New Perspectives on the Impacts of Irrigation on Fisheries

With Emphasis on Rice-Based Farming Systems

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"Our greatest glory is not in never falling, but in rising every time we fall."

Confucius (551-479 BC)

Abstract

Irrigation development and inland fisheries are both important to the production of food, food security and rural livelihoods of many developing countries, particularly in areas with extensive rice-based farming systems. This research investigated the production and livelihood impacts of irrigation on fisheries. It then developed and tested an impact assessment approach that supports management and decision-making for irrigation development.

The review of literature identified the nature and magnitude of the impacts of irrigation on fisheries, and evaluated methods and approaches for the assessment of impact. A quantitative assessment was carried out in Laos through a replicated field survey for sites impacted by small to medium-scale dam and weir irrigation systems. Drawing from the review and the assessment results, an integrated, participatory and adaptive approach was proposed for impact assessment, and tested and evaluated in two country case studies in Laos and Sri Lanka.

The quantification of the impacts in Laos revealed that weirs had no significant impact on aquatic habitat but caused a significant decline in fish catch partly explained by a reduction in fishing effort. Dams significantly reduced riverine habitat and led to a redistribution of catch and fishing effort from non-reservoir habitats into reservoirs, but not to overall changes in catch or effort. The Laos and Sri Lanka test cases showed that the net impact of irrigation on fisheries production was neutral or positive in the project area, but disaggregation by location and socio-economic group revealed negative impacts.

The three case studies revealed mechanisms compensating for losses in production and these originated in the biophysical environment, the exploitation of aquatic resources, and/or in the role and importance of fisheries in rural livelihoods. This provided new perspectives on the impacts of irrigation on fisheries showing that impacts need not always be negative and, especially in rice farming systems, aquatic

ecosystems modified by irrigation can support productive fisheries. Correlatively, inland fisheries can play a significant role in rural livelihoods even in irrigated systems.

The adaptive, participatory and integrated assessment approach developed and tested, broadened the scope and coverage of the impact assessment while including the local knowledge and interests of stakeholders. By analyzing fisheries within the larger context of irrigated systems and the local economy, the approach revealed how improved solutions for management of water resources, fisheries and irrigated agriculture can be developed.

Thesis Contents

Acknowledgements 3

Abstract 5

Thesis Contents 7

List of Tables 14

List of Figures 17

List of Boxes 19

Chapter 1 - Introduction 21

1.1 Background 21

1.1.1 The importance of irrigation and inland fisheries 21

1.1.2 Potential impacts of irrigation on fisheries 26

1.1.3 Existing methods and approaches for impact assessment, and their limitations 29

1.2 Problem statement and outline of methodology 30

1.2.1 Research problem 1: Nature and magnitude of irrigation impacts on fisheries 31

1.2.2 Research problem 2: Improving methods for the assessment of the impacts of irrigation on fisheries 33

3. Thesis Outline 36

Chapter 2 - Nature and Magnitude of Impacts, and Underlying Mechanisms 40

2.1 Inland fisheries in non-irrigated systems 40

2.1.1 Fisheries in the biophysical environment 41

2.1.1.1 Physical characteristics of the catchment 41

2.1.1.2 Ecology of fisheries production 45

2.1.2 Exploitation of aquatic resources 50

2.1.3 Fisheries in the social environment 53

2.1.3.1 Institutions 53

2.1.3.2 Socio-economic environment and livelihoods 55
2.1.4 The fishery system 57
2.1.5 Conclusions on fisheries in natural systems 58
2.2 Fisheries in irrigated systems 60
2.2.1 Biophysical impacts 61
2.2.1.1 Physical damage to aquatic resources 61
2.2.1.2 Changes in the geomorphology, hydrology and land use 62
2.2.1.3 Changes of physical habitats, organic/inorganic inputs and water quality 66
2.2.1.4 Changes in the ecology of fisheries production 72
2.2.1.5 Conclusions on biophysical impacts 76
2.2.2 Impacts on the exploitation of aquatic resources 77
2.2.3 Social impacts 79
2.2.3.1 Impact on fisheries institutions 80
2.2.3.2 Socio-economic and livelihood impacts 82
2.2.4 Impacts on the whole fishery system 86
2.2.5 Conclusions on the impacts of irrigation on fisheries 87
2.3 Mitigation and enhancement of impacts 88
2.3.1 Mitigation and enhancement of biophysical impacts 89
2.3.2 Mitigation of socio-economic impacts 92
2.4 Critical conclusions: lessons for impact assessment 93

Chapter 3 - Quantitative Impact Assessment: a Case Study in Laos 95
3.1 Introduction 95
3.1.1 Irrigation schemes under study 95
3.1.2 Profile of the study area 96
3.2 Methodology 98
3.2.1 Site selection 98
3.2.2 Study Design 99
3.2.3 Survey Methods 100
3.2.4 Data Analysis 102

3.3 Impact Assessment Results 103
3.3.1 Sites characteristics 103
3.3.2 Aquatic habitat availability 104
3.3.3 Household catch and fishing effort 104
3.3.4 Fisheries in rural livelihoods 109
3.4 Discussion 111
3.4.1 Methodological Critique 111
3.4.2 A new light on the impacts of irrigation on fisheries 113
3.4.3 Lessons for impact assessment 119
3.5 Conclusions 123

Chapter 4 - Assessment of the Impacts of Irrigation on Fisheries 125
I. Review of existing methods and approaches for impact assessment 127
4.1 Process frameworks for impact assessment 129
4.1.1 Environmental Impact Assessment (EIA) 129
4.1.2 Social Impact Assessment (SIA) 134
4.2 Specialist impact assessments 135
4.2.1 Specialist biophysical assessments 135
4.2.2 Socio-economic assessments 139
4.2.3 Holistic assessments 144
4.3 Critical conclusions on existing impact assessments: strengths and limitations 146
4.3.1 Reductionist *vs.* holistic? 146
4.3.2 Participation of stakeholders 148
4.3.3 Feasibility in a context of limited data and resources 148
4.3.4 Inadequate support to the management and decision-making 149

II. An Approach for Impact Assessment: Adaptive, Participatory and Integrated Assessment (APIA) of the Impacts 151
4.1 Features of the approach 151
4.1.1 Holistic and integrated assessment 151
4.1.2 Participation by stakeholders 153

4.1.3 Adaptive Approach 160
4.1.4 A composite assessment 165
4.2 Stages of APIA 166
4.2.1 Preliminary assessment, screening and scoping 168
4.2.2 Assessment of Impacts 170
4.3 Conclusions 171
Chapter 5 - Testing and Evaluation in Lao PDR: Ex-Ante Impact Assessment 173
5.1 Methods and activities 173
5.1.1 Project selection 174
5.1.2 Data sources 174
5.1.3 Overview of activities 175
5.1.4 Stakeholder identification and analysis, and capacity building 177
5.1.5 Screening and Scoping 182
5.1.6 Assessment of impacts 184
5.2 Results 185
5.2.1 Background 185
5.2.2 Screening 186
5.2.3 Scoping 187
5.2.4 Assessment 189
5.2.4.1 Baseline Situation 189
5.2.4.2 Prediction of Huay Thouat project impacts 193
5.2.5 Opportunities for mitigation and enhancement 200
5.2.6 Summary and conclusions 202
5.3 Evaluation of the APIA approach 203
5.3.1 Operation 204
5.3.2 Performance 206
5.3.2.1 Features 206
5.3.2.2 Outputs 213
5.3.3 Impact 215
5.4 Conclusions 216

5.4.1 The impacts of irrigation on fisheries 217
5.4.2 The APIA approach 218
Appendix 219

Chapter 6 - Testing and Evaluation of APIA in Sri Lanka: Ex-post impact assessment 222
6.1 Methods and activities 222
6.1.1 Project selection 223
6.1.1 Project selection 224
6.1.2 Data sources 224
6.1.3 Overview of activities 225
6.1.4 Stakeholder identification and capacity building 227
6.1.5 Screening and scoping 229
6.1.6 Impact assessment 230
6.2 Results 234
6.2.1 Background 234
6.2.2 Screening 238
6.2.3 Scoping 240
6.2.4 Assessment of KOISP impacts 241
6.2.4.1 Baseline Situation 241
6.2.4.2 Assessment of KOISP impacts 246
6.2.5 Opportunities for mitigation and enhancement 253
6.3 Summary and conclusions 256
6.4 Evaluation of the APIA Approach 258
6.4.1 Operation 258
6.4.2 Performance 260
6.4.2.1 Features 261
6.4.2.2 Outputs 267
6.4.3 Impact 270
6.5 Conclusions 273
6.5.1 The impacts of KOISP irrigation project on fisheries 273

6.5.2 The APIA approach 274
Appendix 275

Chapter 7 - New Perspectives on the Impacts of Irrigation Development on Fisheries - Challenges for their Assessment 284
7.1 Impacts of irrigation on inland fisheries production and the rural livelihoods: lessons and new perspectives 284
7.1.1 Aquatic ecosystems modified by irrigation can support productive fisheries 285
7.1.2 Inland fisheries can be significant for rural livelihoods even in irrigated systems 287
7.1.3 The management of irrigation may impact fisheries more severely than the irrigation infrastructure *per se* 290
7.1.4 Fisheries production and livelihood objectives do not always match biodiversity conservation objectives 292
7.1.5 The importance of a disaggregated assessment of impacts 294
7.2 Implications in the management and decision-making of irrigation development 295
7.2.1 Management measures 296
7.2.2 Trade-offs between fisheries and irrigated agriculture 297
7.2.3 Policy priorities 299
7.3 Strengths of the APIA approach 300
7.3.1 Broader scope and coverage of assessment 300
7.3.2 Increased use of available knowledge 302
7.3.3 Open-ended and flexible process (no 'blueprint' approach) 303
7.3.4 Potential for conflict reduction or resolution 304
7.3.5 Relevance and utility to the management and decision-making 306
7.4 Limitations of the APIA approach and identification of future challenges 307
7.4.1 Increased complexity and uncertainty in the impact assessment 307
7.4.2 The delicate management of the research process 310
7.4.3 Critical Requirements 311

7.4.3.1 Adequate time and human resources 311
7.4.3.2 Genuine institutional support 312
7.4.4 Priority research needs 314
7.4.4.1 Specific needs from the case studies 314
7.4.4.2 Increase in time and space coverage 315
7.4.4.3 Incremental improvement of the approach 316

Chapter 8 - Conclusions 317
8.1 New perspectives on the impacts of irrigation on fisheries 317
8.2 Challenges raised by the adaptive, participatory and integrated assessment (APIA) of impacts 319
8.3 Implications for the management and decision-making of irrigation development 321
8.4 Further research 322
References Cited 324

List of Tables

Chapter 2

Table 2.1 Main biophysical determinants of fisheries production per aquatic habitat 48

Table 2.2 Empirical estimates of fisheries productivity (mean and range) of different aquatic habitats. Note different area measures used for different habitats. 51

Table 2.3 Livelihood functions of fishing as household incomes rise and livelihood strategies develop 56

Table 2.4: Summary of potential impacts of irrigation development on aquatic habitats 71

Table 2.5: Social impacts of irrigation development 79

Chapter 3

Table 3.1 Effects of irrigation on aquatic habitat areas at village level. Mean area at non-impacted (NI) sites is given as a baseline, and effects are shown as the mean difference in area between paired, impacted and non-impacted sites. Effects in bold are significant at $P < 0.1$ 103

Table 3.2 Paired comparisons of average household fishing effort (HH effort) and catch (HH catch), catch per unit of effort (CPUE), effort (EPUA) and catch (CPUA) per unit area, and species richness. Mean values for non-impacted (NI) sites are given as a baseline, and effects are shown as the mean difference between paired, impacted and non-impacted sites. Relative mean effects are also shown as a proportion of the NI value. Effects in bold are significant at $P < 0.1$ 106

Table 3.3 Parameter estimates (with standard error in parentheses) for the regression models of village level catch (Equation1) Relationships of catch per unit area (CPUA) and effort per unit area (EPUA) for irrigated and

control sites are given in Figure 3.2. There is no difference in per-area fisheries productivity of irrigated and control sites..... 108
Table 3.4 Contribution of aquatic resource use to gross household income 110
Table 3.5 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<0.1 111

Chapter 4

Table 4.1 Review of a sample of EIA Guidelines from a fisheries perspective 130
Table 4.2 Framework for Analysis of Rural Livelihoods 143
Table 4.3 Main benefits and associated risk or constraints of participation to the assessment of irrigation impacts on fisheries 155
Table 4.4 A typology of participation: how people participate in development programmes and projects 160
Table 4.5 Evaluation framework..... 163

Chapter 5

Table 5.1 Planning and content of workshops and parallel surveys 175
Table 5.2 Stakeholder identification and analysis. Expression of interest and self-evaluation of importance and influence (scoring) by workshop participants 178
Table 5.3 List of all impacts of irrigation as identified by the working groups in the screening workshops 180
Table 5.4 Scoping results: Evaluation by local level stakeholders of the likely significance of impacts on hydrology, ecology, livelihoods and institutions against local resources in the respective government institutions..... 188
Table 5.5 Household livelihood assets in the Huay Thouat catchment area 192
Table 5.6 Estimated impact on fish production in the Huay Thouat catchment, assuming maintenance of rain-fed rice cultivation in the wet season and complete loss of mainstream river and associated floodplain production. See Table 2.2 for origin of productivity estimates..... 195

Chapter 6

Table 6.1 Planning and content of workshops and parallel surveys 226

Table 6.2 List of workshop participants and respective affiliations 228

Table 6.3 Proportion of households in surveyed villages engaged in fishing in 2002 244

Table 6.4 Income from fishing and alternative male employment, Rs per day (estimates from household interviews, village survey, February 2002). 245

Table 6.5. KOISP Fisheries balance in terms of production and value 251

Table 6.5(a) Reservoir productivity based on a recent survey by Renwick (2001)..... 251

Table 6.5 (b) Reservoir productivity based on average for Sri Lankan reservoirs by De Silva (1988) 251

Appendix

Table A.6.1 Main village characteristics, natural resources and livelihood activities: Results of reconnaissance surveys: informal interviews of key informants (households and villagers groups) in 8 villages in the project area. 275

List of Figures

Chapter 1

Figure 1.1 Process of investigation and respective chapters.....36

Chapter 2

Figure 2.1 Diagram of fishery components and their interactions in non-irrigated systems 41

Figure 2.2 Relationship between seasonal cycles of flooding, fish biology and fishing in tropical river-floodplain systems 53

Figure 2.3 Diagram of fishery components and their interactions in irrigated systems 61

Figure 2.4 Impact of irrigation schemes on river flow below the intake structure.....63

Figure 2.5 Land use change following the development of a flood control drainage and irrigation scheme Bangladesh.....66

Chapter 3

Figure 3.1 Map of Laos indicating the study area 99

Figure 3.1 Aquatic habitat areas in the weir (a) and dam (b) sites and associated controls Impacted (I) and non-impacted (NI) sites in the dry and wet seasons. Habitats are classified as lacustrine (reservoirs, lakes, and ponds) (black), riverine (streams and rivers) (gray), and rice paddies (white). 105

Figure 3.2 Relationships between fishing effort (EPUA) and catch (CPUA) per unit area in weir (a) and dam (b) sites. Non-impacted controls (open squares) and impacted sites (solid squares).....109

Figure 3.3 Average household catch and fishing effort in the paired weir (a, b) and dam (c-f) sites effort are shown overall for all aquatic habitats (c, d) and for habitats other than reservoirs only (e, f).....113

Chapter 4

Figure 4.1 Frameworks of existing impact assessments.....127

Figure 4.2 Coverage of the fishery system by assessment approaches.....128

Figure 4.3 Diagram of APIA stages.....167

Chapter 5

Figure 5.1 Sketch of the planned Huay Thouat irrigation system and impacted area 193

Chapter 6

Figure 6.1 Implementation of the impact assessment approach 223

Figure 6.2 Map of the Kirindi Oya watershed and the KOISP irrigation system.....237

Figure 6.3 General relationship between relative dry season water area and fisheries yield 255

List of Boxes

Chapter 2

Box 2.1 Features of the natural and man-made river and floodplain habitat continuum....43

Box 2.2 Theories of biological production sources....44

Box 2.3 Main principles for mitigation or enhancement of livelihood impacts....93

Chapter 5

Box 5.1 Results of reconnaissance surveys: informal interviews of key informants in four villages in the project area....187

Box A.5.1 Evaluation questionnaire and results (percentage of participant responses) for the first phase (Problem identification)....219

Box A.5.2 Evaluation questionnaire and results (percentage of participant responses) for the second phase (Assessment of Impacts)....219

Box A.5.2 Evaluation questionnaire and results (percentage of participant responses) for the second phase (Assessment of Impacts)....220

Box A.5.3 Evaluation questionnaire and results (percentage of participant responses) for the final workshop....220

Box A.5.3 Evaluation questionnaire and results (percentage of participant responses) for the final workshop....221

Chapter 6

Box 6.1 Identification of KOISP impacts on fisheries (Screening stage)....239

Appendix

Box A.6.1 Workshop 1 evaluation questionnaire and results (percentage of participant responses)....279

Box A.6.2 Workshop 2 evaluation questionnaire and results (percentage of participant responses)....280

Box A.6.3 Workshop 3 evaluation questionnaire and results (percentage of participant responses) 280
Box A.6.3 Workshop 3 evaluation questionnaire and results (percentage of participant responses) 281
Box A.6.4 Workshop 4 evaluation questionnaire and results (percentage of participant responses).....282
Box A.6.5 Final workshop evaluation questionnaire and results (percentage of participant responses).....283

Chapter 1 - Introduction

Both the development of irrigation for expansion and intensification of agriculture and inland fisheries are important to the production of food and to rural livelihoods. This is particularly the case in rice-based farming systems as rice fields constitute major aquatic habitats. However the development of irrigation can have major negative impacts on fisheries, and may require trade-offs between fisheries and irrigated agriculture. This research aimed firstly to investigate the nature and magnitude of the impacts of irrigation on fisheries and secondly to propose an impact assessment approach that supports management and decision-making for irrigation projects. In this chapter the methods and activities used to address these two main research objectives are described and an outline of the thesis is presented. The focus is on irrigated rice farming systems primarily because fisheries are generally important in these systems, and they support a large share of the rural livelihoods in South, Southeast and East Asia, and in parts of West Africa. However many findings are also relevant to other regions and to irrigation development in general.

1.1 Background

1.1.1 The importance of irrigation and inland fisheries

Irrigation development in rice-based farming systems

Present in all continents to various degrees, irrigated agriculture has contributed to economic growth, to poverty reduction and to the sustainability of livelihoods through improvements in the levels and security of farm productivity, employment and incomes, and associated linkage and multiplier effects in the wider economy (e.g.

Lipton et al. 2003, ADB 2004, Hussain & Hanjra 2004, Smith 2004). Globally the total irrigated area in 2001 was of the order of 270 million hectares, about 17 percent of cultivated land but producing approximately 40 percent of food and other agricultural commodities (World Food Summit 2002, FAO 2004). Given the objective of improving food security in developing countries, considerable emphasis has been placed in the past on the development of irrigated agriculture, prioritising allocation of water to farming and related activities. Without irrigation, increases in yields and outputs that have fed the world's growing population would not have been possible (Rosegrant et al. 2002).

Rice is the staple food for 40% of the world's population, and rice farming systems dominate land use in the lowland areas of tropical Asia. Asian rice fields cover an area of 115 million hectares (Koohafkan & Furtado 2004), over 50% of the continent's total wetland area of 204 million hectares (Finlayson & Spiers 1999). Rice farming systems and their aquatic ecosystems are among the oldest cultural landscapes, having evolved over 6000 years (Ruddle 1982, Koohafkan & Furtado 2004). About 57% of rice cultivation occurs in natural wetlands, while the remainder occurs on land that has been converted to retain rainfall and runoff (Hook 1993). These rainfed and flood-prone rice fields constitute temporary man-made wetlands with many functional similarities to natural floodplains, and they support diverse assemblages of wetland associated organisms (Heckman 1979, Lawler 2001).

