.

3.8 Institutional development and capacity building

Although aimed primarily at delivering strategic research, the project also had a strong element of institutional development and capacity building in Laos. The field programme was implemented jointly by Imperial College and the Regional Development Committee for Livestock and Fisheries, a government body co-ordinating the work of provincial Livestock and Fisheries Sections in southern Laos.

3.8.1 Training and local ownership of results

Most field sampling was carried out by a total of about 20 district–level livestock & fisheries officers, under the direct supervision of three provincial project co-ordinators. All field surveys were preceded by training workshops, and followed by analysis workshops. As a result, a significant number of staff in the participating provinces have been trained in a range of survey methods, including transferable skills such as participatory mapping. Analysis workshops promoted local ownership of results, as well as allowing a cross-checking of information and review of survey procedures.

3.8.2 Villager’s participation in research and ownership of results

Most surveys rely on active participation of villagers, for example in resource mapping and biodiversity sampling. Ownership of results at the village, as well as local government level is highly desirable, not least because this may promote community action for aquatic resource management and conservation. Key information on irrigation and aquaculture impacts was obtained through comparisons between sites, i.e. at a level above that of the individual village. This information has been relayed back to the participating villages on subsequent visits by the district officers.

3.8.3 Linkages between irrigation and aquatic resources institutions

Aquatic resource management (aquaculture and capture fisheries) is the responsibility of the Livestock and Fisheries Sections, while irrigation planning and management is carried out by the Irrigation Sections, both under the provincial Divisions of Agriculture. The promotion of closer links between the Livestock and Irrigation sections is crucial if the consideration of aquatic resources issues in irrigation planning is to be improved. Representatives from the Irrigation Sections were closely involved in the project throughout. This has increased the awareness in both departments of the potential interactions between aquatic resource use and irrigation development, and has prepared the ground for closer co-operation in planning and management.

3.8.4 Reference collection for ichthyological studies

The large-scale sampling programme operated under the present study provides a unique opportunity to establish a reference collection for ichthyological studies on Lao fishes. Such a collection may in the future play a key role in the study of aquatic biodiversity in Laos. Unfortunately, there are at present no qualified staff or facilities to maintain a reference collection locally. Hence the collection has been transferred to The Natural History Museum (NHM) where half of it is held in trust, to be returned at any time upon request from the Lao Government.

Two RDC staff visited the NHM in February/March 2000, to identify the specimens and receive training in species identification and the maintenance of a collection. The RDC staff were trained to a level of parataxonomist, ie. competent to work with available literature to provide accurate identifications at a local level. It is intended to establish a longer-term link between the NHM and the RDC and other relevant institutions, with the aim of supporting appropriate ichtyological capacity building within Laos.

The fishes brought to London form a valuable scientific resource. In the first instance they are probably the largest collection of fishes from Lao PDR to be deposited and made available in a public museum for over 30 years. The collections are now completely sorted and identified to species, within the limits of current taxonomy. The fishes are being registered in the Natural History Museum, London, with half of them being held in trust. After registration is complete, an identification key to all but the rarest species will be produced. This key will be made available in Lao through the RDC.

The collections are an extremely valuable resource for further studies. Some of the taxa included among them are currently undescribed species, which are now being described. The collection will form the basis for revisionary studies of freshwater fish species considered to be widespread across Southeast Asia, eg. *Cyclocheilichthys repasson*, *Systomus orphoides*, and *Ompok bimaculatus*. Also, the samples provide a record of the geographic distribution of freshwater fish species in Lao PDR at an unprecedented scale. Finally, because the collections are from paired sites in time they will provide valuable data on the utilisation of the unique Mekong system by fishes. These further studies will be carried out by Dr Siebert, in collaboration with the RDC and Imperial College as appropriate.

4 Outputs

The anticipated project outputs (characterisation of small-scale aquatic resources and their use, assessment of irrigation and aquaculture impacts, and policy recommendations) have been achieved.

4.1 Baseline data on study sites and households

4.1.1 Overview of sites

A total of 62 study sites (31 pairs) were selected, a complete list is given in Appendix 1. Realised command areas of the selected irrigation schemes ranged from 17 to 515 ha, with an average of 155 ha. With one exception, all sites have been impacted for at least two years. The selected villages varied in size form 15 to 256 households (average 102). The associated paddy areas varied from 3 to 346 ha (average 93 ha).

The photographs in Fig. 5 show an example of a paired set of impacted and control sites.

Abundance of water resources was variable but high on average. Total flooded area, including all waterbodies and seasonally flooded paddies ranged from 15 to 1426 ha (average 154 ha). This implies an average of 1.5 ha of flooded area per household.

An overview of aquatic habitats available in the different categories of sites is given in Figure 6. Weir sites and controls were characterised by the lowest aquatic habitat areas overall, and the smallest difference in dry season paddy area between impacted and non-impacted sites. Dam impacted sites (in all cases villages located close to the dam within the impacted areas) had the highest dry and wet season habitat areas, with the reservoirs making a substantial contribution on average. Pump irrigated sites and their controls were characterised by a high abundance of river habitats, mostly accounted for by the Mekong or its major tributaries on which the sites were located. The small, dry season paddy areas found in non-impacted sites are the result of informal pump irrigation.

Fig. 5. Example of a paired impacted and control site. Weir at Thongbouxa, and non-impacted stream at Bang Jo, Pakse district, Champasak province.

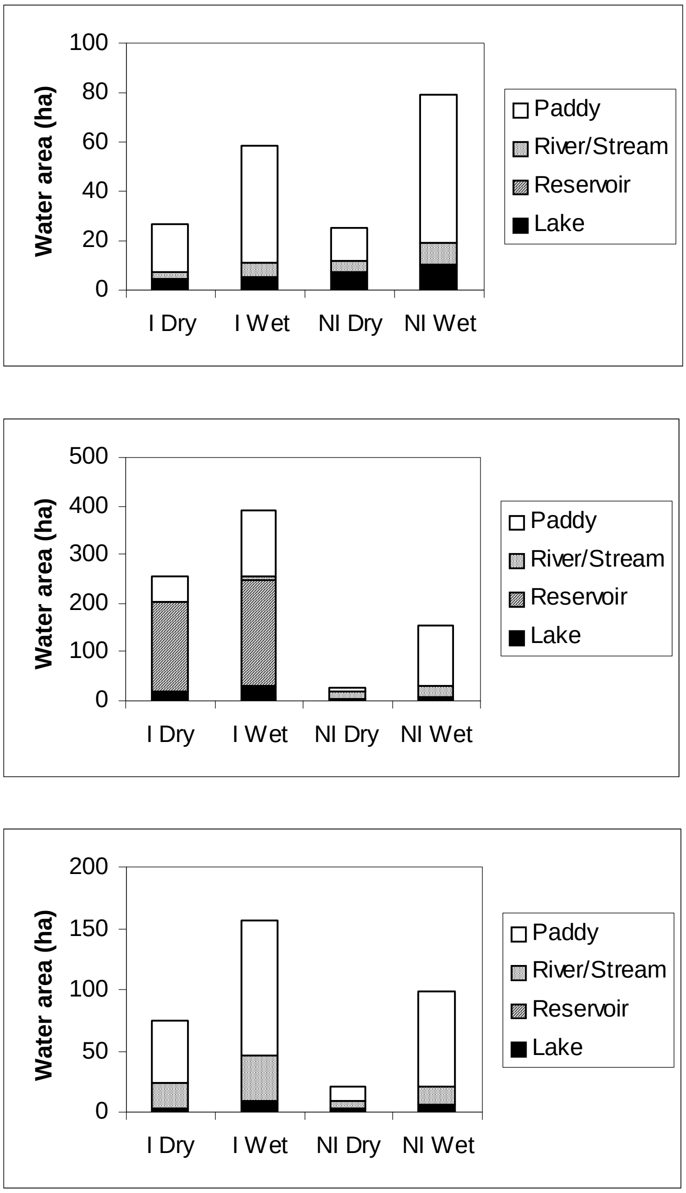


Figure 6. Overview of aquatic habitat areas available in the different categories of study sites: weir sites (top), dam sites (middle) and pump sites (bottom). Impacted (I) and non-impacted (NI) sites in the dry and wet season respectively.

Socio-economic baseline data on households in the study area is given in Table 2. Average household size was 5.8 persons, with a paddy area just under one hectare. On average, households produced a slight surplus of rice (rice index positive), and obtained some cash income from paid employment (mainly government), sale of surplus produce, or business activities. Most households owned some livestock (buffaloes and cattle) and at least one bicycle. Ownership of motorised transport (tractors, motorbikes) was very limited, as was ownership of a shop.

Table 2. Socio-economic baseline data.

	Mean	Min.	Max.
Household members	5.8	2	13
Paddy area (ha)	0.98	0	12
Rice index (-0.5 deficient, 0 sufficient, 0.5 surplus)	0.13	-0.5	0.5
Cash income (US$/year)	195	0	5345
No. of buffaloes	1.6	0	28
No. of cattle	1.4	0	24
No. of tractors	0.06	0	1
No. of shops	0.05	0	1
No. of bicycles	0.73	0	6
No. of motorcycles	0.09	0	7

4.1.2 Socio-economic correlates of irrigation development

Socio-economic effects of irrigation development as measured in the household surveys are shown in Table 3. On average, households in irrigated sites were characterised by a significantly higher rice index, and by significantly higher levels of tractor and shop ownership. Most other indicators including cash income also show a positive effect, if not statistically significant. Hence it may be concluded that on average, households in irrigated areas were better off than in the paired control sites.

Table 3. Average socio-economic indicators for villages in non-irrigated areas, and effect of irrigation development. Effects were determined from paired comparisons. Effects in bold are significant at P<0.1.

	Non irrigated	**Effect**
Household members	5.9	0.05 [-0.48, 0.20]
Rice index (see Table 1)	0.10	**0.05 [0.00, 0.11]**
Cash income (US$/year)	195	20 [-6, 63]
No. of buffaloes	1.7	-0.04 [-0.40, 0.32]
No. of cattle	1.4	0.13 [-0.23, 0.49]
Tractor ownership	3%	**5% [1%, 9%]**
Shop ownerships	1%	**3% [1%, 5%]**
Bicycles ownership	75%	28% [-7%, 63%]
Motorcycle ownership	3%	3% [-4%, +9%]

4.1.3 Discussion

Household cash income and levels of asset ownership were low overall in the project area. As might be expected, households in irrigated areas scored significantly higher on several indicators than those in the non-irrigated controls. However, the differences were moderate overall, and may not be entirely attributable to the effect of irrigation (irrigation development may be focused on villages that are more prosperous and influential in the first place, a possibility we have not been able investigate).

4.2 Aquatic resource use

4.2.1 Overview

Aquatic resources may be exploited as a fishery (harvesting natural stocks as common property resources), or managed more intensively through aquaculture (intervention in the life cycle of aquatic organisms held in private ownership). There are also forms of aquatic resource use that combine aspects of capture fisheries and aquaculture, for example the stocking of fish in communal water bodies (culture-enhanced fisheries). This section concentrates on natural aquatic resources, while aquaculture is discussed in section 4.4.

Participation in natural aquatic resource use was near universal, with 82% of households fishing during at least one of the survey periods. The relative importance of habitats exploited during the survey periods is shown Fig. 7. Rivers and streams account for the largest share of effort and catch, followed by reservoirs and lakes.

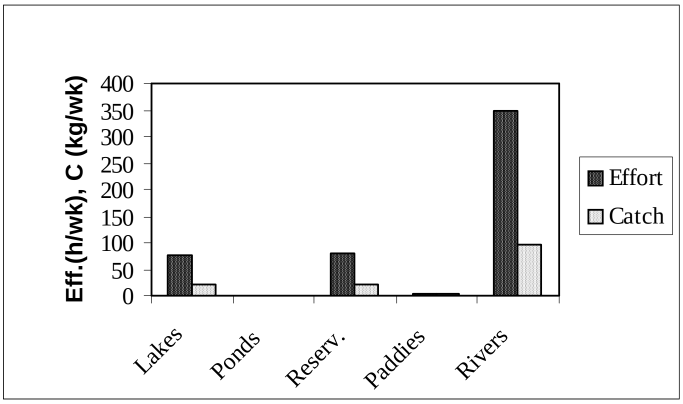


Figure 7. Average weekly fishing effort and catch in different habitat types.

The importance of aquatic resource use to household can be assessed by comparing the value of the fish catch to other household income (in cash and in kind). The value of fish in local markets ranges from 0.5 US$/kg for small "trash" fish to 1.5-2.5 US$/kg for larger fish. Household catches consist of about one third of "small" and two thirds of "large" fish, and the average value is therefore 1.5 US$/kg.

Table 4 provides an indicative estimate of average household income on the project area, including the contribution of fish catches. This suggests that in an average household, aquatic resource use accounts for 21% of gross income.

Table 4 Contribution of aquatic resource use to gross household income (non-fish farming households)

	Physical unit	Value	Proportion
Paddy rice (subsistence)	1.5 t/ha, average area 1 ha, market value 0.1 US$/kg	150	34%
Fish catch (subsistence)	60 kg/year, market value 1.5 US$/kg	90	21%
Cash income	From sale of surplus produce, employment and other activities (survey estimate)	195	45%
Total		435	100%

4.2.2 Catch-effort relationships and area productivity

Bayley (1988) conducted a comparative study of yield-effort relationships in tropical multi-species fisheries and identified the following model as the most universally applicable:

$$\text{Log}(Y) = a\,E^{0.5} + b\,E + c$$

Where Y is yield and E is fishing effort, both on a per-area basis.

Fitting this relationship to the yield-effort data collected in this study (Fig. 8) yields the coefficients a=0.55, b=-0.05 and c=-1.05. The predicted maximum yield is 2.9 kg/ha/week, or 150 kg/ha/year. This value is near the centre of the 95% confidence range (114-188 kg/ha/year) determined by Bayley (1988) for a wider range of river-floodplain systems.

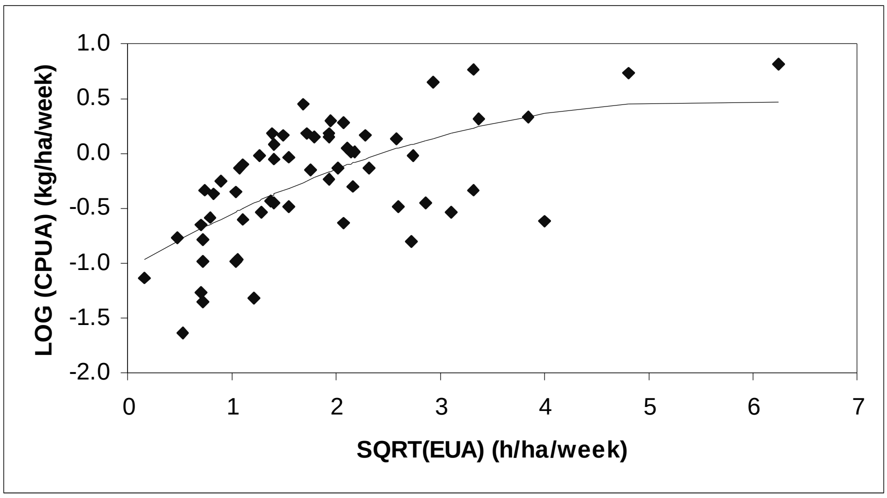


Figure 8. Relationship between fishing effort and yield. The solid line is the fitted model.

The above relationship also suggests that on the whole, fishing effort does not exceed the level where maximum yields are obtained. However, this does not necessarily mean that none of the sites suffer from overfishing.

4.2.3 Socio-economic correlates of fishing effort and catch

Linear models to predict household fishing effort and catch from household characteristic were developed to identify key determinants of effort and catch. A wide range of factors were tested. Household size was by far the most important determinant of fishing effort and catch. Ownership of assets such as a tractor, a shop or a motorbike had a significant but moderate negative effect on fishing effort, reducing effort in an average household by 35%. The effect of asset ownership on catch was also negative, but not significant. This suggests that asset-owning households reduce their involvement primarily in fishing activities that provide low returns to effort. Interestingly, there was no significant effect of cash income on fishing effort or catch.

Overall these results suggest that aquatic resource use is only weakly related to socio-economic status, although it is clearly most important to the poorer households in both absolute and relative terms.

4.2.4 Diversity of fish stocks

The co-operative test fishing experiments yielded a total of 154 species, and a further 25 were identified from test fishing in the aquaculture impacts study. However, 50% of specimens were accounted for by just six species, and 75% by 21 species, which are listed in Tab. 5. Among these, the introduced Nile tilapia *Oreochromis niloticus* was recovered from both open waters and private fishponds, and ranked eighth overall.

Relationships between fish species richness, environmental variables and fishing pressure were explored. The strongest relationship was established between species richness and dry season water area (Fig. 9). This indicates that while wet season (maximum flooded) area determines local fish production, dry season area is a more important determinant of diversity.

Table 5: Fish species most commonly caught by villagers in the co-operative test fishing experiments

Species	Frequency	Cumulative frequency
Esomus metallicus	24.0	24.0
Anabas testudineus	7.7	31.7
Channa striata	6.0	37.8
Trichogaster trichopterus	4.9	42.6
Cyclocheilichthys repasson	4.0	46.6
Parambassis siamensis	3.4	50.0
Puntius brevis	2.5	52.4
Oreochromis niloticus	2.3	54.8
Clarias batrachus	2.2	57.0
Systomus aurotaeniatus	1.9	58.9
Macrognathus siamensis	1.7	60.6
Henicorhynchus cf siamensis	1.6	62.2
Thynnichthys thynnoides	1.5	63.7
Trichopsis schalleri	1.5	65.2
Mystus mysticetus	1.4	66.7
Systomus orphoides	1.4	68.1
Channa gachua	1.4	69.5
Rasbora borapetensis	1.4	70.8
Osteochilus lini	1.3	72.1
Sikukia gudgeri	1.3	73.4
Ompok bimaculatus	1.2	74.6

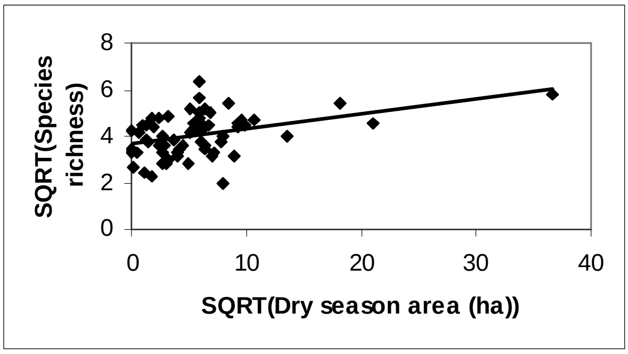


Figure 9. Relationship between fish species richness and total dry season water area.

There was no relationship between species richness and fishing pressure. There was also no relationship between species richness and a habitat diversity index calculated from the abundance of different habitat types.