In much of monsoonal Asia the rainfed rice farming systems are limited to producing a single wet season crop per year, and even this crop may be lost in very dry years. Irrigation development aims to allow cultivation of a second crop of rice (or another field crop), or at least secure a single crop in dry years. In some regions three crops per year may be possible, for example, the floodplains of Bangladesh. Irrigation reduces the need to store water in the rice field itself, and allows intensification including adoption of shallow-water, high yielding rice varieties and associated inputs of fertilizers and pesticides. Intensified farming practices may be adopted for the dry

season crop only while maintaining a traditional rainfed wet season crop, or may be extended to both cropping seasons.

However, as developed below, the sectoral strategy for the development of irrigation has usually been associated with significant impacts on other natural resources. New objectives for multiple uses of irrigation water are now being set. Innovative approaches such as Integrated Water Resource Management (IWRM, e.g. Falkenmark 2003) and the recent emphasis on the multi-functionality characteristics of rice fields (e.g. The International Network for Water and Ecosystem in Paddy Fields, INWEPF) provide the rationale for a more integrated approach to the management of irrigated agriculture. Large research programmes such as the Comprehensive Assessment of Water Management in Agriculture (CAWM 2005) currently seek improved agricultural management options that integrate the other food producers who are also users of water, such as livestock and fisheries.

Clearly the study of multiple users of irrigation water involves greater analytical complexity and technical sophistication than conventional irrigation management. Some authors (such as English et al. 2002) have recently suggested a paradigm shift in irrigation management, and optimum irrigation may be defined more broadly as the optimisation of overall benefits, including the non-monetised benefits of water quality protection, food security, increased employment and resettlement of populations in addition to simply crop production.

Inland fisheries

Whilst the importance of irrigation is little disputed, inland fisheries have tended to be neglected at least in part because of their inconspicuous and often subsistence-oriented nature. More recently, and in the context described above, the environmental, social and economic significance of the activity has been progressively appreciated (e.g. WCD 2000, CAWM 2005).

In this thesis inland fisheries are defined as the exploitation of aquatic organisms (fish, molluscs, crustaceans and aquatic insects) living in inland water ecosystems; these resources are typically held in a form of common property regime (FAO 1997). In contrast aquaculture implies active husbandry and private ownership of stocks.

Inland fisheries rely on inland water ecosystems that primarily include freshwater systems and encompass a wide range of habitats such as rivers, lakes, wetlands and their respective riparian zones. Rivers cover a very small part of the Earth but they are intricately linked to the land use within river basins as well as coastal and near-shore marine ecosystems. Although lacustrine and estuarine ecosystems are generally not included in the definition of inland fisheries they can provide key aquatic habitats (for resident and migratory species), which can be highly productive and contribute significantly to livelihoods in coastal areas. Because of their interactions with both marine and freshwater ecosystems (e.g. Oglesby et al. 1972, Wiley 1976), irrigation development can also affect lagoons and estuaries. Therefore, while recognizing the predominance of freshwater systems, this thesis also considers the lacustrine and estuarine environments.

Inland water ecosystems are highly biodiverse. For example, despite accounting for only 0.01% of all aquatic habitats on Earth (Shiklomanov 1999), freshwaters support more species per unit area than other environments; 10% more than land and 150% more than oceans (McAllister et al. 1997, WCMC 1998). In particular, fish account for about 50 percent of vertebrate species, and about half of these occur in freshwater. The global value of freshwater services, including fisheries and the preservation of the environment, is estimated to reach 3 trillions of dollars (WCD 2000). It is argued that although ecological functions are usually not considered in economic aggregates (e.g. GNP and GDP), they make significant contributions to economies, and freshwater ecosystems are economically more valuable than terrestrial ones (Costanza et al. 1997, McAllister et al. 2000).

Inland fisheries can make particularly important contributions to the economy of developing countries, both in aggregate and at household level. This contribution ranges from food production, food security, nutrition and employment, to more intangible socio-cultural values. In 1998, inland fisheries worldwide accounted for at least 15 percent of total global employment in capture fisheries and aquaculture, and produced 7 million tons of fish, about 10 percent of total global fish output (FAO 2000). These estimates are believed to be under reported by two to three hundred percent, with the implication that the higher range estimate could be as high as 21 millions tons of fish. The great diversity in the range of gears used, types of environments in which they are used and the socially and culturally complex societies in which they operate present unique problems for the collection of inland fisheries statistics (for example, Coates 2002 for fishery statistics of Southeast Asia).

At household level inland fisheries can make a major contribution to livelihoods in developing countries because of their nutritional value, the range of roles they can play in livelihoods (Smith et al. 2005) and their accessibility, particularly for the poor. Fish is often critical in meeting dietary needs for animal protein in an otherwise carbohydrate-based diet. This is particularly the case in Asian developing countries where fish supplies can provide over 75% of the total animal protein consumed by the population (e.g. Cambodia, Bangladesh, Maldives, Philippines; ADB 2004), and in the Amazon where the per capita consumption reaches 67 kg/yr in average (Chao et al. 1999).

Inland fisheries often contribute significantly to the livelihoods of rural households (Tan et al. 1973, Garaway 1999, Gregory & Guttman 2002), in particular in rice farming systems. This is primarily because of its accessibility and importance to the rural poor. In locations as diverse as the lower Mekong (Guttmann 1999, Lorenzen et al. 2000, Jensen 2001), the Amazon (Almeida et al. 2002) and the Lake Chad basin in Africa (Béné & Neiland 2003), rural households typically obtain between 10% and 30% of their total income from inland fishing.

1.1.2 Potential impacts of irrigation on fisheries

Irrigation development and the associated expansion of irrigated agriculture are considered the most important factors that have impacted upon inland fisheries in developing countries (Bergkamp et al. 2000, Jackson & Marmulla 2001, Lorenzen et al. 2004).

Impacts can arise from an irrigation scheme's infrastructure, the operation and management of the irrigation system, and the associated expansion and intensification of agriculture and change in land use. The impacts can arise from physical changes to aquatic habitats, from institutional changes that determine who can access a fishery and a fishing ground, or from other socio-economic factors that influence the level of exploitation. Irrigation systems[1] intentionally alter the natural hydrology to retain or divert water and increase agriculture production. They abstract and deplete (mainly through evapotranspiration) a large proportion of the annual flow from tropical river basins (e.g. Rijsberman & Molden 2001, Molden et al. 2000) and account for the largest use of freshwater by humans (de Fraiture et al. 2001).

These irrigation structures tend to reduce the longitudinal and lateral connectivity and availability of aquatic habitats (Roggeri 1995, Petr & Mitrofanov 1998, Dudgeon 2000, Lemly et al. 2000). However, at project and catchment level, net production impacts are not necessarily negative, because reservoirs, canals and drains can compensate for habitat loss by supporting productive fisheries (Jackson & Marmulla 2001). However, at project and catchment level, net production impacts are not necessarily negative, because reservoirs, canals and drains can compensate for habitat loss by supporting productive fisheries (Jackson & Marmulla 2001).

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[1] In this thesis, irrigation systems are defined as comprising the irrigation scheme and all associated diversion, storage and distribution infrastructure, of particular importance being reservoirs, canals and drains.

Associated changes in land use and the development of agriculture can also affect the productivity and sustainability of fisheries in many ways and potentially with great severity. Engineering of land, often with drainage of natural wetlands or modification of natural drainage channels changes the overall availability and ecological connectivity of natural aquatic habitats. In Asia for example, the focus on rice intensification for increasing food production has probably led to a significant decrease in the production of aquatic animals and vegetables in and around the rice fields (Balzer et al. 2002).

Such impacts also have implications for biodiversity. Subject to increasing pressure through rising demand for water and overfishing, approximately 20% of freshwater species are threatened, endangered or extinct and protection of freshwater biodiversity is internationally recognized as an urgent priority (Revenga et al. 2000). Impacts of irrigation development on the biodiversity and ecological integrity of existing aquatic ecosystems are generally negative (Roggeri 1995, Welcomme 2001) as the species occurring in the unmodified ecosystem are often sensitive to changes in hydrology, water quality and habitat connectivity. Overall, habitat loss and degradation of the terrestrial and aquatic environment have been considered as the greatest threats to the sustainability of inland fisheries (Revenga et al. 2000, Bizer 2000, Lemly et al. 2000).

Changes in fisheries production may result from habitat changes (as described above), but also from changes in the level of exploitation, in terms of fishing effort and efficiency of gear use. The latter may result from changes in fishing practices, the physical accessibility or rights of access to fishing grounds, the seasonality of the activity and changes in the role fishing plays in rural livelihoods and its importance in the rural socio-economy (Smith et al. 2001).

Impacts on the importance of fishing to rural livelihoods will also depend on alternative employment opportunities in the local or wider economy, and degradation of the productive potential of a fishery may be compensated in livelihood terms by

opportunities stimulated by the increased and more continuous output of irrigated farming. In addition to economically rational choices, changes may originate from social and cultural factors, and from interactions with the other sectors, possibly resulting in conflicts between farmers and fishers. Lastly, in response to changes in the biophysical environment, human actions can in turn affect it, for example when shifting to activities that are more damaging for the ecosystem (e.g. lime making in Sri Lanka, Chapter 6).

The impacts of irrigation on fisheries can be multiple and varied, and interconnected. They can be positive or negative, direct or indirect, and they can affect one or several components of the fishery system, i.e. the ecosystem supporting the aquatic resources, the exploitation of aquatic resources, the institutional arrangements pertaining to the regulation of the exploitation, and rural livelihoods and the socio-economic environment.

The impacts of irrigation can vary over a catchment area and with different time scales. These impacts may be distributed differently over the catchment (e.g., downstream impacts tend to have more negative effects than upstream ones) or among the different socio-economic categories (see above). In particular cumulative effects may arise at larger scales (e.g. river basin or regional scale) from interventions in several catchments. Over time, irrigation can have short-term effects on the dynamics of the fisheries system (for example, the collapse of fish production if a reservoir dries up), medium-term effects (for example, the secondary effect of this collapse on the reservoir production in the following years), and much longer term effects that might not be detected at the time of the study (for example, a change in species assemblage composition in the impacted ecosystem, or a loss of species diversity).

In conclusion, irrigation scheme construction and the associated development of agriculture can have a wide range of impacts, and these can be complex. These impacts can occur across the catchment and river basin area, and over different time

scales. However, even in a modified environment, fisheries can continue to play a significant role in rural livelihoods, and recent evidence from tropical Asia shows that productive and diverse freshwater ecosystems can be maintained even in highly modified habitats (Sultana & Thomson 1997, Halls et al. 1999, Dudgeon 2003). This suggests that conservation and restoration measures in such systems need not be in vain, and this supports the potential value of assessing and managing fisheries in irrigated systems.

1.1.3 Existing methods and approaches for impact assessment, and their limitations

Fisheries issues have rarely been adequately integrated into any stage of irrigation planning and development as a result of both a lack of understanding of the nature of the impacts on fisheries and a lack of awareness of the potential importance of the activity to rural livelihoods. Furthermore any recognition of negative impacts on fisheries may have been disputed, or rendered apparently insignificant, by the positive impacts from irrigated agriculture. More recently the increasing social and environmental concerns raised by irrigation development (by large dams in particular) have emphasized the need for improved approaches for planning, impact assessment and management of such projects (e.g. WCD 2000).

A range of approaches and methods that can apply to the impacts of irrigation on fisheries are now available, from reductionist and single-issue assessment techniques to process frameworks. Most methods have been developed through a narrow disciplinary based approach and applied only to specific aspects of the impacts on fisheries. They have tended to focus on biodiversity and ecological impacts, notably through the study of modifications to river flows and longitudinal habitat connectivity (see for example, Clay 1995, Bizer 2000, Larinier 2000, Jackson & Marmulla 2001, Bunn & Arthington 2003). Knowledge about livelihood impacts and respective institutional changes is much weaker (Adams 2000a, 2000b; Smith et al. 2001).

Rigorous impact assessments based on 'before-after' or 'impact-control' comparisons with adequate replication are available only for a few systems, notably flood control and irrigation schemes in Bangladesh (Halls et al. 1999) and small and medium-scale irrigation schemes in Laos (Lorenzen et al. 2000). The lack of reliable quantitative impact assessments has often been perceived as the main constraint to inclusion of such impacts in irrigation project appraisal (e.g. WCD 2000), particularly in cost-benefit analyses. Furthermore the valuation of non-tangible outputs of fisheries, such as biodiversity, culture and value, is highly difficult and uncertain. As a result these values are rarely integrated in the management and decision-making although these may be considered important by both stakeholders and scientists.

Apart from a recently developed set of technical guidelines (Lorenzen et al. 2004) derived from this research, existing knowledge has not yet encompassed all mechanisms occurring in the biophysical, socio-economic and institutional dimensions of fishery systems. In addition a lack of quantitative information may bias decision-making for irrigation projects. The description of the nature of impacts (Section 1.1.2) shows that the assessment of the impacts of irrigation development on fisheries must go beyond consideration of ecological and productivity changes to take account of other significant factors such as the vulnerability of affected households, changing rural livelihood opportunities and the importance and role played by fisheries in the socio-economic development of the affected area.

1.2 Problem statement and outline of methodology

The impacts of irrigation development on fisheries provide a good example of a 'sustainable development' challenge, that is how to increase food production whilst conserving ecosystems diversity and integrity. Accepting the widely shared concept of sustainable development (UN Millennium Project 2000), the goal is thus to reconcile processes of growth with conservation. Ultimately the integration of fisheries issues into the planning and management of irrigation may result in a

significant improvement in the overall benefits and sustainability of projects, and contribute to improved integration of land and water management at a river basin level.

The overarching theme of this thesis encompasses the impacts of irrigation on inland fisheries and the specific objectives of this research are: i) to increase and improve the knowledge of the nature and magnitude of impacts of irrigation development on fisheries and, ii) to develop appropriate ways of assessing the impacts of irrigation on fisheries in order to support management and decision-making for irrigation development. The irrigation schemes considered in this research are primarily small and medium-scale dams and to a lesser extent, weir diversion and pumped surface abstraction schemes.

1.2.1 Research problem 1: Nature and magnitude of irrigation impacts on fisheries

The brief overview of the nature and magnitude of impacts (Section 1.1.2) suggests that interactions between the components of a fishery system and irrigation development are not straightforward, and that these are potentially compounded by the number of factors involved, their temporal and spatial variability, and the possible interactions between some factors. Significant knowledge is available concerning the biophysical impacts of irrigation, but there are still deficiencies in knowledge of many freshwater systems and the livelihoods dependent on them. In addition there is a general dearth of quantification of such impacts and irrigation planners may find this limits the valuation of costs and benefits of fisheries, and their integration in cost-benefit analyses of irrigation investments.

Despite the need to resolve the deficiency of knowledge, the disciplinary and narrow focus of the studies only partially covers the fishery system and its interactions with the development of irrigation. Therefore understanding and assessing the nature and

magnitude of impacts may require going beyond conventional approaches to assessing the impacts of irrigation on fisheries.

The thesis therefore addresses a first research question as follows:

What are the nature and magnitude of the impacts of irrigation on the production of fisheries and their role and importance in rural livelihoods?

This leads to the two following sub-questions:

- *How may irrigation impact on the biophysical characteristics of a fishery*[1] *and the socio-economic and institutional factors that influence the means and levels of its exploitation?*
- *What is the importance and role of a fishery in the rural economy and in the livelihoods of rural households?*

Investigation of the nature and magnitude of impacts

The objective is to enhance the knowledge of impacts, and in particular to improve the understanding and characterization of their nature and magnitude. The methods used to address these questions were first a review of literature to determine the state of existing knowledge of the nature and magnitude of irrigation impacts on fisheries. The ability of the literature to encompass the range and complexity of issues raised by the impacts of irrigation on fisheries (in terms of coverage, adequacy and accuracy) was assessed. The strengths and limitations of existing knowledge were identified to inform the priority research needs and design of subsequent investigations.

Second, a quantitative impact assessment was carried out to provide further characterization and quantification of the impacts of small and medium-scale dams and weirs on fisheries production, diversity, exploitation patterns and consequences for rural livelihoods in rice farming systems. This was a rigorous and resource

[1] Fishery is the exploitation of aquatic organisms under the regime of common property resources or open access (see also Chapter 2, Section 2.1.3.1).

intensive investigation based on a replicated paired comparison of impacted and non-impacted sites. Case studies conducted to test the impact assessment approach subsequently developed (see below) also provided further insights into the nature and magnitude of such impacts.

1.2.2 Research problem 2: Improving methods for the assessment of the impacts of irrigation on fisheries

The likely complexity and wide range of issues raised by the possible impacts (see Section 1.1.2) limit the usefulness of formal prediction techniques and one might not expect accurate prediction of the whole range of impacts. For example impacts can rarely be understood and predicted on the basis of physical habitat impacts alone, and even where physical habitat change is the main driver of fisheries impacts, the complex network of habitats on which many inland fisheries rely can pose great difficulties for understanding and predicting ecological impacts (e.g. Lorenzen et al. 2000, de Graaf et al. 2001). This suggests that limitations in understanding and assessing the impacts may not just be due to a lack of knowledge on particular impact pathways, but also due to a lack of holistic understanding of the impacts.

The results and outputs from impact assessments have direct implications in the management and decision-making of irrigation development. Opportunities for mitigation or enhancement measures may arise at any stage in the causal chain of impact and improved assessment of impacts should inform the selection, design and management of these by government or the communities. In particular trade-offs (and potential tensions or conflicts resulting from these) are likely to arise between fisheries and irrigated agriculture, but they have been rarely addressed in the literature.

The thesis therefore addresses a second research question as follows:

How can the assessment of irrigation impacts on fisheries be improved and provide better support to management and decision-making for irrigation development?

This leads to the following sub-questions:

- *What are the strengths and limitations of existing impact assessment methods and approaches with regard to the impacts of irrigation on fisheries?*
- *What approach and/or methods can be proposed to improve the impact assessment and provide better support to management and decision-making for irrigation projects?*

Investigation of an improved approach to impact assessment

The objective is to design an impact assessment approach that encompasses the entire fishery system (encompassing fishery attributes and respective linkages) and its interaction with the development of irrigation. The methods used to address these questions were first a review of literature to determine the state of existing knowledge of impact assessment approaches and methods. The strengths and limitations of existing methods and approaches for impact assessment were identified. In addition the knowledge and lessons gained from the investigation of the nature of impacts and the quantitative assessment carried out were exploited. A diagnosis of requirements for and constraints to impact assessment supported the formulation of an improved approach.

The approach needed to cover the relevant disciplinary and sectoral analyses in order to account for the relevant range of biophysical, socio-economic and institutional factors, and the interactions between them. The main processes of change underlying predicted or observed impacts on fisheries and dependent rural livelihoods, and any sources of conflict, were established. Optimisation of the use of available knowledge

(coverage and adequacy) including local knowledge[2] was sought throughout the assessments made. The contribution of stakeholders was also required for consideration of their needs and concerns, and for consensus-building and possibly conflict resolution. This should support the development of local capacity to manage impacts and provide an information base.

The outcomes should be relevant to the needs of decision-makers, with the potential to facilitate evaluation of trade-offs and determination of negotiated solutions to conflicts of interest. Ultimately the assessment results should support the improvement of project design and implementation through identification and design of mitigation or enhancement measures and other management options for sustainable irrigated agriculture and fisheries.

An issue that arises in fisheries management is that objectives of fish production and environmental conservation are not always co-terminous (see further explanation in Chapter 2, Section 2.1.4). This research has focused on the availability, productivity and economic use of aquatic resources, whilst recognizing that trade-offs with biodiversity conservation may arise.

The approach that was developed was then tested and refined through the implementation of two case study impact assessments. First an ex-ante assessment of a medium-scale irrigation scheme in Laos and second an ex-post evaluation of a large-scale irrigation and settlement scheme in Sri Lanka. For both cases the operation, performance and impact of implementation of the approach were evaluated in relation to the research objectives.

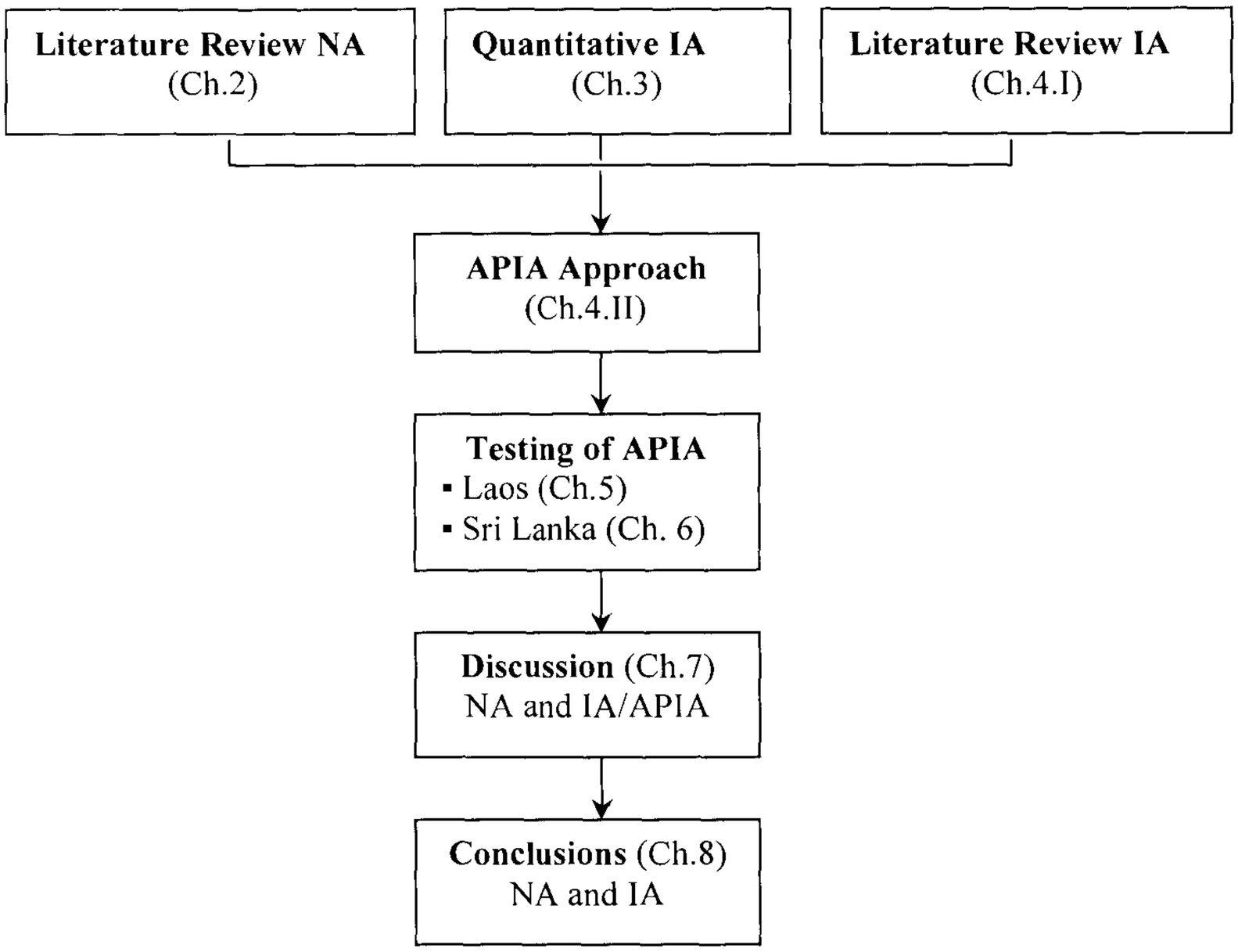
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[2] In this thesis, 'local knowledge' is used to refer to both the indigenous technical knowledge of fishers and the broader technical and other knowledge of all stakeholders including communities and local officials.

1.3 Thesis Outline

The process of investigation and respective chapters follow the structure illustrated in Figure 1.1. An outline of each chapter is described below.

Figure 1.1 Process of investigation and respective chapters



NA: Nature and magnitude of impacts
IA: Impact assessment
APIA: Adaptive, Participatory and Integrated Impact Assessment

Chapter 1 - Introduction

The first chapter gives an overview of the importance of irrigation and fisheries, and the range and complexity of potential impacts of irrigation on fisheries. Existing approaches for impact assessment and implications for management are briefly reviewed. Two main research problems are identified covering the nature and magnitude of impacts, and improved approaches to assess these impacts and support

management and decision-making for irrigation projects. The methods and activities proposed to investigate these two main research questions are briefly described. Finally the structure and respective chapters of the thesis are outlined.

Chapter 2 - Nature and magnitude of impacts, and underlying mechanisms

The central question asked in this chapter is: how and why does irrigation impact on fisheries? The state of knowledge is assessed in a comparative perspective of fisheries in non-irrigated systems vs. irrigated systems in order to highlight the underlying mechanisms of impacts and their respective outcomes. The objective is to develop a picture of causal pathways with identification of potential key determinants of impacts on fisheries ecology and production, and on the livelihoods dependent on these. The management measures proposed to mitigate or enhance the impacts of irrigation on fisheries are also reviewed. Critical conclusions are finally drawn from identification of the strengths and limitations of current knowledge.

Chapter 3 - Quantitative impact assessment in Laos

The impacts of irrigation on fisheries were investigated and assessed quantitatively in the rice farming systems of southern Laos. For this purpose a replicated field study compared sites impacted by dams and weirs with their respective control sites. The observational study design is a paired comparison of physical habitats, diversity and production of aquatic resources, exploitation patterns and livelihoods assets. In the chapter impacts are quantified and key mechanisms by which these impacts arise are identified. Results are discussed and lessons for the design of an impact assessment approach derived.

Chapter 4 - Assessment of the impacts of irrigation on fisheries

In the first part of the chapter (4.I), the literature on impact assessment approaches and methods that can apply to the impacts of irrigation and fisheries is reviewed. The objective is to identify the methods and approaches that have directly or indirectly

addressed the impacts of irrigation on fisheries, and to assess their respective strengths and limitations.

In the second part (4.II), an impact assessment approach is proposed drawing from: the knowledge of the fisheries systems and potential impacts of irrigation (Chapter 2), the results and lessons from the quantitative impact assessment (Chapter 3) and the benefits and limitations of existing methods (4.I). The framework and features of the proposed approach are justified and described in detail. It aims to achieve an adaptive, participatory and integrated assessment of the impacts.

Chapter 5 - Testing and evaluation in Laos: Ex-ante impact assessment

The impact assessment approach proposed and newly developed in Chapter 4 (APIA) was first tested and evaluated in Laos, where rainfed paddies contribute substantially to total aquatic habitat and fisheries production. An integrated and participatory ex-ante assessment was carried out for a planned medium-scale dam irrigation project. Methods and activities are described for the assessment of impacts and identification of management options based on mitigation and enhancement measures. Implementation of the approach has been evaluated for its operation, performance and impact, noting that for this first case study, emphasis was given to the improvement of the approach. Conclusions are finally drawn from the impact assessment results and discussion of the evaluation of the approach.

Chapter 6 - Testing and evaluation in Sri Lanka: Ex-post impact assessment

The APIA approach was secondly tested and evaluated in Sri Lanka, for an existing large-scale irrigation project implemented 16 years ago. The aim was an integrated and participatory ex-post assessment of the impacts of the irrigation system on fisheries. Methods and activities are described for assessment of the baseline situation and evaluation of impacts. Drawing from the impact results, management options based on mitigation and enhancement measures are identified and discussed. Throughout implementation, the approach has been evaluated for its operation,

performance and impact. Conclusions are finally drawn from the impact assessment results and discussion of the evaluation of the approach.

Chapter 7 - New perspectives on the impacts of irrigation development on fisheries - Challenges for their assessment

The results of the three impact assessments - in Laos (two assessments, Chapters 3 and 5) and Sri Lanka (Chapter 6) - are summarised and put into perspective through comparison and generalisation of results where relevant. This sheds new light on the nature and magnitude of impacts of irrigation on fisheries, in particular on fisheries production and rural livelihoods in rice-based systems. This also provides insight on improved impact assessment approaches that support the management of irrigation and decision-making. The discussion of the strengths and limitations of the adaptive, participatory and integrated impact assessment approach highlights the remaining challenges and research priorities for further improvements in the understanding, assessment and management of the impacts of irrigation on fisheries.

Chapter 8 - Conclusions

Conclusions are drawn from the three impact assessments conducted in Laos and in Sri Lanka. They refer to the understanding and assessment of the nature and magnitude of the impacts and identify implications for the management of irrigation for agriculture and fisheries. Conclusions are secondly drawn on the proposed adaptive, participatory and integrated approach to assessing impacts, its strengths and limitations and further research priorities.

Chapter 2 - Nature and Magnitude of Impacts, and Underlying Mechanisms

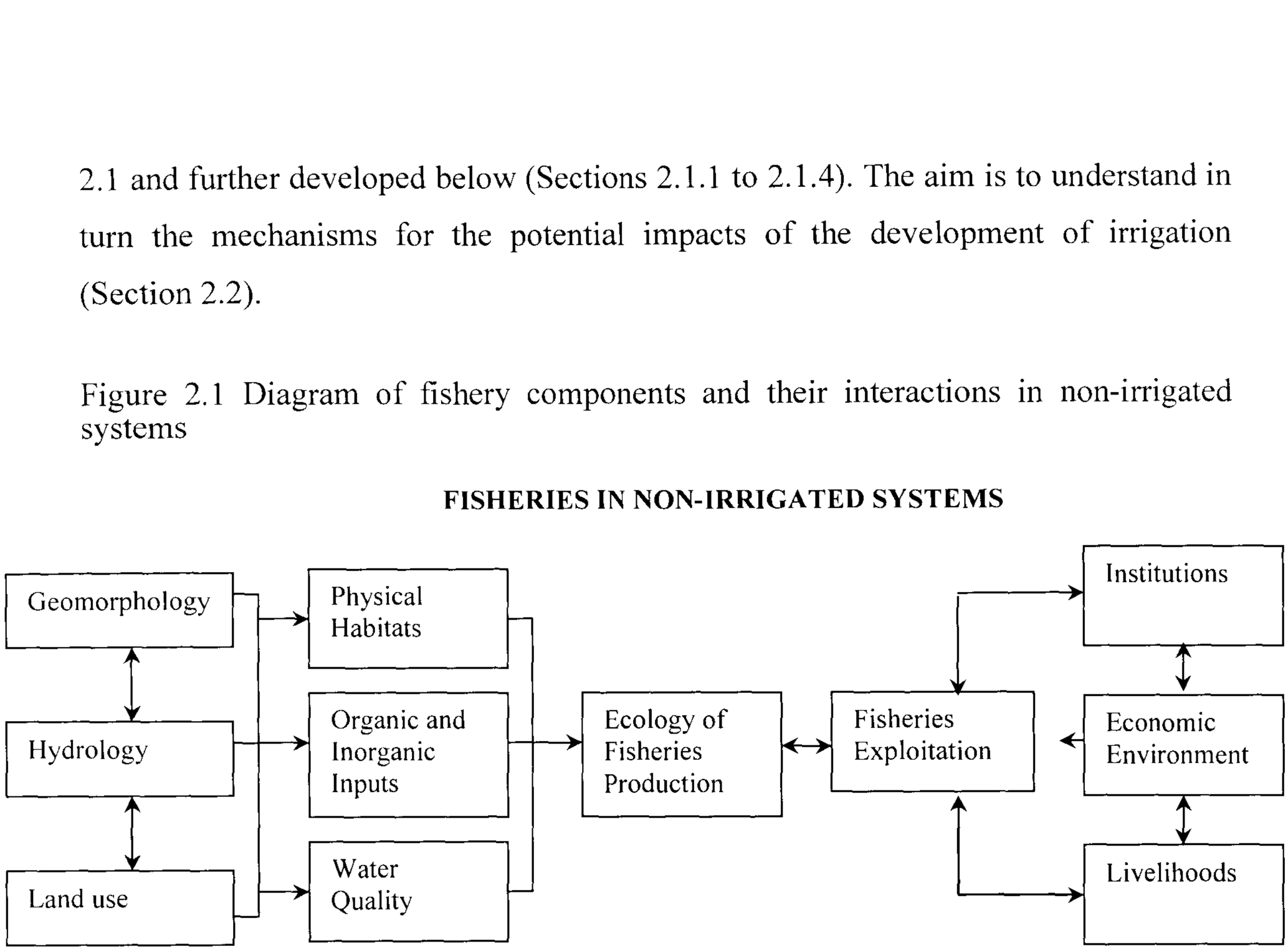
This literature review describes the characteristics of the possible impacts of irrigation development on fisheries and the mechanisms underlying these. While the term impact may have different connotations in terms of value (impact is often taken to imply a negative effect), it will be used as a neutral term in this thesis. The central question asked in this chapter is: why and how does development of irrigation impact on fisheries? In order to highlight the underlying processes of impacts and respective outcomes, the state of knowledge will be assessed in a comparative perspective of fisheries in non-irrigated systems vs. fisheries in irrigated systems. Rather than attempting to list all possible impacts, the focus will be on developing a picture of pathways and impact categories with identification of potential key determinants of impacts on aquatic resource ecology, fisheries production and the livelihoods dependent on these. The management measures proposed to mitigate or enhance the impacts of irrigation on fisheries are also reviewed. Critical conclusions are finally drawn from identification of the strengths and limitations of current knowledge.

2.1 Inland fisheries in non-irrigated systems

Inland fisheries are characterized by their high dependence on the functioning of natural ecosystems and the benefits derived from them depend fundamentally on both their innate biological productivity and the level of exploitation, which in turn depends on a range of biophysical, socio-economic and institutional factors. The state of knowledge regarding fisheries and the biophysical and social environments in which they exist, will be assessed in this review and remaining uncertainties and knowledge gaps identified. Emphasis is placed on key mechanisms that drive the structure and functions of fisheries in non-irrigated systems as illustrated in Figure

2.1 and further developed below (Sections 2.1.1 to 2.1.4). The aim is to understand in turn the mechanisms for the potential impacts of the development of irrigation (Section 2.2).

Figure 2.1 Diagram of fishery components and their interactions in non-irrigated systems



2.1.1 Fisheries in the biophysical environment

The biophysical environment of a catchment or river basin, represented at the left side of the diagram (Figure 2.1), includes the geomorphology, hydrology and land use that influence the physical habitats, the flows of organic and inorganic inputs, and the ecology of aquatic resource production.

2.1.1.1 Physical characteristics of the catchment

The formation of a river basin is a function of the hydrological, geological and morphological processes that have occurred over time and resulting basin characteristics are among the prime determinants of the functioning of aquatic habitats. In particular the hydrological cycle plays a key role in maintaining water levels and flows in aquatic habitats, and in shaping their geomorphology through

erosion, transport and deposition of organic and inorganic inputs from the terrestrial environment. Land use and development activities can significantly affect these natural soil erosion and deposition processes. For example, deforestation and cultivation within the headwaters of the river basin typically give rise to higher levels of soil erosion and sedimentation in rivers.

Aquatic habitats and their physical characteristics

With respect to the ecology of fisheries production, the various aquatic habitats of a river basin may play different ecological functions depending on their physical attributes and the characteristics of the water they contain (fluctuation of water level, velocity, quality of water, etc.). A simple typology of aquatic habitats is drawn here to highlight these different functions.

Ecological studies of fisheries such as by Cowx and Welcomme (1998) have identified the various components of a river basin (river channel, riparian zone, floodplain and alluvial aquifer) and highlighted the linkages between water and land uses in the catchment through marginal zones, in particular the riparian zones (Box 2.1).

The variety of habitats used by aquatic resources and indicated in Box 2.1, means that freshwater, brackish and possibly marine systems need to be considered, since they form the water network on which some fish species life cycles rely (a typical example is given by the diadromous species migrating between freshwater and the sea). Different ecosystems may also need to be considered from upper and lower sections of river basins through to coastal areas including lagoons, estuaries and inshore marine environments. Despite this a dominant feature of the literature is the separate assessment of fresh, brackish and marine environments, similarly of different types of ecosystem within these. Thus adequate knowledge of the interactions between them is often lacking as indicated for most large river systems (Arthington et al. 2004).

Box 2.1 Features of the natural and man-made river and floodplain habitat continuum

Zone		Habitat
Aquatic		
I	Main channel:	Pools
		Riffles
		Point bars
		Islands
		Bank features
II	Estuaries and lagoons characterized by marine influence	
III	Continuously flowing side arms and anabranches	
IV	Side arms connected to river at downstream end only	
V	Seasonally flooded floodplain lakes	
VI	Floodplain lakes rarely influenced by floods	
VII	Man-made reservoirs	
VIII	Man-made canals	
IX	Backswamp areas maintained wet through groundwater seepage	
X	Areas of agricultural land/ marsh/ bottomland hardwood subject to seasonal inundation to an extent dependent on flood intensity	
XI	Rain fed wetlands above the flood level but connected to the river system (principally rice paddies)	
XII	Non-floodable land on floodplain or at floodplain margin. Usually plateau, terrace or levee which directly influence floodplain function	
Terrestrial		

Source: Lorenzen et al. 2004, adapted from Cowx and Welcomme, 1998

In rice farming landscapes, agricultural fields can also constitute significant fish habitats, primarily in lowland and floodprone landscapes. In rainfed or flood recession type farming systems, rice fields can store water and create aquatic ecosystems with many similarities to natural floodplains (Heckman 1979, Welcomme 1985, Lawler 2001). The main differences with regard to fisheries ecology and thus production are that they are designed to retain water from rainfall and/or from inundation by rivers through boundary walls. Hence the intensity of rice production and type of farming practices can have strong influences on the ecology and productivity of fisheries in these habitats (Roger et al. 1991, Kurihara 1989). However, the existing literature relating to such rice field ecosystems, and especially to their biodiversity (e.g. Bambaradeniya & Amarasinghe 2003) is today insufficient to assess these influences.

Flow and distribution of organic and inorganic inputs

The distribution and concentration of organic and inorganic inputs are major determinants of primary production[3] and ultimately fisheries production. These are influenced by the biophysical environment and its dynamic and spatial heterogeneity. For example, in standing bodies such as lakes and ponds fish production is based mostly on the primary production within the lake or reservoir. In streams, rivers and their associated floodplains, fish production may be based at least in part on organic matter produced in terrestrial systems. Terrestrial production derived from the riparian zone and floodplains is thus also acknowledged as a vital source of energy in riverine food webs (Vannote et al. 1980, Junk et al. 1989).

Three main theories have proposed explanations of the main sources of biological production (see Box 2.2), but the precise contribution of such external inputs remains controversial and unresolved.

Box 2.2 Theories of biological production sources

- The **River Continuum Concept** (Vannote et al. 1980) modified for large rivers by Sedell et al. (1989), stresses the importance of organic matter inputs in the upper reaches of streams for downstream productivity, and assumes that primary production in the river makes only a small contribution.