4.2.5 Discussion

The survey has revealed an extremely high degree of participation in the exploitation of natural aquatic resources, and a significant average contribution to household income. Given the difficulty of assessing total household income in a situation where most income is likely to be in kind, the aquatic resources contribution of 21% is possibly an overestimate. However, a recent survey (Funge-Smith 1999) suggested an average net household income of US$ 416 for rural households in five Lao provinces. Even if expenditure on fishing gear is assumed to be 33% of the catch value, this leaves 60 US$/year as net value, equivalent to 15% of net household income. It is clear, therefore that aquatic resource use contributes significantly to household income in the project area. Although aquatic resource use in farming systems has not been assessed as comprehensively elsewhere in the Mekong region, studies in Northern Laos (Coates, pers. comm.), Northeast Thailand (Cowan 1995, Garaway 1995, Demaine et al. 1999) and Cambodia (Guttmann pers. comm.) similarly point to an important role of natural aquatic resources. Natural aquatic resources are used by all socio-economic groups, but are most important in relative and absolute terms to the poorer households.

The yield effort relationship derived for the study sites suggest that overall, the fishery is not overexploited or degraded. Moreover, the data are very similar to those obtained for other river-floodplain systems in the 1960s and 70s (analysed by Bayley 1988). Although total fishing effort may have increased over the past 20-30 years and catch rates may have declined slightly in response, the small-scale aquatic resources are productive and diverse.

4.3 Irrigation development impacts on aquatic resources

The impacts of irrigation development on local aquatic resources were measured in terms of abundance of aquatic habitats, fishing effort and catches, and species diversity.

4.3.1 Effects on abundance of aquatic habitats

Effects of irrigation development on aquatic habitat areas are summarised in Table 6.

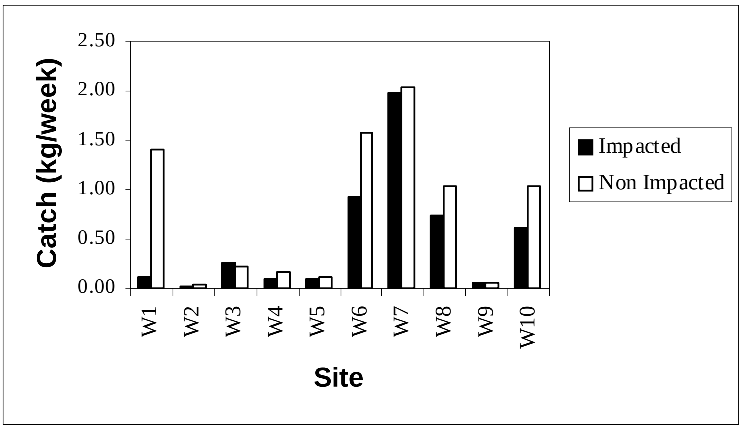
No significant effects were recorded for weir irrigation schemes. Dam schemes were associated with significantly higher lake areas, significantly lower wet season river areas, and significantly higher dry season paddy areas than the non-impacted controls. The difference in lake area is partly the result of creation of new lakes through the damming of small watersheds by irrigation canals, and partly an innate difference between the sites prior to irrigation development. Then negative effect on wet season river/stream area and positive effect on dry season paddy area are the inevitable result of dam construction. Note that reservoir areas have increased dramatically on averages, but the effect is not statistically significant because of the high degree of variation in area. Pump irrigation schemes were associated with a significantly higher pond area, probably the result of intentional construction of ponds along with irrigation structures. The significantly higher river/stream area in pump impacted sites is likely to reflect an innate difference prior to irrigation development.

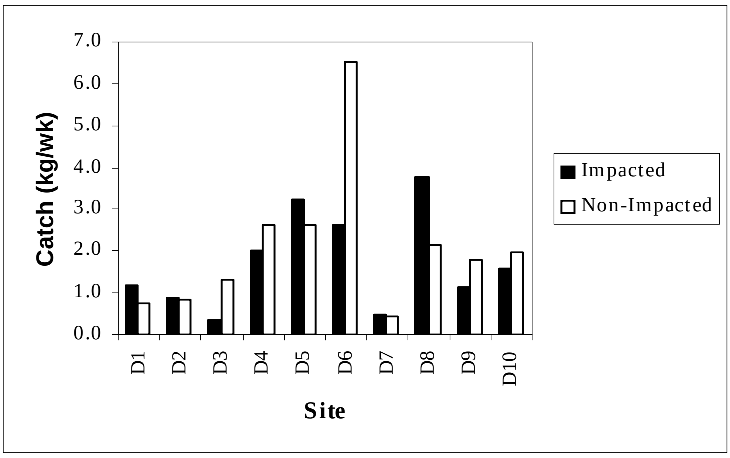
Table 6. Effects of irrigation schemes on aquatic habitat areas (paired comparisons). Significant effects (P<0.1) shown in bold. Effects are based on paired comparisons.

	Lakes		Ponds		Reservoirs		Rivers		Paddies	
	NI	**Effect**	**NI**	**Effect**	**NI**	**Effect**	**NI**	**Effect**	**NI**	**Effect**
Weirs										
DS	7.07	-2.91 [-11.48, 5.67]	0.38	0.73 [-0.58, 2.04]	0	0	4.63	-1.65 [-4.90, 1.60]	13.5	5.8 [-9.1, 20.7]
WS	10.06	-4.87 [-16.63, 6.88]	0.58	0.12 [-0.42, 0.65]	0	0	9.25	-3.32 [-9.78, 3.13]	59.6	-12.3 [-31.5, 6.90]
Dams										
DS	1.98	**18.34 [0.90, 35.78]**	0.18	0.16 [-0.41, 0.72]	2.25	202.3 [-24.9 429.5]	15.7	-13.5 [-30.8, 3.9]	6.8	**47.1 [20.9, 73.2]**
WS	2.58	**27.37 [1.38 53.36**]	0.15	0.31 [-0.36, 0.98]	3.13	241.3 [-16.6, 499.1]	23.1	**-19.8 [-39.0, -0.6]**	124.1	2.3 [-60.0 64.4]
Pumps										
DS	3.30	-0.38 [-6.67, 5.92]	0.08	**0.37 [0.13, 0.61]**	0	0	5.16	**16.4 [6.4, 26.3]**	12.3	37.2 [-5.3, 79.7]
WS	6.58	2.90 [-11.24, 17.03]	0.15	**0.59 [0.24, 0.94]**	0	0	14.3	**22.5 [5.7, 39.2]**	77.9	32.5 [-0.2, 65.2]

4.3.2 Impacts on catches and fishing effort

Overall effects on household fishing effort, catch, catch per unit of effort (CPUE) and effort and catch per unit flooded area are shown in Table 7, and catch data by site are illustrated in Fig. 10. The values shown are averages of the two survey periods.





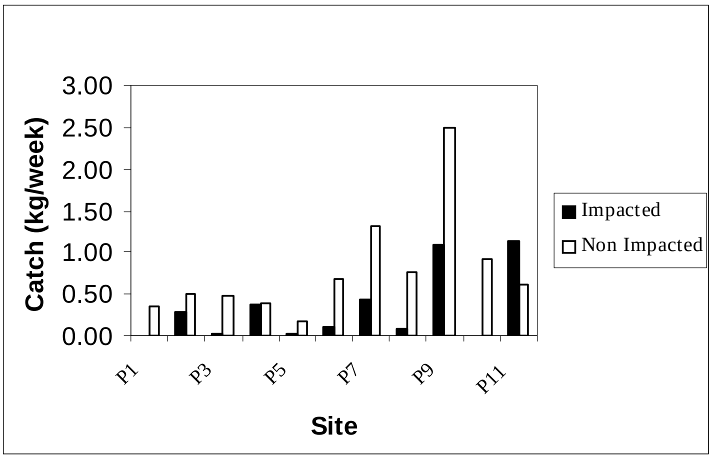


Figure 10. Average weekly catches in the paired weir (top), dam (middle) and pump irrigated (excluding major river) (bottom) sites.

Weir schemes were associated with a non-significant decline of 19 in household effort and a significant, 40% decline in catch. The overall effect on CPUE and catch per area was also negative, but not significantly so. Overall this indicates a negative effect of weir irrigation schemes on fish catches, partly but not fully explained by a decline in fishing effort. Declining fishing effort may in itself be the result of increased demand for labour in other activities (such as irrigated agriculture), and/or a reduction in the actual or perceived opportunity for fishing due to changes in fishable habitat. Quantitative results and villagers perceptions (see 4.6.1) suggest a combination of the two.

Dam schemes were associated with no significant changes overall, although a tendency towards reduced household effort and catch was noticeable. The lack of a significant overall effect does, however, hide very substantial changes that become apparent when the data are broken down into floodplain habitats and the newly created reservoirs. Dam schemes are associated with drastic declines of about 60% in floodplain effort and catch, on a household and unit area basis. These are partially compensated by increases in reservoir effort and catch, so that overall effects are not significant (but noticeably negative).

In order to understand the reasons behind the decline in floodplain fishing, it is instructive to analyse effects separately by season (Table 8). Note that in non-impacted sites, the dry season was characterised by high household effort (4.55 h/week) and moderate catch (1.11 kg/week), while in the wet season far lower effort (2.14 h/week) provides a higher catch (1.32 kg/week). Dam irrigation schemes led to very much reduced effort in both seasons (by 62 and 72% respectively). Catches were reduced by 43% and CPUE was maintained in the dry season, but there was a more pronounced reduction (-69%) in catches and a reduction in CPUE (-67%) in the wet season. (Both effects are strong but not statistically significant. Lack of significance is the results of very high variance caused by an impacted site where most fishing was carried out in a large, non-impacted river some distance from the village. Removal of this outlier results in highly significant effects on catch and CPUE). This indicates a partial loss of wet season fishing catches that is related to a reduction in availability, rather than purely a reduction of effort that may be related to higher demand on household labour from other sources.