- The **Flood Pulse Concept** (Junk et al. 1989) emphasizes the importance of terrestrial organic matter inputs via floodplains in floodplain rivers, during flood events.

- The **Riverine Productivity Model** (Thorp and Delong 1994) holds that aquatic primary production within the river forms the main basis of fish production. While terrestrial organic matter inputs far outweigh aquatic production in most systems, they are not assimilated by aquatic organisms.

Source: Lorenzen et al. 2004

This scientific debate has implications for the precise nature of linkages between aquatic and terrestrial systems. For example, the River Continuum Concept and Flood Pulse Concept imply that seasonal rivers in nutrient-rich landscapes will tend to be

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[3] Gross primary production is the amount of light energy converted to chemical energy in the form of organic compounds by autotrophs like algae. The amount left after respiration is net primary production and is usually expressed as biomass or calories per unit of area and per unit of time.

more productive than non-seasonal rivers, or seasonal rivers in oligotrophic (nutrient-poor) landscapes. Although the debate is still ongoing, these ecological theories have all stressed and demonstrated the importance of linking aquatic and terrestrial systems in fisheries ecological studies. These linkages should be addressed in the assessment of the impacts of irrigation on fish ecology and fisheries production.

Water quality

Water quality with respect to living aquatic resources is characterized by parameters such as temperature, dissolved oxygen, pH, organic content, salinity, suspended solids and concentrations of toxic substances such as pesticides. Water quality is strongly influenced by land-water interactions as indicated above. Water also plays the role of a transport medium for organic/inorganic matter and chemicals within the catchment. The ecology of aquatic resources is strongly influenced by water quality, and that is why fish community characteristics are often used as indicators of water quality (e.g. Karr & Chu 1999).

2.1.1.2 Ecology of fisheries production

Since the hydrology and biophysical aquatic habitats of a river basin support all the biological functions (reproduction, nutrition, locomotion, etc.) of aquatic organisms, the species exploited by fisheries are closely dependent on the structure and functioning of ecosystems.

Trophic levels of aquatic resource production

Aquatic food webs can be structured through three main trophic levels: the primary producers (plants), the secondary producers (herbivores and detritivores) and the tertiary producers (predators) (Lindeman 1942, Petts 1984). This structure provides a simplified description of ecosystem trophic characteristics that forms the basis for identification of interactions and efficiencies of energy transfers between trophic levels. The literature generally shows that the overall level of productivity, and therefore the potential harvest from fisheries, is strongly influenced by the amount of

primary organic matter available in the ecosystems (e.g. Winemiller 2003, for large rivers).

Diversity of aquatic resources

Numerous ecological studies show the close relationship between the diversity of aquatic resources (taxonomic and functional) and the diversity of aquatic habitats in terms of their nature, function and dynamics (Ward et al. 1999, 2001; Robinson et al. 2002, Winemiller 2003). Notably the diversity of fish species (Tochner & Stanford 2002) and the diversity of fish assemblages (Pusey & Kennard 2000) appear to be strongly linked with the spatial and temporal heterogeneity of aquatic habitats and thus the variability of hydrological patterns. Acting as a buffer between water and land uses and biophysical interaction (Naiman & Descamps 1997), riparian zones also play an important role in the diversity and conservation of riverine aquatic resources (Pusey & Arthington 2003).

The greatest freshwater fish diversity is found in Southeast Asia, tropical South America and central Africa, and it is generally accepted that the diversity of species tends to increase from the poles to the tropics (McAllister et al. 2001). Therefore human development in the tropics (in particular water development projects) is likely to have more significant impact on the biodiversity of aquatic ecosystems.

Habitat requirements during the fish life cycle

Most exploited aquatic organisms have complex life cycles in which migrations serve trophic and life cycle functions of spawning, feeding, nursery and resting, at different morphological free living stages such as eggs, larvae, juveniles and adults (Welcomme 1995). To meet different trophic requirements in the course of their life cycle, the organisms rely on the availability, accessibility and quality of aquatic habitats, and in particular the variety of habitats to meet these varying needs (e.g. Lucas & Baras 2001). As described above and illustrated in Figure 2.1, this is determined by the hydro-geomorphology of the catchment and is related to the use of

land. In addition the movement of fish during the migratory phases of their life cycle requires some degree of connectivity between the various habitats.

Migration patterns may strongly differ between fish species. Some species conduct frequent migrations in their life cycle, for example each season, and others conduct only one major migration in their lifetime (e.g. ocean migration of some salmonid species). Two types of migratory behaviour are often distinguished in tropical river-floodplain fish: some fish migrate upwards in the period of rising water in order to spawn in the headwaters (commonly called "whitefish") while others spawn and feed on the floodplain ("blackfish"). For blackfish, rice fields can serve as important feeding and nursery areas (Coche 1967; Heckman 1974, 1979) as long as they can cross the artificial field bunds (see also Section 2.2.1.3). When water levels fall in rice fields, fish tend to migrate back towards permanent water bodies but many remain stranded or are caught. Hence seasonal rice fields are newly colonized with every flood and do not usually support resident fish populations.

Another characteristic insufficiently considered in the effects of physical changes on fish ecology is that some species may display considerable 'plasticity', i.e. they can develop a mechanism of adaptation to environmental changes. As a result they can cope well or even benefit from changes in habitat availability (Lorenzen et al. 2004). For example, while some migratory species are unable to complete their life cycles if they are prevented from conducting their normal migrations, others may adapt their life cycles and, for example, form breeding populations in reservoirs if migration to lower reaches of rivers is blocked by dams. Although knowledge of life cycle plasticity is highly relevant to the studies of irrigation impacts, there are as yet few generalizations. Some relevant information is available, in particular for the Mekong River Basin (Warren et al. 1998, Baird et al. 2000, Baran & Baird 2001).

Fisheries characteristics and yields of different habitat types

The close dependence of fish ecology on the physical environment means that aquatic habitat characteristics are strong determinants of fisheries production. Studies have identified the main biophysical factors and although detailed mechanisms of production are still uncertain, key drivers are reasonably well defined (see Table 2.1). Notably the relationships between river discharge and fisheries production (in-river) (Welcomme 1985), and between river discharge and coastal fish production (e.g. Loneragan & Bunn 1999) have been established. This knowledge can support assessments of fisheries production at different spatial scales - from each type of water body to catchment and river basin levels (aggregate of all aquatic habitats concerned) - and comparative analyses of changes in irrigated and non-irrigated systems.

Table 2.1 Main biophysical determinants of fisheries production per aquatic habitat

Aquatic Habitats	**Main factors determining production**
Rivers without floodplains	Dependent on, and predictable from drainage basin area
River-floodplain systems	Strongly dependent on, and predictable from flooded area. Areas subject to seasonal flooding that are entirely cut off from permanent water bodies will not support significant fisheries production.
Estuaries and lagoons	Dependent on nutrient inputs from the river, depth and accessibility from the sea. Total production is not strongly influenced by salinity, but production of individual species may be (Joyeux and Ward 1998).
Lakes and lacustrine wetlands	Dependent on nutrient inputs, depth and residence time. Lakes and wetlands in agricultural or densely inhabited catchments receive higher nutrient inputs and tend to be more productive than those in forested catchments. Areas subject to seasonal flooding that are entirely cut off from permanent water bodies will not support significant fisheries production
Rice Fields	Traditional rice systems can support very productive fisheries as long as they provide temporal or permanent aquatic habitat. Whilst seasonal rice fields do not support resident fish populations, they are newly colonized with every flood. Production also depends on access of fish to the rice fields, along the drainage lines (the principal migratory pathways), and in natural streams and wetlands.

Adapted from Lorenzen et al. 2004

Ecosystem response to change: compensatory effects

The abundance of aquatic animal production is naturally regulated in that its level matches to the carrying capacity of the environment through a variety of mechanisms including density-dependent mortality, growth and reproduction. Populations can also compensate for loss of animals due to pollution and other environmental catastrophes, although compensation may not be complete. The precise nature and extent of compensatory mechanisms is a subject of controversy and a major area of ongoing research (Rose et al. 2001).

Compensatory mechanisms can also arise at the species assemblage or ecosystem level through inter-species interactions. For example if the abundance of one species is depressed by high levels of fishing, or loss of access to a crucial habitat, the abundance of its prey and/or its competitors may increase and maintain or even enhance the combined biomass of aquatic animals. The result of such interactions is that the overall fisheries yield obtainable from aquatic systems tends to be far more resilient to external pressures than the species make-up of assemblages. This can particularly be the case for tropical inland waters where multi-species fisheries are common.

Although the existence of such mechanisms is crucial to the sustainable exploitation of aquatic resources and to their responses to environmental modifications such as irrigation, they have rarely or inadequately been taken into account in irrigation impact assessments and cost-benefit analyses (see further development in Chapter 4, I.). Despite limitations in current knowledge, and in the ability to assess such changes, principles can be set. For example: i) the occurrence of compensatory processes implies that a reduction in the availability of habitat without direct reduction in population abundance is likely to lead to increased mortality and/or reduced growth and reproduction in fish populations, and ii) while entire compensation may not be possible when virgin ecosystems are involved, overall impacts of irrigation might be

less than anticipated at a species level, and for the combined biomass of aquatic resources (Lorenzen et al. 2004).

2.1.2 Exploitation of aquatic resources

The production of fisheries depends on the productivity of aquatic resources as determined by the biophysical environment (Section 2.1.1) and on the exploitation of the resource. In a single species fish stock, fish abundance is approximately inversely related to the level of fishing effort. As abundance of the stock is decreased, compensatory mechanisms increase biomass production but there are limits to the compensatory processes and eventually production will reach a peak and decline if effort is increased further. Many fisheries, particularly in the tropics, exploit a wide range of species. In such multi-species fisheries, the relationship between total effort and total yield tends to be asymptotic (see for example, Hoggarth et al. 1999, Welcomme 2001).

The level of exploitation results from the degree of fishing effort[4] applied in the aquatic habitat and the efficiency of the gear(s) used. The determinants of fishing effort in turn depend on the productivity of the aquatic habitat exploited, the accessibility of fishing grounds, the aquatic species targeted, the fishing techniques used, and on the seasonality of the activity. As illustrated in the fishery diagram (Figure 2.1), the level of fishing effort also depends on rural livelihoods and their socio-economic environment, as developed below (Section 2.1.3.2.).

Aquatic habitat exploited

Empirical relationships have been established and the anticipated levels of fisheries productivity can be defined per category of aquatic habitat (Table 2.2). Exploitation

[4] Fishing effort (or effort expended on fishing) is a quantitative measure of the level of exploitation of an aquatic resource. It is a key determinant of yields (or amount of catch).

of resources supported by these aquatic habitats also depends on their physical and institutional accessibility (see below).

Table 2.2 Empirical estimates of fisheries productivity (mean and range) of different aquatic habitats. Note different area measures used for different habitats.

Habitat	**Area measure** ha	**Productivity** kg/ha	**Reference**
River without floodplains	Catchment area	0.3 [0.06-0.57]	Welcomme 1976
River floodplain	Maximum flooded area	80 [7-186]	Bayley 1988
Rainfed rice fields (Laos)	Rice field area	60 [4-230]	Lorenzen et al. 2000
Estuaries and lagoons	Average water area	100 [4-2200]	Joyeux & Ward 1998
Reservoirs (Sri Lanka)	Average water area	220 [40-500]	De Silva 1988
Small reservoirs (Laos) ▪ Non-managed ▪ Enhanced and managed	Average water area	 100 [36-176] 250 [50-550]	Garaway 1999

Source: Lorenzen et al. 2004

Accessibility of fishing grounds

Although most inland fisheries tend to be accessible to everyone, there can be physical or institutional barriers which restrict access to all or parts of aquatic habitats (see also institutional arrangements, Section 2.1.3.1), e.g. the seasonal restriction of access to a lake. This has implications for livelihoods (see also Section 2.1.3.2), and a fact that is not generally recognized is that access to fisheries resources at critical times of the year or close to the dwelling may be more important than overall levels of production. In general access rules can be used as a management tool to regulate the fishery (for example, see Hoggarth et al. 1999, for Asian floodplain fisheries).

Aquatic species targeted

Many fisheries, particularly in the tropics, exploit a wide range of species. The aquatic species, including crustaceans and snails, targeted (or not) can vary a lot between regions and countries. In some areas such as the Mekong basin, virtually all macroscopic organisms are exploited (e.g. Gregory & Guttman 2002) while in others such as inland Sri Lanka, a very limited number of fish species may be the focus of

exploitation (e.g. Amarasinghe 1998). In addition different households and different people within households may exploit different resources.

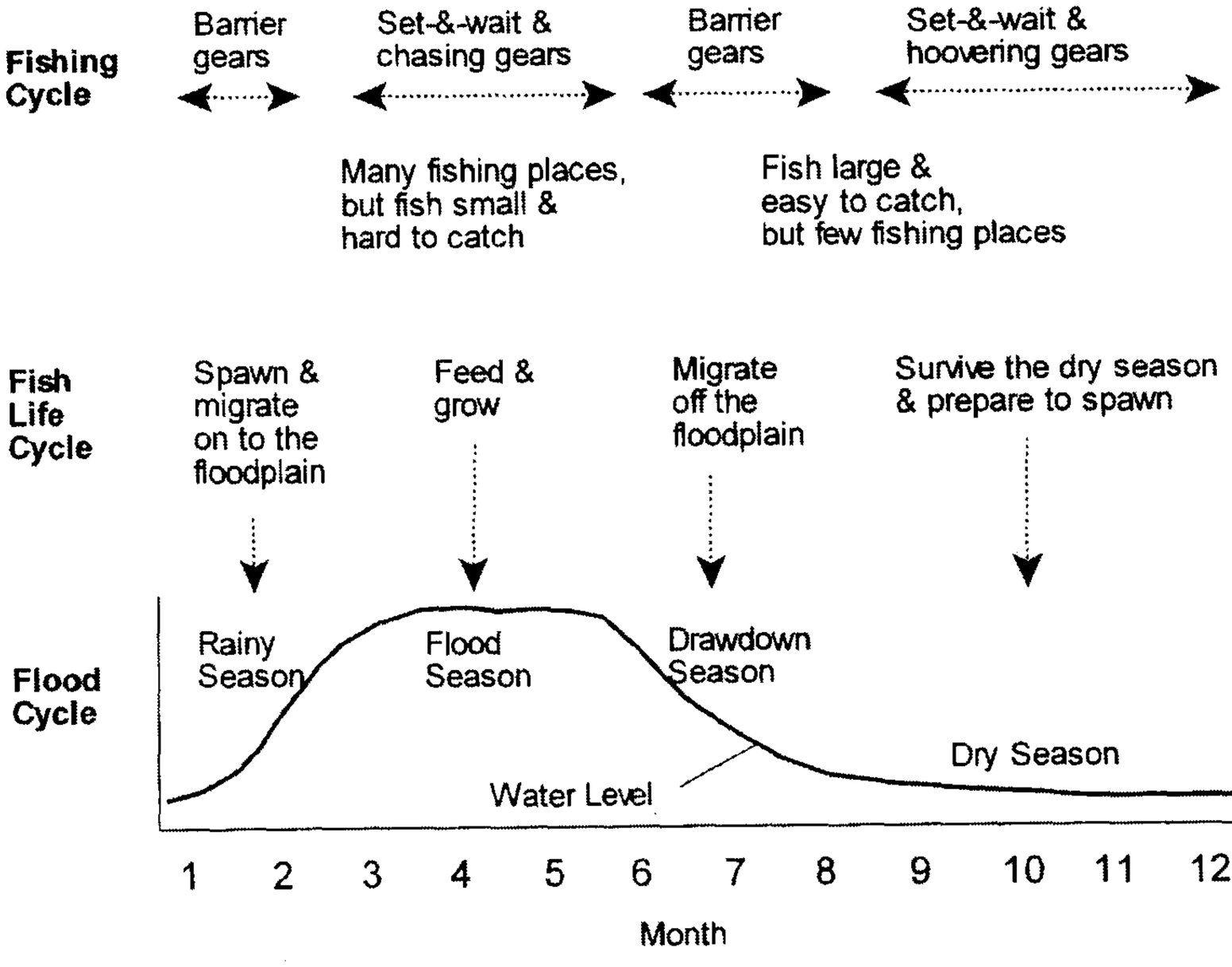
Fishing techniques used

Fishers can use up to 20-30 different methods to catch fish depending on the season, the species targeted and the characteristics of the fisher (gender, age, etc.). For example, Von Brandt (1984) provides a summary list of fishing gears. The efficiency of gear is primarily related to biophysical factors (characteristics of fishing ground, aquatic resource populations), but a range of cultural and economic factors may determine which gears are available to different categories of fishers.

Seasonality of the activity

Inland fisheries, particularly floodplain fisheries, are often most productive during the rise and fall of floods during the beginning and end of the wet season (see for example, Hoggarth et al. 1999). Fishing space and access to a fishery also become scarcer during the dry season and this may force some fishing households to seek alternative sources of income during this period. While the natural biomass production occurs mainly during the flooded period, much of the catch is achieved during the down-migration (Figure 2.2).

Figure 2.2 Relationship between seasonal cycles of flooding, fish biology and fishing in tropical river-floodplain systems



Source: Hoggart et al. 1999

2.1.3 Fisheries in the social environment

In the thesis, the attribute 'social' (in 'social environment' and 'social system', Section 2.2.4) is defined as encompassing all institutional, socio-economic and livelihoods factors. These are illustrated at the right side of the fisheries diagram (Figure 2.1).

2.1.3.1 Institutions

Institutions are generally defined as organizations, or mechanisms of social structure, governing the behavior of two or more individuals (e.g. Greif & Laitin 2004). They range from formal rules (for example, property rights, laws) through to informal

prescriptions (e.g. norms, taboos) that permit, prohibit or require certain actions or outcomes while specifying the sanctions for breaking rules (Crawford & Orstrom 1995). Institutional arrangements can determine the regime or nature of property rights in order to regulate the exploitation of resources (e.g. Orstrom 1990, Pomeroy & Berkes 1997, Neiland 1997). Rules also need to be adapted to local circumstances so that rule compliance is perceived to be beneficial by all concerned.

Such institutional arrangements are of particular relevance to inland fisheries for which a key characteristic is that the resources exploited, i.e. aquatic resources and water (their support), are usually common pool resources that are under the regime of common property or open access. The latter regime is more likely to lead to overexploitation, the well-known 'Tragedy of the Commons' as characterized by Hardin (1968) and further analysed by Ostrom (1990).

Although the institutional arrangements and management requirements for common pool resources are addressed by an extensive literature, guidance relevant to the diverse and dynamic nature of aquatic habitats remains lacking. For example, the institutions needed to regulate access to a perennial fixed boundary lake, a river where the mobility of the resource (migratory species) is important, or to water bodies with dynamic boundaries (e.g. floodplain area, oxbow lakes and seasonal ponds depending on the extent of flooding) may be quite different in form and scope.

This difficulty is compounded when the issue of scale is considered, and the conservation needs of an individual species, fishery or ecosystem must be protected. For example, the contrast between seasonal restrictions to protect a migrating species at choke points and the basin-wide pattern of regulation needed to protect a fishery and the ecology that sustains it at the level of a river basin. Petr (1985) for example, identified the lack of a coordination river basin authority as a major constraint to conservation of fisheries in three major basins of Central Asia.

2.1.3.2 Socio-economic environment and livelihoods

Socio-economic environment

A list of situational factors is given in Lorenzen et al. (2004). These include:

- the economic and policy environment, which through the level of market development and market conditions will influence opportunities and incentives for either fishing or alternative livelihoods;
- the institutional environment and power relations, influencing access to resources and the distribution of the benefits and costs of change;
- the degree of empowerment and effective participation through which people themselves can influence the nature of outcomes.