Table 7. Effects of irrigation schemes on fishing effort, catches and catch per unit of effort (CPUE). Note that effects are based on paired comparisons, and the relative change from the non-impacted mean is indicative only. All values back-transformed from square-root scale. Significant effects (P<0.1) shown in bold.

	Household effort (h/week)		**Household catch (kg/week)**		**CPUE (kg/h)**		**Total effort/area (h/ha/week)**		**Total catch/area (kg/ha/week)**	
	NI	**Effect**	**NI**	**Effect**	**NI**	**Effect**	**NI**	**Effect**	**NI**	**Effect**
Weirs	4.06	-0.76 [-1.57, 0.15] -19% [-39%, 4%]	0.57	**-0.23 [-0.38, -0.03] -40% [-67%, -6%]**	0.13	-0.01 [-0.06, 0.06] -8% [-48%, 44%]	6.96	1.19 [-2.57, 6.10] 17% [-37%, 87%]	0.91	-0.13 [-0.67, 0.97] -15% [-83%, 107%]
Dams										
Overall	5.06	-1.10 [-2.26, 0.27] -22% [-45%, 5%]	1.82	-0.29 [-0.82, 0.34] -16% [-45%, 18%]	0.36	0.15 [-0.12, 0.52] 40% [-33%, 141%]	4.47	-0.46 [-1.78, 1.10] -11% [-40%, 25%]	1.60	0.01[-0.53, 0.65] 0% [-33%, 41%]
Floodplain	4.02	**-2.54 [-3.47, -1.17] -63% [-86%, -29%]**	1.52	**-0.87 [-1.37, -0.03] -57% [-90%, -2%]**	0.37	0.14 [-0.16, 0.57] 37% [-44%, 156%]	3.52	**-2.25 [-3.02, -1.13] -64% [-86%, -32%]**	1.32	**-0.74 [-1.17, -0.03] -56% [-89% -2%]**
Reservoir	0.39	0.71 [-0.24 2.53]	0.09	0.25 [-0.02, 0.69]	0.04	0.07 [-0.02, 0.24]	0.34	0.79 [-0.17 2.60]	0.08	0.29 [0.00, 0.79]
Pumps Irrig. area	0.56	-0.08 [-0.45, 0.56] -14% [-81%, 100%]	0.14	0.10 [-0.10, 0.48] 74% [-71%, 343%]	0.19	0.30 [-0.08, 0.95] 158% [-42%, 501%]	0.55	0.11 [-0.41, 1.02] 20% [-75%, 185%]	0.14	0.13 [-0.09, 0.52] 89% [-65%, 365%]

Table 8. Effects of dam irrigation schemes by season.

	Household effort (h/week)		Household catch (kg/week)		CPUE (kg/h)	
	NI	Effect	NI	Effect	NI	Effect
Dry season						
Overall	5.69	-2.05 [-3.83, 0.31] -36% [-67%, 5%]	1.43	-0.03 [-0.77, 0.99] -2% [-54%, 69%]	0.23	-0.21 [-0.05, 0.57] 91% [-19%, 251%]
Floodplain	4.55	**-2.81 [-4.14, -0.55]** **-62% [-91%, -12%]**	1.11	-0.51 [-1.01, 0.40] -46% [-91%, 36%]	0.21	0.16 [-0.1, 0.57] 74% [-48%, 268%]
Reservoir	0.16	0.24 [-0.28, 1.66]	0.06	0.18 [-0.05, 0.69]	0.18	(0.15)
Wet season						
Overall	2.64	0.23 [-0.87, 1.60] 9% [-33%, 61%]	1.5	-0.34 [-0.98, 0.54] -23% [-65%, 36%]	0.77	0.08 [-0.24, 0.47] 10% [-31%, 61%]
Floodplain	2.14	**-1.54 [-2.13, -0.08]** **-72% [-99%, -4%]**	1.32	-0.91 [-1.32, 0.14] -69% [-99%, 11%]	0.83	**0.45 [0.03, 0.96]** **54% [3%, 115%]**
Reservoir	0.16	0.81 [-0.06, 2.57]	0.06	**0.20 [0.01, 0.49]**	0.47	**-0.14 [-0.18, -0.10]**

Not surprisingly, dam irrigation schemes led to increased fishing effort in reservoirs. Somewhat unexpectedly, however, this effect was most pronounced in the wet season when reservoir catches were also significantly higher than in non-impacted sites. Overall, the importance of reservoirs was quite limited and in particular, there was no major thrust towards exploitation of these new dry season habitats.

No significant effects were recorded on fishing effort or catches in pump irrigated areas. Data from this study were particularly variable, probably reflecting the fact households carried out most of their fishing in the major rivers and only occasionally ventured into the other areas. As a result, this study must be regarded as inconclusive.

4.3.3 Impacts on diversity

The measured effects of irrigation schemes on fish species diversity are summarised in Table 9. No significant effects were measured, and it is very unlikely that effects of more than 30% have occurred.

Table 9. Impacts of irrigation schemes on fish species richness and diversity. None of the effects are significant.

	Species richness		Simpson diversity index		Simpson equitability ind.	
	NI	Effect	NI	Effect	NI	Effect
Weirs	12.91	-0.43 [-3.13, 2.60] -3% [-30%, 16%]	5.38	-0.22 [-1.58, 1.35] -4% [-36%, 20%]	0.44	-0.02 [-0.09, 0.06] -4% [-24%, 12%]
Dams	14.97	1.22 [-2.63, 5.60] 8% [-22%, 30%]	5.76	0.06 [-1.92, 2.46] 1% [-48%, 31%]	0.38	0.00 [-0.08, 0.10] 0% [-27%, 22%]
Pumps Irrig. Area	22.90	-2.88 [-6.47, 1.06] -13% [-30%, 4%]	8.00	-0.57 [-2.71, 1.94] -7% [-42% 20%]	0.36	0.02 [-0.07, 0.13] 7% [-23%, 29%]

These results indicate that individual, small to medium scale irrigation schemes do not have major impacts on local fish species diversity. It is not possible to say, however, to what extent the local diversity in irrigation schemes is maintained by immigration from surrounding non-impacted areas. If this was the case, expansion of small or medium irrigation schemes may eventually lead to an overall effect on diversity. This may be established by continued monitoring, for which the current survey provides a baseline.

4.3.4 Discussion

Small-to-medium irrigation schemes are associated with significant impacts on local aquatic resources and their use. These impacts are related to both, changes in resource availability and changes in the allocation of household labour between activities. Despite of these changes, however, natural aquatic resource use continues to make a substantial contribution to household incomes.

To obtain an indication of the average change in the gross value of household fish catches, the survey effect estimates were scaled up to annual catches and multiplied with a value of 1.5 US$/kg. The resulting changes are shown in Table 10. Overall, both weir and dam schemes are associated with a loss of about 20 US$ per household per year.

Table 10. Indicative estimate of reduction in the gross value of household fish catches due to weir and dam irrigation schemes. (Note that values are based catches back-transformed from the square-root scale, and therefore the floodplain and reservoir effects do not sum to the overall effect).

Irrigation scheme	Indicative change in value of annual household catch (US$)
Weirs	-18 [-30, -2]
Dams	
Overall	-23 [-64, 26]
Floodplain	-68 [-107, -2]
reservoir	20 [-2, 54]

The average loss 20 US$ per household per year is equivalent to the average increase in cash income associated with irrigation development (see 4.1.2). Positive effects on the rice index and levels of asset ownership suggest that the overall impact of irrigation development on household income exceeds the effect on cash income. This also suggests that on average, the change in fish catches does not negate the overall benefit of irrigation.

However, the indicative value of fisheries loss is clearly significant in relation to the levels of household benefits, and it is even more significant at the policy level when the full costs and benefits of irrigation schemes are considered (villagers do not bear the full costs associated with irrigation development). Hence it is important that fisheries impacts are considered in cost-benefit analyses of irrigation schemes.

Two areas, namely differential impacts in space (i.e. on villages near dams and those further downstream), and on different socio-economic groups require further investigation. In both cases, it is crucial to understand the relative contributions to the observed change in resource use of (1) changes in resource availability, and (2) re-allocation of household labour to other activities. The present study indicates that both are important, but does not allow a quantitative separation because the focus has been on aquatic resource use rather than overall household decision making. To clarify these issues, a follow-up project (see 5.4) will include a livelihood analysis of households in key project areas, ands an assessment of resource use impacts downstream of irrigation schemes.

The present study was designed to measure impacts of isolated, small-to-medium size irrigation schemes within rainfed areas. More pronounced impacts are likely to occur in larger schemes, and as a result of increasing density of small-to-medium schemes. It is important therefore that impacts are considered on a watershed scale as well as locally.

4.4 Aquaculture development impacts on aquatic resources

4.4.1 Contribution of aquaculture to overall aquatic resource use

Six per cent of households considered themselves fish farmers, cultivating ponds of an average area of 0.12ha. Overall, the measured catches from private fish ponds contributed 2% to total fish catches in the study area (Table 11). However, while natural aquatic resources are exploited more or less continuously throughout the year, harvesting of fish ponds is known to be centred around festivities and other occasions when a large amount of fish is required (Funge-Smith 1999). Hence the survey is likely to underestimate fishpond production. Pond production data from a recent FAO aquaculture survey (Funge-Smith 1999) has therefore been included for comparison. This figure is likely to provide the most realistic estimate, and puts the contribution of aquaculture at 10% overall. In any case, however, it is clear that the bulk of fish production is based on capture fisheries.