Rural livelihoods

On one hand fishing activity is embedded in rural livelihoods where it can play a variety of roles, on the other hand the characteristics of rural livelihoods influence the exploitation patterns of fishing. For example, the determinants of fishing effort originate both from rational biophysical and economic choices, and subjective reasons (cultural, traditional, etc). In addition livelihoods are dynamic, evolving in response to economic and social development and to the changing constraints and opportunities that this creates. Determination of the impacts of irrigation on fisheries thus implies proper understanding of the role or roles (in terms of contribution and function) fisheries play in rural livelihoods. For this purpose the livelihoods concept has proved useful in assessing the diversity of roles that fishing can play in rural livelihoods.

The literature reviews conducted by Allison and Ellis (2001) and Béné (2003) highlight the common perception that households who specialise in fishing will be a recognisable and distinct social group, and one that is typically among the most deprived and poorest. Indeed inland fisheries require relatively few resources from those exploiting them, making them accessible and often important in the livelihoods

of poor people. However fishing can also range from such an activity of last resort in hard times or for the poorest sections of the population (Jul-Larsen & van Zwieten 2002, Béné 2003), through a part-time use of surplus labour (often complementary to farming), to a specialised and wealth generating activity when returns are high (Smith et al. 2005). The latter authors conclude that fishing can provide a primary source of income, a supplementary source of income or own food production, or a means for exchange by barter or in reciprocal social networks (Table 2.3).

Scudder and Conelly (1985) described the evolution of fisheries from a traditional to a commercial state through four stages: 1) primarily subsistence, 2) semi-commercial, 3) primarily commercial and 4) marginalized. The last category may result from overexploitation, impact of other sectors and/or inappropriate management. The socio-economic gap between a majority of small-scale fishers and a minority of successful entrepreneurial fishers may also widen, and women often become excluded from the sector.

Table 2.3 Livelihood functions of fishing as household incomes rise and livelihood strategies develop

Livelihood strategy	**Livelihood functions of fishing**
'Survival'	• Subsistence (food production and income) • Nutrition – protein, micronutrients, vitamins
'Semi-subsistence' diversification	• Own consumption – food security and nutrition • Complementarities in labour use with farming • Means for barter, or for participation in reciprocal exchange and social networks • Occasional cash source • Diversification for: o labour and consumption 'smoothing' o risk reduction o as a coping strategy/buffering against shocks.
'Specialisation' (as fishers)	• Market production and income • Accumulation
'Diversification for accumulation'	• Accumulation • Retention in a diversified accumulation strategy. • Recreation

Source: Smith et al. 2005

Again contrary to common perceptions, the literature shows that fishing is most often a part-time rather than a specialized activity (e.g. Kremer 1994, Smith et al. 2001, Béné & Neiland 2003). For example, only 20-30% of the total catch comes from full-time fishers in the floodplains of Bangladesh. Across Asia, part-time fishers have other occupations (often seasonal) although fisheries remain an essential component of their livelihoods (Chong et al. 2003). In this livelihood strategy fishing is an "opportunistic endeavour" (Allison & Ellis 2001) to which effort allocated can be very flexible according to the inputs available (primarily labour) and in response to returns to be made (Smith et al. 2005).

Despite the potential significance of these issues, only few studies (e.g. Allison & Ellis 2001, Béné 2003, Neiland & Béné 2003, Smith et al. 2005) have taken account of the diverse functions that fisheries can perform in rural livelihoods. These studies have highlighted the importance of rural livelihood determinants for the effort expended on fishing and thus on the catch and production of fisheries. These location specific factors need to be analysed in the context of socio-economic development at project level and at wider scales for the local or regional economy.

2.1.4 The fishery system

The review of the components of the fishery system has shown that the ecology of fisheries production and the exploitation of aquatic resources depend on both the biophysical and social environment (see the fishery diagram, Figure 2.1). However the literature generally does not encompass all attributes of the fishery system nor reflect the overall processes and dynamics that lead to outcomes in fisheries (the guidance manual by Lorenzen et al. 2004 is a notable recent exception). This can have important implications for the assessment and management of the fishery system.

As described in Sections 2.1.2 and 2.1.3, the biophysical characteristics of an aquatic habitat may not be the only driver of production, and socio-economic and livelihood

factors may equally (if not more so) influence the level of production and characteristics of fishing effort (this is exemplified by the quantitative assessment in Laos, Chapter 3). As a result the exploitation of aquatic resources may have detrimental impacts on the environment through depletion of fish populations and removal of species with respective consequences on the biodiversity of the ecosystem (Welcomme 2001, Pauly et al. 2002).

Consequently objectives of fisheries production and environmental conservation are not always co-terminous. For example, the loss of certain habitat types or habitat connectivity may cause a loss of biodiversity or ecological integrity without strongly affecting overall production levels while conversely, a quantitative reduction in the extent of habitat may cause a proportional decline in fisheries production without great loss of diversity (Lorenzen et al. 2004). Therefore there may be cases where trade-offs between the objectives of production and conservation will be required.

Implications for the management of fisheries can thus be two-fold. On one hand, the need for sustainable fisheries may provide strong incentives for the preservation of aquatic habitats and the ecosystem. Where this is the case, fisheries can bridge the generally perceived dichotomy between the production of food and the preservation of the environment. On the other hand, the need to increase fisheries production (in particular for improving the livelihood of fishing dependent households) may lead to fisheries enhancement measures and the development of aquaculture, and these are likely to have damaging effects on the environment (see also Section 2.3.1).

2.1.5 Conclusions on fisheries in natural systems

The main biophysical processes of fish ecology and fisheries production have been extensively covered by hydrological and ecological studies. Emphasis has been placed on the importance of aquatic habitats in terms of their nature, dynamics and spatial distribution, as driven by hydro-geomorphologic processes and land use. This

background knowledge provides a reasonable understanding of the key processes likely to be involved in the impacts of irrigation on fisheries, and the main determinants of their outcomes.

Several points of attention have also been raised and they have informed the study design and interpretation of results for the case studies (Chapters 3, 5 and 6). The main points are summarized as follows:

i) In principle, the ecological requirements of aquatic resources make them especially vulnerable to modifications of aquatic habitats as a unit (in terms of quantity and quality of water) and as a network (in terms of connectivity between habitats).

ii) The variety of aquatic habitats and their characteristics and functions (including their dynamics) need to be considered.

iii) The degree to which fish depend on migration for completion of their life cycle should be considered as well as the plasticity of some species (though difficult to evaluate). This may change the estimated magnitude of impact, typically meaning that it may be lower than initially expected.

iv) The importance of the land-water interface has been highlighted through various mechanisms of fisheries production: the quality and availability of aquatic habitats, the ecological role of land-water interfaces such as ecozones, and the influence of land use on the productivity of aquatic resources through distribution of terrestrial inputs and impacts on the quality of water.

The review of social attributes has highlighted the role and importance of fisheries in rural livelihoods, and the influence of the socio-economic and institutional environment at various spatial scales. This suggests that fisheries in livelihoods must be understood and assessed in broader terms than just income, including for example, the benefits and seasonality of fishing for livelihood diversification, for nutrition, as a ready source of cash, and for their role in cultural and social networks and in the local economy. Impacts of irrigation on the socio-economy and rural livelihoods may be as

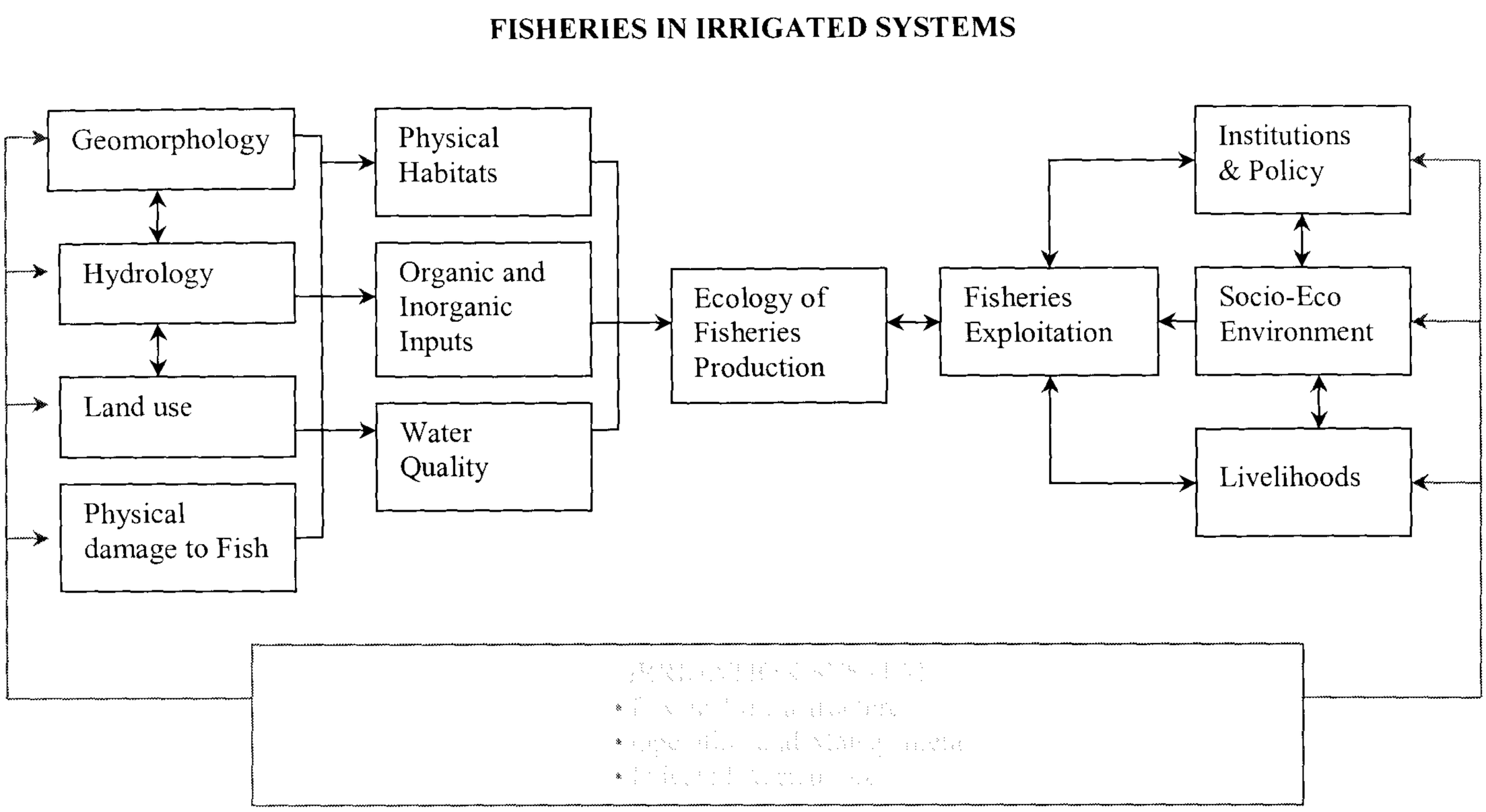
important, if not more so, than biophysical impacts. These conclusions support the need to cover and understand the whole fishery system, and to assess the fishery components and their respective dynamic and interconnections.

2.2 Fisheries in irrigated systems

In this review the definition of irrigation systems covers the infrastructure of irrigation, its operation and management, and the associated irrigated agriculture. Irrigation systems are designed to supply and remove water to match the water demands of crops, either as a supplement to rainfall in humid zones or as the main source of water in arid zones. These systems are specifically designed to increase agricultural production, and their management aims to achieve an efficient spatial and timely distribution of water to agricultural fields. The preservation or enhancement of fisheries is not usually an objective of irrigation development.

The development of irrigation systems may impact most aspects of the local fisheries system: the biophysical characteristics of aquatic habitats, the ecology of fisheries production, the exploitation of aquatic resources, the livelihood functions that fisheries provide, and their socio-economic and institutional context. Drawing from the illustration of the fishery system (Figure 2.1), the diagram presented in Figure 2.3 incorporates the introduction of irrigation and potential pathways of impacts on fishery components. This framework illustrates potential linkages (arrows in the diagram) between the attributes of irrigation and fishery systems, and offers a structure to review the mechanisms underlying impacts of irrigation on fisheries.

Figure 2.3 Diagram of fishery components and their interactions in irrigated systems



2.2.1 Biophysical impacts

Mainly represented on the left side of the diagram (Figure 2.3) biophysical impacts refer to the physical changes and their consequences on the ecology and diversity of aquatic organisms, and on the ecosystem supporting their life cycle. Based on the framework proposed in Figure 2.3, the literature on key mechanisms of biophysical impacts and respective main outcomes is reviewed in this section.

2.2.1.1 Physical damage to aquatic resources

Fish populations may be directly physically impacted by the development of irrigation in particular by the introduction of irrigation infrastructure in the ecosystem. During their downstream migration fish are subject to various forms of stress like

shocks from the turbine, sudden variations in velocity, pressure and cavitation, and mortality can be significant (Larinier 2000). Fish may also be entrapped in the irrigation network of gravity flow systems, and screening is sometimes used to reduce entrapment (e.g. Larinier & Travade 1999, see also mitigation measures, Section 2.3.1). Indirectly fish that are shocked and disoriented after their passage through the main infrastructure, and fish that are delayed in the tailwater, are more subject to predation.

2.2.1.2 Changes in the geomorphology, hydrology and land use

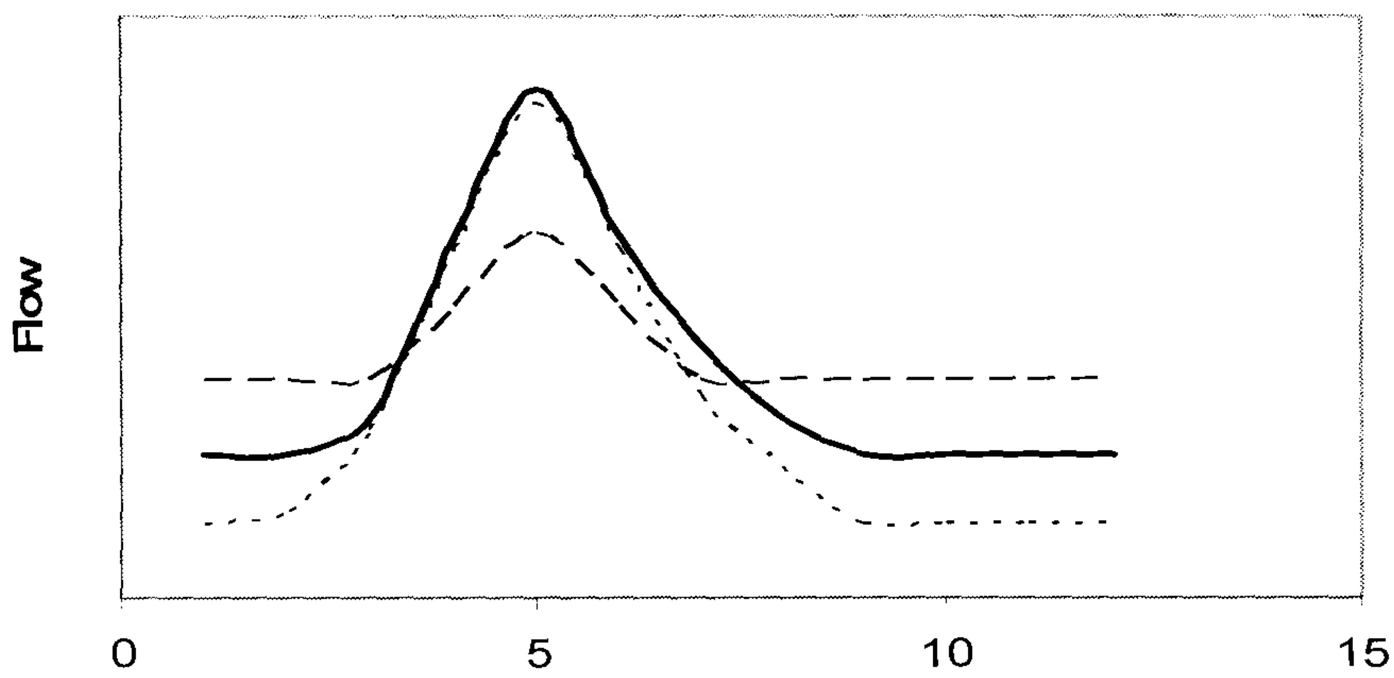
The hydro-geomorphology of a river basin and water quality have been considered key to biophysical impacts of irrigation, as they are the underlying mechanisms by which aquatic habitats and the distribution of organic and inorganic matter inputs are modified (e.g. Naiman et al. 2002). The development of irrigation affects the natural hydrology, soil erosion and sediment transportation or deposition processes that are significant in the geomorphology of a river basin, channels, floodplain and delta/estuaries. Irrigation systems, in particular the infrastructure, can significantly affect the geomorphology of aquatic habitats especially through direct effects on the distribution and transportation of sediment (see Section 2.2.1.3). Geomorphologic changes also result from modifications in hydrological processes and land use. The main changes are reviewed below.

Modification of river flow and flood regimes

In order to allocate water to agricultural fields, irrigation schemes abstract or divert a large proportion of the annual flow from rivers (particularly large storage dams). This primarily affects the dynamics and diversity of the fluvial hydrosystem (as defined by Cowx & Welcomme 1998, see Section 2.1.1.1) in terms of magnitude, duration and timing of flow discharge and flooding events. Overall the total annual flow of the impacted river is reduced (e.g. WCD 2000).

Dams and weirs have different effects on the flood hydrograph (Figure 2.4). Dams store a significant proportion of the high flow and release water into the irrigation structures during the low flow (dry season). Hence they attenuate the natural flow patterns and smooth the seasonal flood hydrograph. They also retain a large share of peak flows leading to a significant storage of water in reservoirs (see also below). Weirs are relatively low structures that abstract water from streams or small rivers without storing a significant amount of water. Although peak flows are not much affected, the low flows are much reduced by abstraction of water mostly during the dry season when irrigation demand is highest.

Figure 2.4 Impact of irrigation schemes on river flow below the intake structure



Non-impacted river (heavy solid line); Dam irrigation scheme (dashed line);
Weir or pump scheme (dotted line)

Source: Lorenzen et al. 2004

Irrigation scheduling (for timing and volume of water discharge) based on crop water requirements may disturb the natural triggers of migration when, for example, flows or floods are induced by dam releases during the dry season. Aquatic organisms, particularly migratory fish species in rivers are highly sensitive to these modifications of hydrological regimes. For example in rice farming landscapes, many fish species

migrate into rice fields at the beginning of the wet season and return to permanent waterbodies as water levels decline (Coche 1967, Fernando 1993, Meusch 1996).

Variations of river flows and flood regimes may affect fish migrations because these are mostly triggered by meteorological and/or hydrological conditions such as rainfall and/or level of discharge (Halls et al. 1998, Welcomme & Halls 2004). However it is not well understood which of these hydrological factors (be it river flow, flooding and/or water level) act as key triggers since all occur around the same time in natural river-floodplain systems. Yet the identification of trigger(s) could be key to adjusting irrigation operation and management for facilitating fish migration throughout the irrigated landscape.

Irrigation systems may also be designed to control the extent and magnitude of flooding, with additional embankments along rivers and possibly regulators particularly in rice fields. The objective is to prevent water from entering the floodplains at high flow while retaining water in the floodplains at low flow. The implications of the irrigation system on fish migration and water level fluctuations in the downstream floodplain have been extensively studied in Bangladesh within the wider Flood Action Plan Program (FAP 17, 1995). Of particular relevance in the study of impacts on fisheries, the dynamics of fish population has been modeled in relation to flooding patterns (Halls et al. 1998; see also Chapter 4, Section 4.1.1.2).