Table 11 Overview of aquatic resource use and the contributions of fisheries and aquaculture (Average wild catches calculated for all households, catches in participating households are slightly higher). The aquaculture survey estimate is based on an average production of 850 kg/ha/year (Funge-Smith 1999), and an average pond size of 0.12 ha.

	Non fish farmers	Fish farmers	Total
Households	5933 (94%)	391 (6%)	6324 (100%)
Participation in fishing	83%	60%	82%
Average wild catch (kg/hh/year)	60	60	60
Total wild catch (t/year)	356	23	379
Average catch from pond (kg/hh/year)			
Measured this survey	0	18	
Aquaculture survey estimate	0	102	
Total catch from pond (t/year)			
Measured this survey	0	7	7
Aquaculture survey estimate	0	40	40
Proportion of total catch from aquaculture			
Measured	0	23%	2%
Aquaculture survey estimate	0	63%	10%

4.4.2 Socio-economic correlates of aquaculture adoption

Comparing socio-economic indicators between adopters and non-adopters of aquaculture (Table 12), it is clear that adopters score much higher on virtually all indicators, with significant differences in rice index, cash income, shop and motorcycle ownership. Given the FAO estimate of productivity and our survey estimate of average pond size, adopters would on average gain 102 kg of fish, with a cash value of 153 US$ per year. However, given that most adopters farmed fish for their own consumption (only 8% sold any farmed fish), and that the average value of farmed fish is less than the difference in cash income between the groups, it is unlikely that the status differences are primarily the result of aquaculture adoption. Rather, it is likely that aquaculture is more readily adopted by households that are already better off.

Table 12. Average socio-economic indicators for non-fish fish farmers and fish farmers in villages with several fish farmers. Values in bold are significantly different between the groups.

	Non-fish farmers	Fish farmers
Household members	6.0	6.3
Rice index (see Table 1)	**0.21**	**0.30**
Cash income (US$/year)	**124**	**375**
No. of buffaloes	1.46	1.73
No. of cattle	1.96	3.52
Tractor ownership	9%	17%
Shop ownerships	**4%**	**8%**
Bicycles ownership	84%	100%
Motorcycle ownership	**16%**	**32%**

The distribution of average income in the adopting and non-adopting groups is shown in Fig. 11. Although households of above-average cash income are disproportionally represented among the fish farmers, adoption is not restricted to such households. However, only about 20% of adopters fall in the below-average income category. This also suggest that, while aquaculture may contribute 10% to household fish production (and consumption) overall, this share is much lower (about 2%) in households of below-average income.

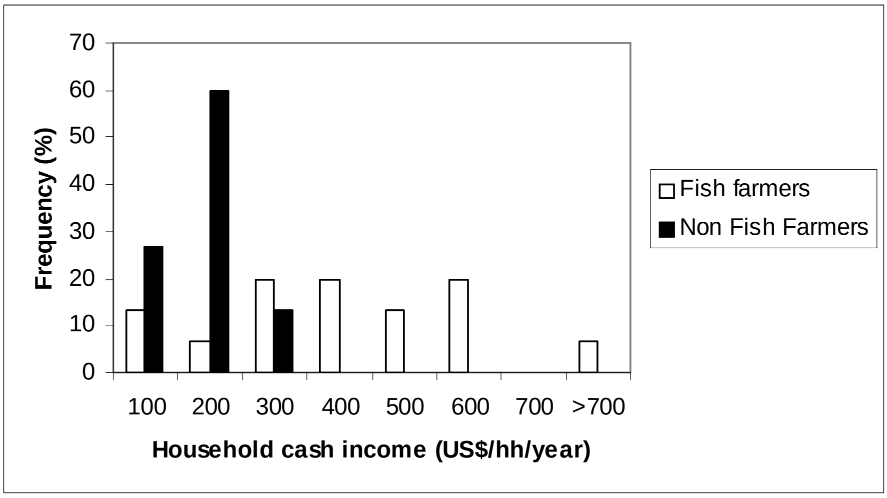


Figure 11. Distribution of average income of non-fish farmers and fish farmers.

4.4.3 Impacts on aquatic habitats

Aquaculture ponds currently account for 0.4% of wet, and 1.0% of dry season aquatic habitat. Hence at present, habitat modifications for aquaculture are insignificant. This may change in the future should aquaculture adoption increase significantly. As an extreme example, if all households were to set aside 0.1 ha for a fish pond (or one in ten households converted their paddy holding into 1 ha of fishponds), aquaculture ponds would account for 7% of wet, and 20% of dry season habitat.

Access restrictions to paddies and waterbodies within them are likely to accompany aquaculture development, but this is unlikely to restrict natural aquatic resource use significantly. While paddy areas play an important role in the overall aquatic productivity of floodplain systems, their importance as fishing grounds is relatively limited (4.2.1).

4.4.4 Diversity of wild stocks in aquaculture ponds

Private aquaculture ponds were sampled separately from open waters in 38 villages to establish their role as habitats for wild fish, and the contribution of wild fish to catches from aquaculture ponds. The number of species recovered from aquaculture ponds ranged from 0 to 16, with an average of 2.5. This relatively low average diversity must be seen in relation to the very small area of aquaculture ponds.

The fish species recovered and their frequency of occurrence are summarised in Table 12. A total of 40 species were recovered from aquaculture ponds. The stocked Nile tilapia (*O. niloticus*), common carp (*C. carpio*) and silver barb (*B. gonionotus*) are clearly the most common species, but 18 wild species occur in between 5 and 11% of ponds, and further 19 occur occasionally.

This suggests that aquaculture ponds provide habitat for a wide range of wild species, and that wild fish in aquaculture ponds contribute to household nutrition. However, given the low overall contributions of aquaculture to aquatic habitats and fish consumption, both effects are fairly insignificant at present.

Table 12. Fish species caught in private fishponds and frequency of occurrence. Stocked species are underlined.

Species	Frequency of occurrence (%)
Oreochromis niloticus	34
Cyprinus carpio	24
Barbodes gonionotus (stocked/wild)	21
Anabas testudineus	11
Esomus metallicus	11
Puntius brevis	8
Channa striata	8
Mystus mysticetus	8
Cirrhinus sp (stocked/wild)	8
Hypophthalmichthys molitrix	8
Thynnichthys thynnoides	5
Parambassis siamensis	5
Clarias macrocephalus	5
Osteochilus lini	5
Osteochilus cf hasselti	5
Cyclocheilichthys apogon	5
Clarias batrachus	5
Scaphognathops bandanensis	5
Oxygaster pointoni	5
Parachela siamensis	5
Mystus cf atrifasciatus	5
Cyclocheilichthys cf enoplos	3
Cyclocheilichthys sp	3
Pristolepis fasciatus	3
Macrognathus siamensis	3
Mystacoleucus marginatus	3
Cyclocheilichthys repasson	3
Labiobarbus leptocheilus	3
Henicorhynchus cf siamensis	3
Systomus orphoides	3
Ompok bimaculatus	3
Mystus rhegma	3
Xenentodon cancila	3
Rasbora retrodorsalis	3
Rasbora paviei	3
Rasbora myersi	3
Pseudomystus siamensis	3
Poropuntius deauratus	3
Oxyeleotris marmorata	3
Osteochilus melanopleurus	3

4.4.5 Impacts on wild fish catches and effort

The effects of aquaculture adoption on household fishing are summarised in Table 13. Adopting households reduce total (pond and open water) fishing effort significantly by about 31%, and increase total catch slightly by 17%, leading to a large effective increase of CPUE by 105%. Hence adopters gain primarily in labour use efficiency rather than total quantity of fish produced (and consumed).

Adopters reduce fishing effort in open waters significantly by 36%, while maintaining catches almost unchanged and again gaining in labour efficiency. This suggests that adopters become more selective in their open water fishing, concentrating on activities that provide good returns to labour and harvesting from their pond at other times. Overall, however, adopters do not significantly reduce their harvest of wild fish.

Table 13. Impacts of aquaculture adoption on fishing effort, catch and catch per unit of effort (CPUE). Note that effects are based on paired comparisons, and the relative change from the non-impacted mean is indicative only. All values back-transformed from square-root scale. Significant effects (P<0.1) shown in bold.

	Household effort (h/week)		**Household catch (kg/week)**		**CPUE (kg/h)**	
	NFF	**Effect**	**NFF**	**Effect**	**NFF**	**Effect**
Total (incl. pond)	3.85	**-1.19 [-1.98, -0.26]** **-31% [-51%, -7%]**	1.31	0.22 [-0.30, 0.85] 17% [-23%, 65%]	0.36	**0.38 [0.02, 0.86]** **105% [6%, 236%]**
Open waters	3.85	**-1.39 [-2.18, -0.45]** **-36% [-57%, -12%]**	1.31	-0.03 [-0.51, 0.56] -2% [-39%, 43%]	0.36	0.64 [-0.15, 2.03] 176% [-42%, 557%]

It is concluded that aquaculture development has no significant effect on the harvest of wild fish, and that even the expected expansion of aquaculture is unlikely to have such an effect. It is worth noting here again that 80% of aquaculture adopters had an above average household cash income, a further indication that harvesting wild fish remains important even to the high income group.

4.4.6 Impacts of feral tilapia populations on diversity

Impacts of feral tilapia populations on wild fish species richness have been assessed in a test fishing experiment comparing small water bodies where tilapias have been intentionally introduced, and local controls where tilapias were absent. Results of the paired comparison are shown in Table 13. There is no significant effect of on species richness, and a reduction by more than 10 is unlikely.

Table 14. Impact of feral tilapia populations on species richness of wild fish stocks.

	Species richness	
	NI	**Effect**
Tilapia stocked (19 paired waterbodies)	2.9	2.0 [-0.3, 7.1] 71% [-10%, 245%]
Tilapia present in test fishing catch (6 paired water bodies)	4.7	4.1 [9.9, -0.3] 87% [-6%, 210%]

Although the possibility of more long-term and subtle effects can not be excluded, the evidence suggests that the establishment of feral tilapia populations is not a major concern for fish biodiversity.

4.4.7 Discussion

Aquaculture adoption was estimated at 6% of households and has occurred at all levels of income, although households of below-average income account for only 20% of adopters. Aquaculture is estimated to contribute 7% overall to aquatic resource production in the project area, but less than 2% to production (and consumption) by households of below-average income. Hence rural households in general, and the poor in particular still rely overwhelmingly on natural aquatic resources.

Aquaculture is unlikely to impact significantly on natural aquatic resources and their use. Ponds are created largely in addition to existing aquatic habitat, and offer new habitat for a range of wild species. Wherever possible, the integration of indigenous species into aquaculture systems should be promoted, this is already being recognised in Laos and elsewhere. Survey results indicate that the establishment of feral populations of the Nile tilapia are unlikely to have major impacts on the species richness of resident fish populations.

4.5. Institutional arrangements

4.5.1 Institutional arrangements for aquatic resources management

Institutional arrangements for aquatic resources management in Laos have been studied in detail by Garaway (1999), and only brief overview is given here.

Formal responsibility for aquatic resources management in Laos rests with the Livestock and Fisheries Department under the Ministry of Agriculture and Forestry. (The situation is somewhat unclear for protected areas, for which the Department of Forestry has overall responsibility).

In practice there is little active management of natural aquatic resources by the Department of Livestock and Fisheries. Although there are regulations, for example banning the use of destructive fishing gear and the capture of fish during the spawning season, these can not realistically be enforced by the government. This should not be taken to imply that destructive fishing is rampant. Rather, fishing is often regulated by local customary rules.

Most active management of natural aquatic resources is carried out by communities. The right of communities to manage these resources is recognised by the government, and community management initiatives are encouraged and supported. However, as a result of the difficulties in sustaining such initiatives when several villages are involved, active management is largely restricted to small areas and individual water bodies.

While community management initiatives can be highly effective in regulating aquatic resource use locally, they are less effective in dealing with pressures on resources that arise outside the local area, such as cumulative effects of irrigation development. This is an important role for the government, which at present receives little attention.

Involvement of the Livestock and Fisheries Department in aquatic resources management is primarily focused on aquaculture and culture-enhanced fisheries. Natural aquatic resource issues are becoming increasingly integrated with aquaculture development. This is evident in tendencies such as the development of native species for aquaculture, or the development of rice-fish culture technology with explicit consideration of wild as well as cultured stocks.

4.5.2 Irrigation planning

Irrigation planning is the responsibility of the Department of Irrigation and Micro-Hydropower in Laos. Decisions regarding small and medium irrigation schemes are made mostly at provincial level. Provinces in Lao PDR have a relatively high degree of autonomy and may differ in their approaches to irrigation planning as well as the types of irrigation schemes promoted.

An exploratory survey in 17 of the study villages showed that in the majority (70%) of cases, the idea to develop an irrigation scheme had originated from government, in 18% of cases from the village and in the remaining 12%, it was a combination of the two. Government promotion of irrigation was most commonly at Provincial level, the national government were also involved in some cases. In cases where the scheme involved more than one village (mainly the dam schemes in Savannakhet province), the role of government was greatest, with none of the requests being village-only initiated and only 16% mixed government/village involvement. Comparing the Provinces, in all cases government initiation was the most common, ranging from 67% (Savannakhet) to 75% (Khammouane).

Government played the most significant role not only in initiating irrigation schemes, but also in the consequent feasibility studies and planning. In most cases, villagers had a very minimal role in that they were informed that the survey was to take place and consequently informed of the results of that in terms of the type and scale of irrigation system they could expect. Surveys were carried out either by the provincial Irrigation Department staff, or by staff from the Ministry in Vientiane. In some cases, however, villagers were more actively consulted (as opposed to being informed) at the planning stage. In all three cases of more active village involvement, the irrigation scheme was for one village only.

In no cases were villagers asked about local fishery resources and fishing practices. There was also no evidence that this issue was taken into consideration in the surveys designed by the government irrigation department. No villagers were aware of any questions on the surveys about fishery resources or fishing practices and neither were they aware of these issues being discussed in any other way.

In conclusion, local involvement at the planning stage is minimal, though perhaps more active in cases where only one village is involved. Local people's knowledge of fishery resources is not utilised when planning irrigation schemes, and the potential impact of irrigation schemes on fishery resources does not appear to be a major concern of irrigation department staff.

4.5.3 Financing of irrigation schemes.

In every village studied, the government paid for all materials and equipment required to build the larger irrigation canals, to provide pumps or to build weirs/damns. In the majority of cases villages did not have to pay this back. In 4 villages (24% of whole sample), the capital had been provided as a low interest loan. This applied mostly to the relatively new (post 1994) pump schemes in Khammouane.

Whilst government generally provided the capital (or loan), in most cases villagers provided the vast majority of the required labour. In all cases all tertiary canals were built by the villagers themselves. A variety of arrangements existed for maintenance. The majority of villages (60%) did not have to pay for the use of water and/or electricity. However, in all of the recently developed pump schemes villagers had to pay for the use of resources. Where individual households did pay a fee for electricity, this was usually based on a proportional-to-size-of-irrigated-area basis.

In summary, community financial and labour involvement in irrigation schemes is greater than their involvement in planning and initial decision-making. There was some evidence to suggest that this was likely to increase, with newer irrigation schemes having more financial commitment attached to them than older ones.

4.5.4 Water management

The presence of water-user groups and their precise method of operation varied between irrigation schemes. Formal water user-groups were present in 70% of cases, and, the vast majority had had training and/or advice from government on water user group formation and water-control administration. In only one case was the formation of distinct groups initiated by the village itself. Whilst water-user groups and water control was acknowledged to exist in all cases, in many, the rules to be followed were not particularly clear to the informants. This suggests possibly that the rules did not always function well, if at all, or that other more informal mechanisms might be in place to regulate use.

In cases where more than one village was involved, who water flow was controlled by varied. There was only one instance where there was a formally recognised supra-village organisation made up of village administration members from user villages. In other instances, government staff were involved in controlling the flow into the main canals and in other cases it appeared to be the responsibility of the village who received the water first. As with water use by individual households, the precise details of rules in use to govern total supply and its allocation were, in the majority of cases, vague.

Conflict resolution again this was in the hands of the village administration where only one village was involved. The situation for inter-village conflict was less clear. Again, there were no recognised supra-village groups set up specifically for this purpose and it appeared conflict had to be dealt with by the government irrigation department, at district level. Such staff did not necessarily have the capacity to resolve such conflicts.

4.5.5 Discussion

Aquatic resource management, as well as water management at the local level are effectively under village control. The sustainability of institutions regulating these activities varies from case to case (Garaway 1999, 2000). However, the presence of sustainable and effective institutions at this level in many cases is encouraging. Given the high degree of participation in aquatic resource use, irrigation water users are likely to be aquatic resource users as well. All of these factors indicate a good potential to integrate aquatic resource and irrigation management at the village level. The tendency in new irrigation schemes to recoup a large share of construction and operating costs from beneficiaries is likely to force villagers to consider overall costs and benefits of irrigation, including aquatic resources impacts, more fully than is presently the case.

The planning and implementation of irrigation schemes, on the other hand, is driven largely by the provincial (and to a lesser extent, national) Irrigation Section or Department, albeit in partial consultation with villagers. Planning at this level appears to be relatively insensitive to aquatic resources issues. This is likely to be the result of lack of appreciation of aquatic resources and their importance to livelihoods, as well as lack of knowledge on irrigation impacts and possible mitigation measures. To develop such knowledge and incorporate it into the planning process is an important task for the Livestock and Fisheries Department.

To be effective at catchment level, aquatic resources management requires effective co-management with sharing of information and responsibility between government and village institutions. Previous DFID-funded work on river fisheries (Hoggarth et al. 1999) current collaborative work by the project team on adaptive co-management of small water body fisheries in Laos provide a conceptual framework and starting point for the development of such institutions.

4.6. Perceptions and policy issues at village and government level

4.6.1 Villager's perceptions of irrigation impacts

During an exploratory survey, villagers were asked two separate questions on irrigation impacts. Firstly they were asked how they perceived the overall abundance of aquatic resources had changed since the irrigation scheme had been initiated, and secondly what did they attribute these changes to.

In weir sites (Champassak Province), most informants thought that fish populations had decreased since weirs had been built or improved. In contrast, most village informants in dam sited believed that fish populations had increased since the damns had been built. In pump sites, informants could not say what the impact had been on fish populations, possible because the schemes had only been constructed recently.

Where fish abundance was perceived to have decreased (mainly weir sites), only one directly attributed the change to irrigation. This was in Champassak where the lowering of the water level, on account of irrigation, was perceived to have made fish easier to catch, effectively increasing fishing pressure. A further 5 cases attributed the decrease to increased fishing pressure as a result of increased human populations. A further village thought it was due to deterioration in water quality (due to a hydro-electric power scheme upstream). This was the only village that had perceived a change in water quality in general. Finally one village did not know why fish populations had decreased but did not believe that the reason was connected to irrigation.

Where abundance was perceived to have increased (dams in Savannakhet only), 80% believed it was due to increased water resources as a result of the impoundment and 20% that it was due to a general decrease in fishing effort. This decrease in effort was not directly, or even indirectly, attributed to the irrigation system.