Storage and distribution of water

Dam and to a lesser extent weir irrigation schemes, result in the flooding of entire sections of rivers that are transformed into water storage impoundments and thus lose their riverine character. Part of the water stored will return to the river and other wetland habitats as irrigation drainage or seepage, and the net effect on river flow and water availability for aquatic habitats is generally a decrease in the wet season but an increase in the dry season. In the case of drainage, wetland areas are reduced overall but river and stream flows possibly increase in the wet season. However the

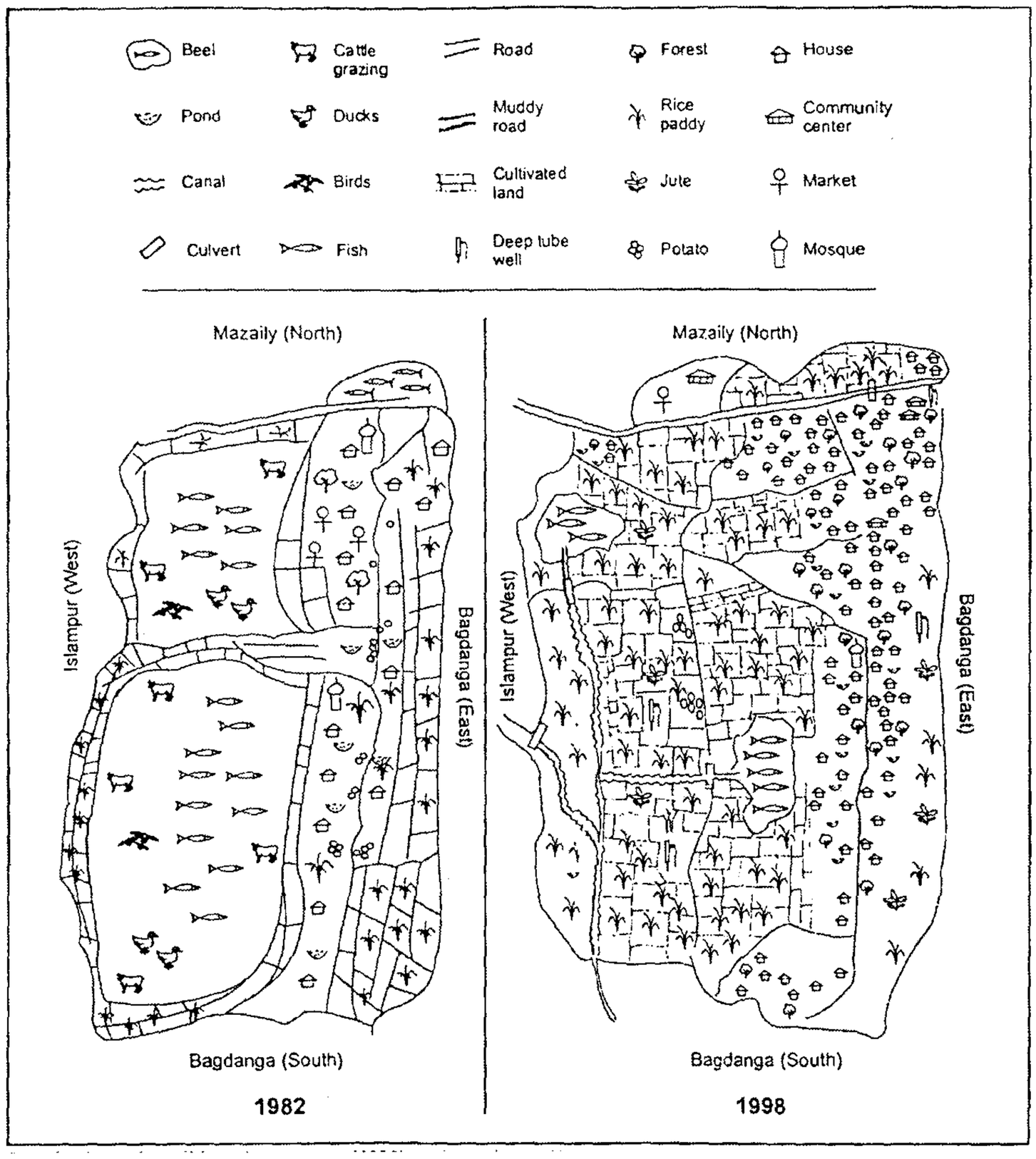
percentage of return flow from irrigation systems is relatively small and the total depletion of water by irrigation is much higher than with industry or domestic water supplies. Substantial amounts of the diverted water are returned to the atmosphere through direct evaporation (especially from reservoirs) and indirect evapotranspiration from crops (e.g. Molden 1997).

The water diverted by the irrigation scheme is distributed to the fields through other structures, mainly irrigation and drainage canals and a variety of smaller structures to facilitate and/or regulate the distribution of water e.g. culverts, aqueducts to pass the canals across obstructions, drop structures and outfalls. Canals and drains can provide aquatic habitat and migration pathways as long as their hydrological and biophysical characteristics are suitable to the living of aquatic resources (see Section 2.2.1.3), in particular fish life cycles.

Land use

In the irrigated area, the development of agriculture is likely to increase cropping intensity, reduce wet season storage in rice fields, and increase drainage of wetlands. As a result rice landscapes may be turned from aquatic into mostly terrestrial habitats (see for example Figure 2.5) affecting the availability of aquatic habitats but also the quality of water and distribution of organic and inorganic matter inputs. On the other hand irrigated fields provide aquatic habitats during the dry season. The ability to contribute to the ecology of fisheries production depends on their connectivity with the river-floodplain, the fluctuations of water level and their water quality as further developed in the next sections.

Figure 2.5 Land use change following the development of a flood control drainage and irrigation scheme Bangladesh



Source: Mazumder & Lorenzen 1999

2.2.1.3 Changes of physical habitats, organic/inorganic inputs and water quality

Changes in hydro-geomorphology and water quality modify the physical landscape, water levels and flows in aquatic habitats, the geomorphology of habitats, and the distribution of organic and inorganic matter inputs throughout the catchment.

Loss of natural aquatic habitats

Irrigation development tends to reduce the extent and carrying capacity of initial aquatic habitats such as the river downstream, the floodplain, oxbow lakes, ponds, and streams. Especially where dams are constructed for water storage, the river and floodplain downstream of the scheme is likely to be reduced, and much of the natural floodplain habitat in the command area will be converted to irrigated fields (see also Section 2.2.1.2).

Abstraction of the dry season river flow (up to complete abstraction) can also break the longitudinal and/or lateral connectivity of the natural water network downstream of the irrigation scheme. In particular reduced river flow and flooding may isolate floodplain habitats from the river and, especially with irrigation systems associated with flood protection measures, the reduced flooding may permanently isolate floodplain habitats. Infrastructure for water distribution and removal system such as canals, drains, culverts and bridges across drainage lines, and access roads may also break or reduce the lateral connectivity of the floodplain, and the longitudinal connectivity in small tributaries.

Aquatic habitats created by irrigation systems

Along with causing these losses, irrigation systems will also create a range of aquatic habitats, such as reservoirs (in dam storage irrigation), canals and drains, and possibly agricultural fields especially rice fields, where minimum water levels are maintained most of the cropping season. Return flows may also establish some habitats where water was not available before irrigation, particularly in the dry season. Where significant the habitats created by irrigation can provide partial or full compensation for the loss of fisheries production and especially in dam irrigation projects, reservoir fisheries are one of the frequently claimed benefits of impoundments (McAllister et al. 2001).

Storage reservoirs create large aquatic habitats similar to lakes but with major differences with regard to water fluctuations and flooded vegetation. Many studies have shown that reservoirs provide suitable habitats for aquatic resources (e.g. Bernacsek 1984, Amarasinghe 1998) and they may offer a good opportunity for developing a fishery, and eventually for enhancing fish stocks (see also Section 2.2.1.4). However the management of reservoir water, in particular the degree of water drawdown in medium and small-scale reservoirs may significantly affect the suitability of reservoir habitat to fisheries. For example too frequent (and thus also a-seasonal) and extreme water level drawdowns are likely to threaten aquatic life and the sustainability of fish populations. The development of agriculture water use may subsequently increase beyond that envisaged at the planning stage further reducing downstream flows or reservoir water levels and in extreme cases, storage reservoirs can be completely drained (as for example in the Sri Lanka case study, Chapter 6).

The ability of canals and drains to support aquatic resources depends on their size, shape and hydrological characteristics, and the quality of the water they convey. In principle the more similar to natural habitats they are, the more suitable to aquatic resource ecology they are likely to be. Canals often provide relatively poor habitats because they tend to be uniform, aligned or with straight sections connected by curves, and clean (or at least with little vegetation), whereas aquatic organisms generally prefer sinuous channels with some vegetation. Natural drainage channels that are often earthen and sinuous, though often realigned to straight sections connected by curves, generally offer better physical habitats because they can maintain a variety of fish habitats (with vegetation, woody debris, shade, etc.) and ecological functions.

During maintenance the removal of vegetation and sediment from canal and drain embankments for increased irrigation performance and efficiency, can reduce shade and food availability and may thus degrade the ability of these aquatic habitats to perform ecological functions (for shelter, spawning grounds, nutrition and growth, etc.). The hydrological characteristics of canals and drains can also be limiting factors. For example, the flow velocity and retention time in the distribution and removal

water network are often inadequate and in particular small canals that convey water only intermittently cannot offer suitable habitats.

Distribution of organic and inorganic matter inputs

Irrigation development modifies the transportation and deposition of organic and inorganic matter inputs throughout the catchment. Longitudinally the irrigation scheme (especially dams and reservoirs) block or reduce the flow of sediment from the catchment (downward) and laterally irrigation canals and flood embankments prevent the transportation and deposition of sediment onto the floodplain. The accumulation of sediment near the infrastructure tend to reduce the carrying capacity of the water body and silt-laden flows may affect the ecological functions of habitats, e.g. fish breeding, nursery or overwintering habitat in rivers. During maintenance, the sudden release of large quantities of fine silts and clays can have catastrophic effects on fish populations (McCartney et al. 1999).

Irrigation systems such as dams also interrupt the downstream transport of nutrient and organic matter and associated reservoirs act like a nutrient trap (Tolmazin 1979). This may drastically affect the amount and timing of nutrients available downstream (e.g. nutrient trapping by Lake Nasser reservoir, Egypt; Halim et al. 1995), affecting fisheries production downstream of reservoirs (Welcomme 1985), river channels (Hess et al. 1982) and estuarine and marine environments (Ryder 1978). Conversely the increase of nutrient concentration in water bodies as a result of land use and agriculture development (see Section 2.2.1.2) can lead to eutrophication of water bodies and subsequent reduction of fisheries production.

Water quality

Through the processes described above, irrigation development changes the quality of water mainly in terms of sediment load, nutrient enrichment or impoverishment, agrochemicals inputs and variations in water temperature, affecting aquatic life in various ways. The increased turbidity of water affects biota directly with algal

development attenuated by inorganic particles and indirectly through decreased photosynthesis and reduced primary production. Also the reduction of water transparency may change the extent of movement of fish and feeding behaviour throughout the riverine landscape (Jordan & Arrington 2001).

Irrigation development tends to trigger the intensification of farming activity and thus usually increases the use of fertilisers and pesticides. The higher concentration of agrochemicals in drainage water increases the risks of toxicity to aquatic resources and cause food safety hazards to fish and end consumers, i.e. mainly birds and man (see for example, Brigham 1994, Key et al. 2003, Petr et al. 2004) but the level of toxicity is not yet defined for most species.

Concluding remarks

This review of physical habitat changes shows that the net effect in the extent and volume of aquatic habitats can be positive or negative. Despite this fact, most impacts of irrigation are not assessed through the comparison and net balance of gains and losses per category of aquatic habitat at catchment and river basin levels. The focus has tended to be on particular aquatic habitats, notably the reservoir (in terms of gain and enhancement measures) and the river (usually in terms of loss and mitigation measures), potentially underestimating the positive and negative changes in other aquatic habitats within the catchment and river basin. Irrigation development also affects the dynamics of aquatic habitats throughout seasons. This review thus raises the importance of water management and associated changes in agriculture and land use, and not only impacts of the irrigation infrastructure itself.

Table 2.4 adapted from Lorenzen et al. 2004 summarizes the range of potential impacts of the infrastructure and management of irrigation systems, and associated agriculture development.

Table 2.4: Summary of potential impacts of irrigation development on aquatic habitats

Process	Impact
Physical system	
Storage of water for irrigation	Affects river flow regimes, attenuating floods but increasing available dry season flow, unless abstraction for irrigation is direct from the reservoir. Dam or weir structures can reduce longitudinal habitat connectivity. Can create habitat and a fishery, but rapid or extreme volume and area fluctuations threaten stock survival.
Diversion of water for irrigation	Fish losses in pump impellers. In gravity flow systems fish may enter without harm but may become entrapped. Complete abstraction of dry season flows may break connectivity of rivers. Canals can provide habitats but not if fast flowing, lined and without natural vegetation.
Flood protection	Reduced lateral connectivity between river and floodplain habitats, although 'fish friendly' operation of regulators can mitigate this. Reduction in flooding may permanently isolate floodplain lakes.
Change in land use	Conversion of natural floodplain habitat to irrigated command.
Water delivery	Canals usually comprise straight sections connected by curves whereas fish prefer sinuous channels. Lining, discontinuous or fast flow and lack of natural vegetation provides very poor habitat. Canals and access roads may reduce lateral connectivity of the floodplain, and/or longitudinal connectivity in small tributaries. Culverts/bridges across drainage lines will not necessarily maintain habitat connectivity, depending on current velocities and the height of any steps/cascades.
Water removal	Drainage of wetlands reduces habitat area, but may increase stream flows during rain. Disposal of drainage flows into inland water bodies can degrade water quality and habitat. Natural drainage lines often realigned to straight sections connected by curves, but drains generally offer better habitats for fish than canals, though pesticides in drainage water can be damaging.
Management	
Irrigation scheduling	Scheduling to match crop water requirements may affect fish present in canals or ricefields, and abstraction from rivers.
Maintenance (waterways)	Removal of vegetation and sediment may degrade habitat and spawning grounds. Use of herbicides may severely impact fish populations.
Maintenance (embankments)	Removal of vegetation from canal and drain embankments can reduce shade and food availability and thus degrade habitats.
Irrigated Agriculture	
Land use	Cropping pattern influences water demand and consequently the water available to support aquatic resources. Farming practices can affect fish populations in drainage channels through to natural waterways. Pesticide and herbicide contamination are the most obvious causes of fish mortality, but land management practices such as bare soils during the rainy season leading to erosion through surface runoff can also have negative impacts.

Adapted from Lorenzen et al. 2004

2.2.1.4 Changes in the ecology of fisheries production

Changes in the physical characteristics of aquatic habitats, the distribution of organic/inorganic matter inputs, and water quality have direct consequences on the ecology of fisheries production. Habitats modified or created by irrigation will have different potentials for fisheries production. Productivity primarily depends on the extent of aquatic habitats and on the quality of habitats to perform ecological functions, at the level of water body and ecosystem due to the required movement of migratory species.

Changes in the food web

The modified distribution of organic and inorganic matter inputs has positive or negative effects on fisheries production depending on the respective concentrations in the specific location. Accumulation of nutrients and seston in some sites can lead to localized increase of aquatic resource production, as for example, in tailwaters right below a dam. However while nutrients enhance primary production excessive levels of nutrients (notably eutrophication) threaten the viability of fish populations, essentially through the reduction of oxygen concentration in water. The balance of nutrient concentration in different parts of the catchment and river basin is thus important to aquatic life (e.g. Winemiller 2004) but knowledge of the spatial distribution of nutrients and their effect on fish production is generally limited at catchment and river basin levels.

Loss of fisheries production from the river-floodplain habitats

Biophysical impacts of irrigation on fisheries production within the area arise due changes in the availability of aquatic habitats, their ability to perform ecological functions and connectivity. Irrigation development usually reduce the extent of the river and floodplains habitats downstream the scheme, including lakes, streams and ponds. The production potential of each category of aquatic habitat, as estimated by

various authors (see Section 2.1.1.2), will be respectively reduced (see also Chapter 4, Section I.4.2.1 for assessment of production changes).

Lower water levels in aquatic habitats downstream the irrigation scheme (including agricultural fields) and loss of permanent wetlands and connectivity are also likely to significantly reduce the production of fish and the diversity of aquatic resources in irrigated rice fields (e.g. Bergkamp et al. 2000, Bizer 2000). However the subsequent loss of natural fish production from these modified wetlands has usually not been estimated.

The reduced physical connectivity between aquatic habitats generally disrupts the ecological connectivity, essentially translated in the ability of aquatic resources to migrate from one habitat to the other. Beyond physical disruption, ecological connectivity may also be disrupted by too high flow velocities, currents and turbulences, and the height of any steps or cascades throughout the irrigation infrastructure (Larinier & Travade 1999). Whilst most aquatic organisms exploited (fish, crustaceans and mollusks) may be affected by the blockage or impedance of longitudinal and lateral migration (see Section 2.1.1.2), irrigation impact studies have traditionally emphasized the interruption of longitudinal connectivity in the river by the irrigation infrastructure in particular dams (see also mitigation measures, Section 2.3.1) and the consecutive blockage of fish migration. Despite their importance for migration during the fish life cycle (see Section 2.1.1.2), changes in the connectivity between aquatic habitats have rarely been addressed or did not receive adequate attention in irrigation impact studies, and their effects of the ecology of fisheries production are known for only a few targeted species.

Productivity of aquatic habitats created by irrigation systems

Reservoirs have varied potentials of fisheries productivity depending on a range of factors, notably the geomorphology of the water body and the geographical location of the dam, under various climatic conditions. For example, shallow reservoirs in the

tropics generally have higher productivity potentials than in temperate regions, and very deep reservoirs are generally unproductive (e.g. Miranda 2000). The productivity of the reservoir also depends on its location on the river continuum (Jackson & Marmulla 2001), partly due to the flow of organic and inorganic matter inputs. For example, reservoirs in the lower part of the catchment generally have lower fisheries productivity. Variations also occur throughout the life cycle of the reservoir and especially right after the filling, the abundance of available nutrients lead to a high increase of production progressively slowing down, referred to as the "boom-and-bust" cycle by several authors (e.g. Welcomme 1995, Jackson & Marmulla 2001).

The reduction of the extent of water level fluctuations, and low water level (up to dewatering) are likely to decrease aquatic resource mortality and sustain fish populations. Reservoirs with extreme drawdowns and refill such as temporary storage reservoirs (e.g. Petr 1998) cannot sustain important fish stocks, as for example the Temengor reservoir in Malaysia (Jackson & Marmulla 2001). Despite their importance to fisheries production, the appropriate water fluctuations and minimum levels required for sustaining fish population in aquatic habitats have rarely been studied and these are known for a few case studies only (e.g. Lorenzen et al. 2003).

As introduced in Section 2.2.1.3, canals and drains can provide habitats to aquatic resources as long as minimum requirements, mainly in terms of hydraulics (flow velocity) and water quality, are satisfied for aquatic life. In particular inflow and disposal of drainage flows into inland water bodies can significantly degrade water quality and habitat. However measures to increase fisheries production may also compromise irrigation performance, for example when improving suitability of canals for fish habitat and reducing the efficiency of water conveyance.