In summary then, in only one case were *negative* effects on fish populations perceived to be related to irrigation development whilst the majority of perceived *positive* effects were attributed to irrigation.

4.6.2 Perceptions of impacts and responses to project results at government level

Government staff at provincial and national level found it difficult to gauge the overall effects of irrigation development on aquatic resources. However, they pinpointed a range of possible positive and negative effects.

Positive effects:

- Increased availability of water in dry season. Before irrigation, fishing used to be limited during the dry season. Under irrigation, more places are available to fish around the year.
- Creation of new fish habitats, e.g. reservoirs and the irrigation canals.

Negative impacts:

- Reduced fish catches have been reported, mainly from villages below the irrigation scheme or further downstream.

- Decreasing water availability downstream, some waterbodies drying up, and villagesr have to travel longer distances to fish.
- New restrictions in the use of waterbodies are implemented
- Dams and weirs are obstacles to fish migration. (This constraint is particularly important during the breeding season.)
- Reduced availability of natural fish habitats

4.6.3 Recommendations from government workshops

The following technical measures were proposed to mitigate negative impacts of irrigation development:

- Fishing restrictions: gear, temporal and spatial restrictions such as minimum mesh sizes, reserves, community fisheries with fishing days
- Aquaculture development. Aquaculture development can complement irrigation for several reasons. Pond construction can be integrated with the construction of irrigation canals, and irrigation water can be used for fish ponds in the dry season.
- Fish stocking in lakes, reservoirs and irrigation canals. (Interactions with wild fish should be considered, and indigenous species are preferred for stocking).
- Technical aids to fish migration: fish ladder, outlet, inlet

The workshops recognised the need to integrate aquatic resources considerations into irrigation policy, planning and management:

- Close co-operation between Irrigation and Livestock & Fisheries Sections/Departments during the whole process of the irrigation planning to integrate fisheries impact assessment into the process. Requires regular meetings and workshops between both sections and departments and increased technical cooperation
- Organise both water use and fishing activity after the implementation of the irrigation scheme. Integration of aquatic resources management in water users groups.
- Increase awareness of aquatic resource conservation needs in order to maintain fish populations and diversity for a long-term use of aquatic resources.

As priority areas for action were identified:

- Development of a manual to identify specific impacts on aquatic resources before implementing irrigation schemes
- Integration of comments and suggestions from all involved organisations,
- Provide a suitable design criteria to prevent or minimise any negative impacts,
- Investigate ways of mitigate negative impacts of existing irrigation schemes.
- Consider fisheries and other activities in the allocation of water rights.
- Provide standards on quantity and quality in water distribution.

The Lao government is in the process of drafting new water rights and irrigation legislation, and the participants considered that these issues should incorporated.

4.6.4 Discussion

Villagers perceptions of irrigation impacts were fairly inconclusive. Although villagers identify key factors impacting on aquatic resources such as changes in water availabilty and fishing effort, they were unable to gauge the overall effects. This is not surprising given that the net impacts detected in this study are moderate (with a maximum of –40% in the case of weirs), and related to changes in labour allocation as well as availability of resources. Moreover, inter-annual variation and confounding factors make it difficult to detect impacts of this magnitude in a single site. Hence comparative studies such as the one reported here are important to provide information for decision making even at village level.

Survey results, which have been made available at every level of government (district, provincial and national), have increased awareness of small-scale aquatic resources, and the impacts of irrigation development. There is clearly a willingness to address aquatic resources issues in irrigation policy and planning, and the current drafting of new legislation provides a good opportunity to formalise requirements to consider these issues. The assessment methods practised and results established in the present project provide a good basis for locally appropriate guidelines on assessment. However, much of the technical information required for impact mitigation and watershed-level planning will only become available as a result if longer-term monitoring and experimental management. The Lao government’s capacity to carry out such tasks is currently very limited, and external support is likely to be required for the foreseeable future.

4.7 Conclusions and recommendations

4.7.1 Small-scale aquatic resource use

Participation in the use of local, small-scale aquatic resource use is almost universal in Southern Laos. On average, natural aquatic resource use contributes 90 US$/year (about 15-20%) to household income.

Data obtained in the present study suggest that overall, small-scale aquatic resources are productive and diverse, and not significantly degraded.

Recommendations:

- The importance of small-scale, natural aquatic resources to the rural population should be fully recognised in Southern Laos, the wider Mekong region, and elsewhere. Assessments of impacts on such resources should be carried out whenever development is likely to impact on.
- Aquatic resources in agricultural areas should not automatically be regarded as degraded or diminishing.
- Natural aquatic resources add considerable value to the use of water in agricultural areas, both rainfed and (to a lesser extent) irrigated. This value should be quantified and considered in water allocation decisions.

- The knowledge of small-scale natural aquatic resources, their conservation and enhancement is extremely limited in the tropics and should receive increased attention.
- Efforts and resources devoted to the conservation and enhancement of natural aquatic resource productivity should reflect the importance of these resources to rural population, and the poor in particular.

4.7.2 Impacts of irrigation development

Small-to-medium irrigation schemes are associated with significant impacts on local aquatic resources and their use. These impacts are related to both, changes in resource availability and changes in the allocation of household labour between activities. Despite of these changes, however, natural aquatic resource use continues to make a substantial contribution to household incomes.

The present study focused on impacts of isolated irrigation schemes and it must be born in mind that increasing density of small schemes may lead to cumulative and synergistic impacts.

Recommendations:

- Individual small and medium scale irrigation schemes have significant (but not severely destructive) impacts on local aquatic resources. Such impacts should be considered in cost-benefit analyses and environmental impact assessments.
- Adequate guidelines and tools for the assessment of irrigation development impacts on aquatic resources should be developed and integrated into the commonly used EIA frameworks.
- The overall impacts of irrigation development on aquatic resources must be regarded as moderately negative. The creation of new aquatic habitats such as reservoirs provides partial compensation for the loss of natural floodplain habitat, but does not add to overall habitat or resource productivity.
- Even within irrigation systems, natural aquatic resources can continue to play an important role in rural livelihoods, maintain much of their diversity, and add considerable value to irrigation water. This potential should be realised, and the conservation of these resources in the face of increasing competition for water and further agricultural intensification should be a high priority.
- Impacts on small-scale aquatic resources at the supra-scheme (catchment) level should be monitored and considered in water resources planning.

4.7.3 Impacts of aquaculture development and opportunities for integration

The role of aquaculture in aquatic resource use at the village level is still relatively limited, with a total contribution to fish production estimated at of 2-10%, and only 20% of this in households of below-average income. Hence rural households in general, and the poor in particular rely overwhelmingly on natural aquatic resources for their fish (and probably total animal) protein. However, aquaculture provides opportunities for households in all socio-economic groups, and is likely to expand significantly.

Aquaculture does not pose a significant risk to the diversity or productivity of natural aquatic resources in Southern Laos, and is unlikely to pose such a risk even after significant expansion.

Recommendations:

- Aquaculture promotion and the conservation of aquatic resources are commonly carried out by the same institutions. Opportunities for linkages and integration between the two forms of aquatic resource use should be fostered.
- The overall balance of policy, planning and research investment in the two areas should reflect their true importance to the economy.
- The expansion of inland aquaculture in the Mekong region should not be regarded as a threat to natural aquatic resources.

4.7.4 Conservation and enhancement of small-scale aquatic resources in the face of increasing pressures

Small-scale aquatic resources in Southern Laos are presently productive and diverse. Isolated irrigation development has led to moderate local reductions in productivity, but does not appear to have reduced diversity. It is likely that small-scale aquatic resources are in a similar state in other areas of the Mekong basin. However, pressures of development are increasing in the form of more and possibly larger-scale irrigation schemes, and agricultural intensification within the schemes. At present, the conservation of small-scale resources in the face of these pressures constrained by adequate institutional arrangements and relevant technical knowledge.

Recommendations:

- The value of natural aquatic resource productivity should be estimated and considered when assessing the value of water use, both within and outside irrigation schemes.
- There is an urgent need for the relevant government agencies to support active management and conservation of small-scale aquatic resources at the catchment level. This should integrated closely with village-level management.
- Closer co-operation and institutional linkages between irrigation, fisheries, and agriculture professional is required at the research, planning, administration and operational level.
- The knowledge of small-scale aquatic resources management and conservation is extremely limited, and environmental management-oriented research on these systems is urgently required. There is great potential for relevant management experiments to be integrated into development efforts.

5 Contribution of outputs

5.1 Contribution to DFID's developmental goals

DFID's developmental goal is the elimination of poverty in poorer countries through: policies and actions which promote sustainable development; better education, health and opportunities for poor people; and protection and better management of the natural and physical environment.

The present project contributes to these goals in several ways:

- The contribution of small-scale aquatic resource use to the livelihoods of rural people, in particular the poor, in Southern Laos has been quantified. Because of its diffuse, subsistence-oriented and inconspicuous nature this contribution has often been underestimated and undervalued, and neglected in development decision making.
- The study shows that sensitive wetland habitats support productive and diverse resources of considerable use value to the local population, and identifies policy and planning requirements for their conservation.
- The impacts of irrigation development on the use, abundance and diversity of small-scale aquatic resources has been quantified for the first time. This provides a solid basis for incorporating aquatic resources considerations into cost-benefit analyses and environmental assessments of irrigation development options.
- The project has resulted in substantial capacity building within the partner institution, the Lao Department of Livestock and Fisheries.