Impact on aquatic resource biodiversity

From the conservation perspective, the impacts on ecological integrity and biodiversity are intrinsically negative since irrigation always disturbs to some extent the natural functioning of ecosystems. As introduced in Section 2.1, aquatic resources can be sensitive to changes in hydrology, habitat structure, water quality, and habitat connectivity. Studies based on geographic variations in riverine fish diversity have established significant relationships between species richness and catchment area (Welcomme 1985) or discharge (Guegan et al. 1998). Welcomme (1995) indicates that the regulation and simplification of aquatic systems resulting from irrigation development has progressively produced a corresponding simplification in the diversity of the aquatic fauna and flora.

In many rivers worldwide the alteration of hydraulics, seasonal flows and patterns of flow variability and the reduced extent of connectivity in the river-floodplain system have affected the genetic structure of regional fish populations (e.g. Arrington & Winemiller 2003). Because the impoundment of dams on rivers converts lotic (running water) habitats into lentic (still water) habitats (see Section 2.2.1.3), species dependent on running water will diminish or disappear and in almost all cases, the diversity of fish species will decrease (McCully 1996). Impact assessment studies conclude that this may lead to a faunal shift from species adapted to rivers to species adapted to lentic environments. This will also depend on the response of species assemblages that are likely to change particularly in landscapes with previously very nutrient poor waters (Winemiller 2004).

Biodiversity has also been affected by the disruption of ecological connectivity between river channels and the floodplains (Dudgeon 2000, Bizer 2000, McAllister et al. 2001). The magnitude of this effect is likely to be greater in tropical and temperate seasonal rivers than for temperate a-seasonal rivers where migrations of aquatic resources are less dependent on connectivity and seasonal triggers (Winemiller 2003).

2.2.1.5 Conclusions on biophysical impacts

The biophysical root causes of impacts of irrigation on fisheries are numerous and the literature provides an extensive list of potential factors ranging from the irrigation infrastructure, the operation and management and the associated development of irrigated agriculture. Although knowledge of potential causation pathways of biophysical impacts and respective outcomes is relatively extensive (in particular the identification of outcomes) important gaps remain in the understanding and assessment of detailed and location specific impacts and their implications at wider scales.

This review suggests that irrigation systems usually damage or disrupt the habitat or the functions of fish life cycles but also create aquatic habitats that can perform ecological functions and provide some degree of compensation for fisheries production in certain conditions. However the net effect of irrigation impacts and associated development of agriculture on the productivity of fisheries will depend on the balance of these factors and the degree to which the ecology of fish production is based on the quality of aquatic habitats.

Impacts on fisheries production do not only result from changes in the extent of aquatic habitats but also from changes in the typology of habitats and their connectivity and ecological characteristics. This highlights the need for identification and ecological characterization of aquatic habitats throughout a catchment, and not only the focus of studies on a few prime habitats as commonly found in the literature. The productivity of aquatic habitats also strongly depends on water level fluctuations, and subsequently the management of irrigation water.

Research is thus required to further assess biophysical needs of fisheries in irrigated systems. This would support evaluation of respective trade-offs to optimise the benefits of irrigation development, where preservation or enhancement of fisheries has been justified.

2.2.2 Impacts on the exploitation of aquatic resources

Impacts of irrigation on fisheries catches are due to both changes in production potential (as described in Section 2.2.1) and changes in the level of exploitation as described in this section. The productivity and production of fisheries depend on both biophysical (habitat availability, quality or connectivity) and social factors via the level of aquatic resource exploitation. The latter results from the effort expended on fishing in the different aquatic habitats (expressed in terms of fishing effort) and the efficiency of gear use. Therefore changes induced by irrigation on one of these components will have an effect on the productivity of fisheries.

Efficiency of fishing

Irrigation, particularly the infrastructure, can change dramatically the efficiency of fishing. For example, where facing a physical barrier (e.g. dams) or bottlenecks (e.g. culverts) in the new water resource network, fish usually accumulate near the structure and can be harvested very efficiently; also tailwater fisheries immediately below a dam tend to become more productive (see also Section 2.2.1.3). If not regulated, the increased fishing efficiency in these specific locations is likely to lead to local overexploitation.

Aquatic habitats used

Potential impacts of irrigation on aquatic habitats have been developed in Section 2.2.1.3. For example, the location of fishing grounds may change with potential concentration in the newly created reservoir. Fishing effort may change depending on accessibility (as considered below), travel distances and costs, and implications for personal security, particularly for female fishers.

Accessibility of fishing grounds

The development of irrigation may reduce the physical or institutional accessibility of fishing grounds through changes in land use such as the restricted access to water bodies in irrigated rice fields, and respective management of land and water such as the restricted use of water to preserve the benefits of irrigation in the dry season and more generally in times of water scarcity.

Species targeted

The likely negative impacts of irrigation on the diversity of aquatic resources (see Section 2.2.1.4) may lead to a shift in the species targeted by fishers. A strong example is given by the collapse of lagoon shrimps in Sri Lanka and the resulting marginal exploitation of finfish species of less economic value (see Chapter 6). Stocking or farming fish in reservoirs also tends to be a popular mitigation measure (see Section 2.3.1), but this may reduce the overall species diversity and counteract ecosystem conservation measures.

Fishing techniques

Changes in fishing techniques may result from changes in fishing patterns, for example as a result of intensification through fish stocking in reservoirs and ponds or as a result of modifications in the distribution of fishers. For example, the contribution of women and children using lighter and smaller gears may increase due to an improved availability of aquatic habitats close to the household. Fishing techniques may also vary as a result of changes in faming practices e.g., the increased use of passive fishing gears due to increased labour requirements for irrigated farming.

Seasonality of the activity

The seasonality of fishing may change as a result of modifications in fisheries production potential (for example, variation in river flow and flooding patterns leading to potential reduction of fish recruitment, see Section 2.2.1.4), or as a

consequence of changes in livelihood activities and strategies, usually due to an increase in resources spent in irrigated agriculture.

2.2.3 Social impacts

Essentially represented on the right side of the diagram (Figure 2.3), social factors cover institutions and policy, the socio-economic context and livelihoods. In general social benefits from irrigation development are generally expected through the following main mechanisms (Smith 2004): i) improvements in the level and security of productivity, employment and incomes for irrigating farm households and farm labour; ii) the linkage and multiplier effects of agricultural intensification for the wider economy; iii) provision of opportunities for diversification of rural livelihoods; iv) and multiple uses of irrigation supply. Table 2.5 provides a summary of the different types of social impacts induced by irrigation development, as developed below.

Table 2.5: Social impacts of irrigation development

Key mechanism of impact	Potential Outcomes
INSTITUTIONS • New property and usufruct rights • Changes of rules • Representation of sectoral and individual interest • Power and influence in decision-making **SOCIO-ECONOMIC ENVIRONMENT** • Socio-economic development: • Increase of employment opportunities, income • Infrastructure development (roads, etc) • Market development **LIVELIHOODS** Changes in: • Livelihood assets • Household labour allocation • Livelihood strategies	**FISHERIES SECTOR** • Nature and degree of success of policy and institutional change on fisheries sector • Potential decrease of political power and representation vis-à-vis farmers **FISHERIES EXPLOITATION** • Economic opportunities: increase opportunity cost of fishing • Access to resources: potential reduced access to fishing grounds • Seasonality **FISHERS LIVELIHOOD OUTCOMES** • Vulnerability • Social differentiation • Distributional impact (issue of equity) • Livelihood improvement or impoverishment

2.2.3.1 Impact on fisheries institutions

The development of irrigation usually brings along new institutional arrangements that aim to regulate and manage the irrigation system and associated development of agriculture. Institutions crafted for the development of irrigation will not be introduced into an institutional vacuum with regard to the management and decision-making of water and aquatic resource use. The review focuses on how irrigation affects fisheries institutions in terms of rights and rules, and in the representation of stakeholders in decision making and control over these rights and rules.

Rights and rules

While the introduction of an irrigation system in a catchment does not modify fisheries institutions *per se*, the social and biophysical changes induced by irrigation may counteract existing arrangements, and these may render fisheries rules obsolete, redundant and inappropriate. It may also become clear that new institutions are required. Most often the institutional framework for the management of irrigation water is based on irrigation and agriculture needs rather than encompassing the different users of the same resources across sectors, among them fisheries. However studies on the management of natural resources recognize that when a resource system changes dramatically by season, rendering multiple uses for multiple stakeholders, the legal and institutional framework needs to identify and support overlapping land and water use systems preferably distinguished by resource type and user groups (Ratner et al. 2004).

For example, irrigation can change regulations on the use of water and land (e.g. access and property rights) restricting access to one or the other. Restriction of access for farming purposes may subsequently lead to exclusivity for fishing and the landless may be deprived from a precious alternative source of livelihood. Where the livelihoods of fishers are badly affected, their compliance to the new rules may significantly decrease (see also below) because the new regulation is not perceived to

be beneficial to them or it is seen as too much affecting their interests. This underlines the importance of understanding the livelihood strategies of stakeholders and explains why many of the potential impacts of irrigation on fisheries or fishers may have an institutional or part-institutional root-cause (see also Figure 2.3 and below).

Representation of stakeholders and power and influence in decision making

Power relations and influence in decision making are set in the pre-existing pattern of access rights to a fishery and may evolve over time. The introduction of new institutions for the management of irrigation and irrigated agriculture, particularly new resource user groups and associations may counteract the initial authority relationships that specify who decides and in relation to whom. Hence if done without sensitivity to existing power relations and with strong unbalances in the representation of water users, the introduction of new institutional arrangements for irrigation may cause social tensions. In particular, the Participatory Irrigation Management (PIM) approaches and the creation of Water Users Associations (WUAs) (e.g. as reviewed by Vermillion 1991, IIMI & FAO 1995, and the World Bank 1996) have generally focused on farmers only and have promoted their representation and contribution to the management of irrigation systems.

However the lack of recognition of other water users (livestock, fisheries, domestic use, etc.) in the management of irrigation may create conflicts of interests as a result of changes in management regimes and patterns of access. For example, if fishers perceive that an irrigation scheme will seriously affect their livelihoods then sabotage of the scheme may become one of the strategies they will consider. Possible solutions are extensive public consultation prior to implementation and, wherever possible and acceptable in terms of social equity, the utilization of existing user groups and/or power relations. In this context community management of fisheries has often been promoted (e.g. Pomeroy & Rivera-Guieb 2005), but this may still be subject to domination by elite groups unless empowerment and participation for all are well established.

In conclusion, despite the lack of literature specific to the management of fisheries in irrigated systems, the extensive knowledge of institutional arrangements for the management of natural resources demonstrates that, as the principal means to govern human behaviour, institutions can play a fundamental role in the avoidance or mitigation of harmful impacts of irrigation systems. The development of irrigation may provide a "window of opportunity" to support the crafting or adaptation of institutions in the management of water and fisheries, and it may challenge and reform existing hierarchies and power structures among the stakeholders of the irrigation, agriculture and fisheries sectors (see also mitigation measures, Section 2.3.2).

2.2.3.2 Socio-economic and livelihood impacts

Because irrigated farming and fishing are embedded within society and because society is dynamic, any irrigation intervention will, to a greater or lesser extent, contribute to social and economic change. Such variations can occur through direct changes in the patterns of fishing activity and respective incomes, or indirectly through changes in the role of fishing in rural livelihoods or in institutional arrangements governing the access to aquatic resources and their exploitation.

Direct impacts

As indicated above (Section 2.2.3), impacts of irrigation on fisheries exploitation originate from changes in aquatic resource productivity, and in the determinants of aquatic resource use. Direct impacts may also depend on a series of socio-economic attributes of the area (see Section 2.1.3.2). In addition to these factors, direct impacts will also vary for households or individuals depending on their physical location in relation to the location of fishing grounds (existing and newly created by irrigation). The precise impacts for a given household will further depend on a series of factors: the relative importance of fishing as a livelihood strategy; who fishes, where and when the individual(s) fish(es) or prefer(s) to fish; the fishing techniques; and the incentives for alternative use of labour. Furthermore fishing communities or other

socio-economic groups affected by such developments may perceive and interpret change differently. For example they may anticipate changes and react strategically (for example, through speculation) if conflicts with their interests are likely to arise (e.g. sandbar opening in Sri Lanka, in Chapter 6).

Therefore direct impacts will usually be broader than just changes in income, including for example, the benefits and seasonality of fishing for diversification, nutrition as a ready source of cash and for their role in culture and social networks. Therefore one key question in the study of irrigation impacts is whether diversification is a reflection of worsening impoverishment or increasing prosperity. Net gains or losses are unlikely to be uniformly distributed because of social differentiation, and the assessment must seek to clearly identify who are the gainers and losers of irrigation development.

Indirect impacts through changing the role of fishing in rural livelihoods

The introduction of an irrigation system will tend to precipitate changes in livelihood opportunities and may affect the role of fishing in rural livelihoods. The principal mechanisms are via changes in the opportunity costs of fishing (ICID 1993, Roggeri 1995) and household own labour allocation. Although wider socio-economic conditions will also influence indirect impacts, these will tend to be more general in their incidence (Smith et al. 2005).

A more developed agriculture generally stimulates markets and the rural economy overall (e.g. irrigated agriculture, crop processing, trade, service provision), potentially creating a range of new livelihood options through stimulation of entrepreneurial and employment opportunities. In principle, if the development of irrigation reduces the productivity and/or accessibility of a fishery, the importance of fishing as part of rural livelihood strategies will probably be directly reduced (Smith et al. 2005). Alternatively, growth in the rural economy may lead to increased local demand for fish, higher prices and thus increased incentives for fishing. Unless there

are barriers to entry to the fishery these incentives will attract more fishers to the point where returns to labour in fishing fall to the level of the next best alternative source of employment for unskilled labour (Smith et al. 2005). Although still seasonal, fishing can also help balance the household labour demand across the year particularly during the dry season when farming labour is relatively under-employed or in surplus.

Impacts can be reflected in various trajectories of change in livelihoods. The following example of a causal chain of impact provides a sequence of probable events. An increase in the efficiency of fishing resulting from the contraction of floodplain habitat downstream of a dam may increase incentives for fishing and lead to overexploitation. After initially rising, returns from fishing will decline, and vulnerable households may seek alternative livelihoods. Pressure on other open access natural resources such as forests and grazing land is likely to increase with any resulting degradation of land further contributing to change in aquatic habitats. Kularatne (1999) reports the example of the decline in lagoon fisheries production in South-East Sri Lanka and associated increase in shell mining for lime making and firewood collection.

Most studies have focused primarily on the direct consequences of irrigation development and these have not necessarily addressed the indirect impacts and processes of socio-economic change. This neglect is partially explained by the increasing complexity in the assessment of indirect impacts. However the likely significance and role of these determinants reinforces the case for a more holistic approach to impact assessment.

Differentiation of impacts

The mechanisms and strategies described above may have different effects both across communities over the catchment, socio-economic groups and individual households. Within the command area, the major differentiation of impacts is likely

to be reflected between upstream and downstream communities. At the lowest scale, differentiation can be both inter- and intra-household (gender, age, etc.).

In the study "Social Impact of Large Dams: Equity and Distributional Issues" carried out by the World Commission on Dams (WCD 2000), the identification of potential "winners" and "losers" of dam irrigation reveals fisher groups in the category of "winners" (from fisheries in the created reservoir) as well as in the category of "losers" (from downstream floodplain fisheries). The study recognizes that the concept of "winners/losers" is too simplistic since people can experience both positive and negative impacts, the nature of impact can change over time, and different socio-economic groups may evaluate impacts differently. Despite this, the results showed the potential differentiation of impacts among fisher households.

Recent emphasis has been given to the livelihoods of the most disadvantaged groups (ADB 2004) recognizing that they can be more strongly affected, particularly as a result of displacement and resettlement, and loss of social value and culture (e.g. WCD 2000). This literature reflects the strong concern that irrigation can be equity reducing in developing countries emphasising the competition of irrigated agriculture with other uses for scarce water resources. Smith et al. (2005) have shown how these effects may differently affect various categories of households. On one hand, irrigation may create economic and employment opportunities, and incentives that draw labour away from fishing or compensate for reduced productivity of, or access to, a fishery. This can benefit poor households as well as those with more irrigated land. On the other hand, poor households without access to the benefits of irrigation or its linkage effects may be driven to rely more heavily on fishing as a survival strategy. Excluded from other livelihood activities, their situation can become particularly critical if the fishery is directly degraded by irrigation development.

In conclusion, socio-economic impacts of irrigation can be stronger when alternative livelihoods are lacking, for example, where droughts are limiting economic activities that depend on the exploitation of natural resources (an example of a local economy

in recession due to drought is considered in Chapter 6). Understanding the roles and functions of fishing and likely trajectories of change in livelihood strategies is thus critical in the assessment. Despite this, the socio-economic dimensions of impacts of irrigation on fisheries have generally been neglected in the past and most analyses were non-quantitative with little predictive or diagnostic power (Pitcher et al. 1998).

2.2.4 Impacts on the whole fishery system

While the literature review has demonstrated that impacts on fisheries are likely to affect both the biophysical and social systems in a varied and complex way, the holistic understanding of the various pathways of impacts across the components of the fisheries system and across sectors is far more limited. The overarching hypothesis of most irrigation impact assessments is that impacts occur in a sequential manner: the hydrological alteration produces ecological effects on the aquatic resources and the ecosystem; this in turn changes the productivity of fisheries, and then affects the rural livelihoods. The structure and dynamic functioning of physical aquatic habitats have been identified as the main drivers of impacts on most inland fisheries. However, this is not taking into account the biophysical impacts directly caused by social factors and the potential reactions of fishers and other stakeholders (e.g. anticipation of reservoir creation, and/or of increased efficiency at bottlenecks, conflicts). All these can counteract or aggravate the former perturbations on aquatic ecosystems.

As a result the outcomes and mechanisms of impacts identified for each component of the fishery system (see Figure 2.3) may not reflect the overall dynamics resulting from interactions between biophysical and social factors in the fishery system, and between fishery and irrigated agriculture. In addition, impacts may not simply add up and as a result, final outcomes may be significantly different from the ones expected through reductionist or narrow approaches. On the basis of the previous results

(Sections 2.2.1 and 2.2.3), the review has identified the main sources of misinterpretation and bias possibly resulting from these approaches.

The usual expectation is that irrigation will degrade the productive potential of fisheries and further marginalise fishing as an economic activity. Firstly the potential production of a water body may not be the only driver of fishing effort, and secondly socio-economic and livelihood factors may at least equally influence the level and characteristics of fishing effort. As a result, the estimation of impacts on fisheries production is likely to be a poor predictor of the impacts on rural livelihoods.

Smith et al. (2005) have developed the argument by identifying from a livelihoods perspective, the main reasons for this potential bias: i) changes in access to aquatic resources can be more important to livelihoods than changes in production; and ii) the ability to catch fish, even a small quantity, during the dry season may bring more benefits to the livelihoods of the poorest than reaching high production levels during the wet season. This also implies that even where fisheries have been degraded by irrigation, a lower level of production may still be an important source of food security and/or income for livelihoods of last resort. In all these situations, what appears sub-optimal when viewed only in terms of fishery bio-economics may be socially valuable viewed with a holistic livelihood perspective.

Existing knowledge of impacts on the biophysical and social components of fisheries may not reflect the interactions between effects on components of the fisheries system, and the effects that may occur across sectors. Ultimately this could lead to errors of omission and bias in impact assessments.

2.2.5 Conclusions on the impacts of irrigation on fisheries

Whereas this review of the numerous and varied impacts of irrigation on fisheries cannot be completely comprehensive in terms of detail, the identification of key

mechanisms of impacts and respective outcomes has been used to structure an assessment of the state of knowledge of the impacts of irrigation on fisheries. As a result the literature review has shown that irrigation can impact one or several components of the fishery system, leading to further impacts through various causation pathways.