5.2 Identified promotion pathways

The study was designed as a short (18 months) project based entirely around a large-scale field survey implemented in partnership with Lao Livestock and Fisheries Department. As a consequence, key results have only become available at the very end of the project and have not been formally published yet. However, in the process of the project results have been promoted and taken up at all levels of the partner institution.

5.2.1 Publications

Two publications are in preparation, to be submitted in July 2000:

Nguyen Khoa, S., Lorenzen, K., Garaway, C., Chamsingh, B. & Siebert, D. (in prep). Small-scale aquatic resource use in the lowland regions of southern Laos. To be submitted to Fisheries Research.

Nguyen Khoa, S., Lorenzen, K., Garaway, C., Chamsingh, B. & Siebert, D. (in prep). Impacts of irrigation development on small-scale fisheries in Laos. To be submitted to Fisheries Research.

5.2.2 Internal reports

Lorenzen, K., Nguyen Khoa, S., Garaway, C.J., Kirkwood, G.P., Chamsingh, B., Litdamlong, D., Siebert, D. & Innes-Taylor, N. (1999) Impacts of irrigation and aquaculture development on small-scale aquatic resources. Interim report to DFID.

Garaway, C.J. (2000) Exploratory studies on village involvement in irrigation planning and villagers' perceptions of irrigation impacts. 15 pp.

5.2.3 Presentations at conferences and workshops

Presentation of results at the final project workshop, Lao Aquatic Resources Research Institute. Attended by representatives of the Lao Ministry of Agriculture-Forestry (Livestock & Fisheries, Policy & Planning and Irrigation Departments), Science Technology and Environment Organisation, Mekong River Commission (Basinwide Fisheries Project), FAO (Aquaculture Development Officer). Vientiane, 19 May 2000.

Poster at the electronic conference on aquatic resources and poor people, DFID Southeast Asia Division. June 2000.

5.2.4 Workshops and training courses organised

Site Selection Workshop, 30/9-1/10 1998, Savannakhet. Attended by district and provincial staff from Savannakhet, Khammouane and Champassak provinces (16 participants). Preliminary selection of the project sites

Site Survey Training Workshops (3): Savannakhet 9-13/11/98, Champassak 23-27/11/98, Khammuane 07-11/12/98. Training of district and provincial staff to site survey and interview methods, including field practice.

Site Survey Results Workshop, 02-04/2/ 1999, Savannakhet. Attended by district and provincial staff from the 3 Provinces (25 participants). Survey results presented by surveyors and coordinators, comments and discussion on survey, review of the data collected.

Household Fishing Survey Training Workshop, 23-27/3 1999, Khammuane. Attended by district and provincial staff from the 3 Provinces (25 participants). Trained district and provincial staff on methods of household survey, including field practice.

Household Survey Results Workshop, 2nd week of May 1999, Khammuane. Attended by district and provincial staff from the 3 Provinces (25 participants). Survey presented by surveyors and coordinators, review of data and discussion.

Biodiversity Survey Training Workshop, 14-17 June 1999, Champassak. Attended by district and provincial staff from the 3 Provinces (25 participants). Training of staff in the methods of participatory test fishing and fish preservation, including field practice.

Biodiverstity Survey Results Workshop, 3rd week of September 1999. Champassak. Attended by district and provincial staff from the 3 Provinces (25 participants). Survey presented by surveyors and coordinators, discussion of experiences and results.

Household and Biodiversity Survey Training Workshop, 12-15/10 1999, Khammuane. Attended by district and provincial staff from the 3 Provinces (25 participants). Remind staff of survey methods and focus attention on second round of surveys.

Final Workshop on Project Results, District Level, 15 May 2000, Savannakhet. Attended by project surveyors and coordinators (25 participants). Review of data, discussion of results.

Final Workshop on Project Results, Provincial Level, 16 May 2000, Savannakhet. Attended by representatives of Agriculture Division, Irrigation Section, L&F Section, Cooperation and Planning Section, Project coordinators (15 participants). Discussion of project results and implications.

Final Workshop on Project Results, National Level. 19 May 2000. Vientiane. Attended by representatives of Livestock and &Fisheries Department, Irrigation Department, Cooperation and Planning Department, Lao Aquatic Resources Research Center, Science Technology and Environment Organisation, Mekong River Commission, FAO (20 participants). Presentation of project results, group and plenary discussions on policy implications.

Training in fish identification and maintenance of a reference collection. Natural History Museum, London, 24/2 to 10/3 2000. Attended by Mr Pansi Homekingkeo & Mr Khunboulum Vonghachak.

5.3 Uptake of project results

Results on irrigation impacts have been taken up by the Lao government, and it is anticipated that the need for fisheries impact assessments will be incorporated into new water resources and irrigation legislation being drafted over the next couple of years. The follow-up project (see below) will assist this process further.

5.4 Follow-up necessary to achieve developmental benefits

Results of the present study provide a solid basis for the fisheries impact assessment of small and medium size irrigation schemes. Two key issues should be addressed to achieve full development impact:

(1) The knowledge gained from this study on small-scale irrigation impacts, and from other studies (e.g. FAP 17 1995, Halls et al 1998) on large flood control and irrigation systems must be incorporated into irrigation policy, planning, and management. This will require improved linkages between aquatic resources,

irrigation, and agricultural institutions, and would be facilitated by improved guidelines for the consideration of aquatic resources impacts in irrigation development.

(2) Technical knowledge on the mitigation of aquatic resources impacts of irrigation development in the tropics is extremely limited. Research in this area is urgently required.

A project focusing on issue (1) has already been approved by the DFID KaR (Water for Sustainable Food Production) Programme. The project will build upon and disseminate results of the present project. Guidelines for impact assessment and planning will be drafted and field-tested Laos and one location in South Asia before being finalised in a workshop with a range of relevant organisations. Guidelines for the integration of aquatic resources issues into irrigation planning and management will be disseminated through a wide range of channels including IWMI, FAO, the World Bank Participatory Irrigation Management Initiative, the Global Water Partnership and the new regional DFID Aquatic Resources Management Programme in SE Asia. The integration of these guidelines with existing frameworks for impact assessment, participatory management etc. will be promoted.

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Appendix 1: Sites selected for the impact surveys

Code	Province	District	Impacted site	Scheme	Impact type	Completed	Command area	Control site	Impact type
D1	Savannakhet	Khantabouly	Bungva Tai	Bungva	Dam	1987	100	Gnangsoung	None
D2	Savannakhet	Khantabouly	Phonsim Tai	Nongtao	Dam	1987	20	Huay	None
D3	Savannakhet	Champhone	Nanokyang	Bak2	Dam	1996	515	Thouat Nua	None
D4	Savannakhet	Champhone	Laonat	Huay Makmi	Dam	1997	50	Huay Namsang	None
D5	Savannakhet	Champhone	Kok Lo	Huay Chiao	Dam	1997	250	Mouangkhai Tok	None
D6	Savannakhet	Songkhone	Dongsavang Thong	Huay Sala	Dam	1992	320	Donyanong	None
D7	Savannakhet	Xaypouthong	Phontham	Kouttapor	Dam	1987	40	Phonsomhong	None
D8	Savannakhet	Phine	Palek		Dam			Nakayong	None
D9	Khammouane	Thakek	Pakpeng	Papkeng	Dam		20	Donthong	None
D10	Champasak	Pathoumphone	Palay Bok	Papoi	Dam		42	Chonghouay	None
W1	Champasak	Pakse	Thongbouxa	Konlay	Weir	1977	28	Bangyo	None
W2	Champasak	Pakse	Kang	HuayNgang	Weir	1962	87	Nachiang	None
W3	Champasak	Bachieng	Thongkim	Palay	Weir	1998	150	Makngeo	None
W4	Champasak	Bachieng	Thongphai	Tonghphai	Weir	1997	24	Nong Oudom	None
W5	Champasak	Bachieng	Chiangsai	Chiangsai	Weir	1993	17	Nikhomsai	None
W6	Champasak	Pathoumphone	Thongpha	Tongpha	Weir	1985	74	Laogna	None
W7	Champasak	Pathoumphone	Tomo Nok	Tomo	Weir	1983	513	Thahou	None
W8	Champasak	Sanasomboune	Xelabam	Kongthao	Weir	1997	280	Thongthing	None
W9	Savannakhet	Xaypouthong	Mouangkhai Tai	Namphou	Weir	1994	50	Sisavang	None
W10	Savannakhet	Champhone	Nongkhai	Huay Khai	Weir		45	Tankon	None
P1	Khammouane	Thakek	Jomgeing	Jomgeing	Pump	1992	82	Phonsae	None
P2	Khammouane	Thakek	Tham	Tham	Pump		260	Xiangven	None
P3	Khammouane	Thakek	Sykhot	Sykhot	Pump	1989	350	Nomgiang	None
P4	Khammouane	Hinboun	Dondou	Dondou	Pump	1996	150	Vanghouapa	None
P5	Khammouane	Hinboun	Hinkhan	Hinkhan	Pump	1996	78	Nongboua	None
P6	Khammouane	Hinboun	Poung Nua	Poung Nua	Pump	1996	50	Nanua	None
P7	Khammouane	Nongbok	Navang Gnai	Navang Gnai	Pump	1996	90	Nang	None
P8	Khammouane	Nongbok	Namanpa	Namanpa	Pump	1998	250	Dongkhouang	None
P9	Khammouane	Mahaxai	Mahaxai Tai	Mahaxai Tai	Pump	1997	49	Dang	None
P10	Khammouane	Mahaxai	Phova Tai	Phova Tai	Pump	1996	19	Kengsavan	None
P11	Khammouane	Khouaxe	Hathkamiang	Hathkamiang	Pump	1991	300	Naphok Kao	None