Impacts occur primarily from hydro-geomorphologic and water quality changes with resulting effects on the ecology of fisheries production. The biophysical root causes of impact are numerous and the literature gives an extensive list of potential causes ranging from the physical works of an irrigation system to its operation and management. Whilst impacts may also result from social changes in fisheries, knowledge for this is much less extensive, but a wider literature on rural livelihoods, and socio-economic and institutional disciplines can be exploited to understand and assess the range of social impacts.

While gaps remain in the knowledge that applies specifically to the impacts of irrigation on one or several components of the fishery system, knowledge is even more limited at the system level. The absence or lack of holistic understanding and analysis is likely to be an important limitation in assessing the impacts of irrigation on fisheries, and in identifying means to mitigate or enhance these impacts. This thesis will attempt to address these limitations.

2.3 Mitigation and enhancement of impacts

A range of measures exists, from avoidance of impacts to the mitigation of negative impacts and enhancement of positive effects for example, the creation and enhancement of a reservoir fishery. These measures generally focus on biophysical impacts, and to a lesser extent on socio-economic impacts. Mitigation is the most widely used option in irrigation development projects.

2.3.1 Mitigation and enhancement of biophysical impacts

The main measures identified are the restoration of fish migration, the restoration of aquatic habitats and downstream hydrographs, and enhancement of fisheries production through stocking or farming. These measures generally tend to focus on the irrigation infrastructure and engineering, and the main strategies commonly adopted are the mitigation of negative effects on fish migration through adjustments to the engineering design.

Restoration of fish migration

Engineering guidelines have intended to aid dam design and operation for preserving fisheries interests. The aim is to facilitate the upstream or downstream migration of some fish species or to manipulate the artificial aquatic environments upstream and downstream so as to optimize fish production. These guidelines focus on the impacts on fish migration and thus concern various types of fishways or passes (e.g. Porcher & Travade 2002). Devices such as fish ladders and fish passes including fish lifts and hydraulic fish locks have been experimented and evaluated (FAO & DVWK 2002). Results show that many fish passes do not function correctly. In addition, unrestricted movement is usually a near permanent but rarely satisfied requirement that needs regular maintenance of fishways (Vigneux & Larinier 2002).

Bernacsek (1984) has provided a summary of design and operational features for dams that address fisheries concerns. The author indicates features such as maximum possible crest elevation, discharge structure intakes positioned at highest possible elevation, artificial reoxygenation of tailrace discharge water, annual water level fluctuation of the reservoir (to be within the range of 2.5-4.0 m and drawdown rate not to exceed 0.6 m/month), and downstream discharge to include an artificial flood event. In general installation of fish ladders is not recommended by the author. Another major constraint to integrating mitigation measures is the added costs (Bizer 2000), and the generally low performance of engineering and technical mitigation

measures such as the fish ladders. This can affect the financial feasibility of irrigation projects.

In general, the primary constraint to integrating these measures into large irrigation projects is the lack of sufficient information on the roots of causes of impact, the types of measures that can be effective and the underlying assumptions and information necessary to design effective measures. Overall it is concluded that measures to avoid, mitigate or compensate for specific adverse effects of dam and weir infrastructure are available and the main weaknesses lie in the adequacy and management of measures rather than in technical inputs.

Restoration of aquatic habitats and downstream water discharge

Restoration measures have generally targeted key components of the structure or functioning of biophysical systems on which fisheries rely i.e. aquatic habitats and downstream water discharge, with a strong focus on the riverine system. Attempts have been made to restore wetlands to their initial conditions although this is not possible absolutely (see for example, the Comprehensive Everglades Restoration Plan 2005).

The main measures generally recommended include: improving the main channel diversity, reconnecting the floodplains to the main river channel, improving water quality where polluted, and managing instream and riparian vegetation for the benefit of fish such as the control of excessive vegetation, the use of aquatic and riparian vegetation to improve habitat quality and cover (Pretty et al. 2003, Cowx & Welcomme 1998 with emphasis on European rivers). Although in irrigated systems, canals and drains can also support the production and ecology of fisheries especially in providing migration pathways, these habitats have not been considered in the design and planning of restoration measures. Attention to the linkages between fish and riparian systems is required in efforts to rehabilitate degraded stream environments.

Protecting and restoring river flow regimes and hence the ecosystems they support by providing environmental flows have become a major aspect of river basin management (Arthington et al. 2004). Releases from dams may be modified to more closely parallel natural discharges relative to timing and sediment loads (Miranda 2000). However preserving minimum water level in reservoirs may well be as much important from a livelihood perspective. Reservoir fisheries may be more productive than the unmodified river channel, and their creation may initiate a positive round of changes in livelihood opportunities and use of natural resources. Trade-offs for allocation of water to the different needs of fisheries should be considered in such cases.

Enhancement of fisheries production through stocking or farming

In developing countries, the dominant assumption of irrigation planners is that enhancement of fish production through stocking or farming in available or created aquatic habitats (particularly in the created reservoir and ponds) will compensate or more than compensate for any loss to the natural fishery. For example, fisheries yields in the new reservoir are expected to be far greater than the existing river fishery (e.g. De Silva 1988, see also the Lao example in Chapter 5, Section 5.2.5).

Fish stocking has thus appeared a relatively easy and straightforward mitigation measure to the impacts of irrigation, dams in particular. However there is considerable evidence suggesting possible failure if stocking is not adequately managed and does not take into account the wider issues likely to affect the outcome of stock enhancement (Cowx 1999). In view of multiple examples of management failures (e.g. Kianji reservoir, in Ita 1984; and Itezhi-tezhi reservoir, in Kapasa & Cowx 1991), there is now a general consensus that "stocking has been a much used, but too often abused, tool in fisheries management" (Cowx 1999).

Similarly aquaculture (or fish farming) is often cited as a mitigation measure but detrimental impacts on the environment through pollution, introduction of species, etc.

have been increasingly raised (e.g. Philips 1990, Beveridge & Muir 1997). Because aquaculture requires capital investment, inputs and controlled access to water (and is thus more akin to farming), environmental and social trade-offs between the capture of wild fish and the culture of farmed fish may also arise. For example aquaculture may increase the impacts of irrigated agriculture in terms of water pollution and restricted access to water and aquatic resources and at the same time, the activity may fail in reaching the poor who are often the most affected by the development of irrigation.

2.3.2 Mitigation of socio-economic impacts

Mitigation of socio-economic impacts has received belated attention mainly because, as mentioned in Section 2.2.3, the general perception is that any negative impacts on livelihoods arising from degradation of the productive potential of a fishery will be compensated by wider improvement in economic opportunities. However understanding of the nature and mechanisms of impacts has shown that the development of irrigated agriculture as a direct compensation measure may not be sufficient, particularly for the poor and/or the marginalized categories of the population.

Mitigation of socio-economic impacts and attempts to sustain the value of fishing to rural livelihoods can aim at factors that caused reduced production potential or reduced physical accessibility or rights of access to fishing grounds. The provision or wider development of opportunities for livelihood diversification that are accessible to the poor is also important. Allocation of rights to irrigated land and irrigation supply may need to take account of this. Finally appropriate compensation measures for groups that lose in the process may be needed.

A set of main principles for mitigation or enhancement of livelihood impacts has been set out in Lorenzen et al. (2004) (Box 2.3).

Box 2.3 Main principles for mitigation or enhancement of livelihood impacts

- Based on biophysical conditions and engineering constraints, attempt to sustain a viable fishery and livelihood activities dependant on it. Focus particularly on sustaining fishing for poor and vulnerable groups with fewest livelihood alternatives;
- Take full account of indigenous technical knowledge about fisheries in project design;
- Recognizing that it may not be possible to sustain the original fishery in a viable form for all previous user groups, and that there may be explicit trade-offs between irrigation and fisheries, seek to optimize compensation measures such as development and effective management of fisheries in the new modified system, development of aquaculture or culture-enhanced fisheries in irrigation reservoirs, canals, drains or farm ponds, provision of capacity building and training for management of new/modified habitats;
- Recognizing that fishing may decline in importance for some full-time or part-time fisher households, seek to develop and optimize alternative livelihood opportunities by addressing barriers to entry in farm and non-farm employment, improving access to input and output markets, and the integration of local markets in the wider economy; creating a facilitating or enabling institutional and policy environment for private sector entrepreneurial activities.

Source: Lorenzen et al. 2004

2.4 Critical conclusions: lessons for impact assessment

The review of literature on the nature and magnitude of the impacts of irrigation on fisheries has been carried out through comparison between fisheries in non-irrigated systems and fisheries in irrigated systems. Identification of outcomes and respective underlying mechanisms showed that impacts may arise from a wide range of factors and through a variety of causal pathways: essentially from the physical modifications of aquatic habitats and their ecological effects, but also from changes in exploitation patterns and the role of fisheries in rural livelihoods and the wider socio-economy, and from institutional changes.

Disciplinary knowledge on one or several attributes of the fishery system is relatively extensive, in particular on biophysical impacts. However specialist assessment does not encompass the whole fishery system, and this may lead to misinterpretations or mis-estimation of impacts. This chapter has shown the critical need to understand the

whole fishery system in the study of the impacts of irrigation on fisheries components and interactions between the components.

Impact assessment studies should lead to, or at least support, the identification of adequate mitigation and enhancement measures to inform the management of impacts. This review and critical conclusions have provided analytical insights for developing a new approach to assessing the impacts of irrigation on fisheries, as presented in Chapter 4.

Chapter 3 - Quantitative Impact Assessment: a Case Study in Laos

3.1 Introduction

The impacts of irrigation on fisheries were investigated and assessed quantitatively in the rice-based farming systems of Southern Laos. Key mechanisms by which these impacts arise were identified. The study was designed as a paired comparison of household fishing effort and yield as well as local fish stock diversity between irrigated and non-irrigated sites. While the holistic assessment encompasses a range of biophysical and social factors, it emphasises the main determinants of impacts on fish production and livelihoods.

The aim of this study is to assess overall impacts of irrigation on fisheries in rainfed rice farming landscapes, and to identify key mechanisms by which these impacts arise. An observational study was conducted and designed as a paired comparison of household fishing effort and yield as well as local fish stock diversity between irrigated and associated (non-irrigated) control sites. This addressed knowledge gaps given a lack of similar studies in the literature, and the results and generalisable lessons derived informed the design of the APIA approach.

3.1.1 Irrigation schemes under study

The study was concerned with small to medium-scale irrigation schemes, with command areas of up to about 500 ha. Most irrigation schemes in the project area are small and irrigate less than 100 ha; schemes with a realised command area of more than 500 ha are rare. The schemes considered in this study use gravity to supply water to fields via canals, but differ in the diversion structures used to abstract water from rivers. Most irrigation schemes under study involve a significant local re-distribution

of water and/or modification of aquatic habitats. These irrigation schemes are constructed and maintained under the auspices of the Department of Irrigation and Micro-Hydropower in Laos.

The two types of formal irrigation under study, dam and weir irrigation, are common in southern Laos. In dam irrigation, water is distributed to rice fields through canal systems, either by gravity or more commonly in lowland Laos, by pumps. Some shallow reservoirs in the area do not have any 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. Weirs are relatively low structures that abstract water from streams or small rivers, but they do not create a storage reservoir. Distribution of water from weirs is almost exclusively by gravity. They are used mostly for supplemental irrigation in primarily rainfed cropping systems. The realised command area of both dams and weirs is often substantially smaller than the design command area.

Dam and weir irrigation schemes have been built at a fairly constant rate. While most weirs have been built during the last decade, about half of the dams under study are more than ten years old.

3.1.2 Profile of the study area

With an estimated GNP per capita of US$320 in 2001 (World Bank 2003), Lao PDR is the poorest and least developed country in the East Asia region. More than three-quarters of the population live on less than US$2 a day and social indicators are among the worst in the region. Landlocked, the country covers 236,800 km2 with a population of 5.4 million growing at 2.6 percent annually (National Statistical Centre 2000). The climate 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-October).

Agriculture remains the major driver of the economy, contributing 53 percent of GDP and employing over 80 percent of the labour force. Since the introduction of reforms under the New Economic Mechanism (NEM) in 1986, the Government has transformed the economy from a centrally planned to a market-oriented system. Agriculture performance benefited from the new policy and its production increased – except during the droughts in 1987 and 88 – particularly rice production. However, only 17% of the land area is cultivated (850,000-900,000 ha) (National Statistical Centre 2000), that is less than 4% of the total area. Despite government efforts to encourage crop diversification, rice agriculture generally remains a monoculture system.

In the year 2000, rice accounted for about 84 percent of the total cultivated area of approximately 820,000 ha per year (National Statistical Centre 2000). More than 85 percent of rice produced is of traditional deep-water varieties of the glutinous type, and annual yields are in the range of 1.5 to 2.8 t/ha (SUAN 1989). In the rainfed areas, agricultural production tends to be subsistence oriented. Under usual conditions, rainfall is adequate for rice production but if rainfall decreases at a critical time in the rice growing cycle, yields will be significantly affected. Low lying areas of prime importance for paddy production may also be vulnerable to flooding, resulting in yield reduction and often, complete loss of crop. The dependence on rainfed systems is thus seen as the major constraint to the expansion of rice production (SUAN 1989, IRRI 1999).

A major benefit of irrigation (sometimes including flood control) is the reduction of vulnerability in household food security and expanded dry season cultivation and production. For this reason irrigation has expanded rapidly, from 3% of the rice-field area in the mid-1980s (SUAN 1989) to 18% in the late 1990s (FAO 2003). As noted, irrigated land constitutes up to 18% of total agricultural land but small-scale village irrigation projects rather than large-scale systems still predominate. A further objective is to help reduce traditional slash and burn cultivation, which can contribute to deforestation and soil erosion.

In the 1990s, degradation of the environment particularly the forests, and the reported loss of several endemic species have prompted the government to consider the impacts of economic development on the environment. With regard to irrigation development, environmental impacts of irrigation projects were not studied in the past (Sitideth, pers. comm.), and a quantitative assessment of impacts on fisheries was perceived as both timely and appropriate. Given the importance of fisheries in rural livelihoods, in particular for the poorest sections of the communities, it was also clear that these households were likely to suffer most from any negative impact on natural aquatic resources.

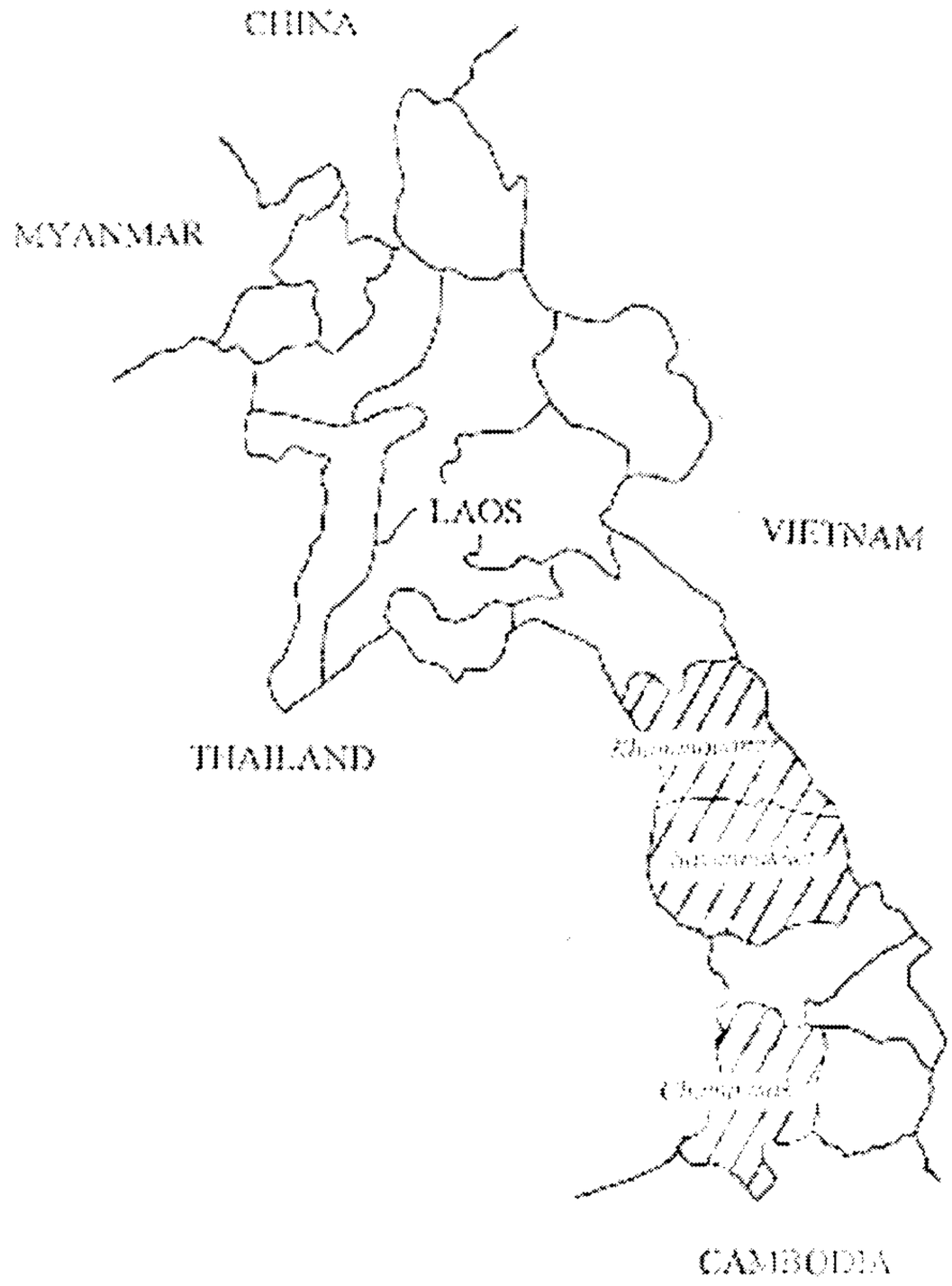
3.2 Methodology

3.2.1 Site selection

Field studies were carried out in three provinces of Southern Laos: Khammouane, Savannakhet and Champassak. The lowlands of Savannakhet and Champassak provinces are among the major rice producing areas in Laos, together accounting for over a third of national rice production. Much of Khammouane is mountainous, making the province a less important, but still significant area for rice production.

The study covered weir and dam irrigation schemes. Within all irrigation schemes, the wet season rice crop was cultivated as a largely rainfed crop and there was little land engineering. In the area, aquatic resources are exploited as a capture fishery or managed more intensively through aquaculture (see definition in Chapter 1). 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 then referred to as culture-enhanced fisheries.

Figure 3.1 Map of Laos indicating the study area



3.2.2 Study Design

The impact assessment was designed as a paired observational study, replicated at irrigation scheme level, comparing irrigated sites with non-irrigated controls sites selected to be as similar as possible to the irrigated sites (Eberhardt & Thomas 1991). Each site centred on a village and covered all aquatic habitats located within the land belonging to that village. In order to compare catch, effort and species richness, a paired design was chosen to minimize environmental variation and maximize the statistical power of the comparisons. Controls were located in the same watershed as the irrigated sites, on a stream or river of the same order, and were similar in terms of

village population and agricultural land area. Irrigation impacts were measured as average differences between impacted and non-impacted sites in aquatic habitats areas, catch and fishing effort, species richness and ecological composition of fish assemblages.

Preliminary investigations suggested that a 50% reduction in household fish catches would be sufficient to offset the net benefits of many irrigation schemes. Hence the survey was designed to detect a 50% reduction in household catch at a level of significance of $\alpha = 0.1$ and power of $1-\beta = 0.9$. Based on estimates of within and between-villages variance in fish catches (Garaway 1999), power analysis suggested that ten paired sites with samples of 10 households per site would be sufficient to meet the design criteria. Ten site pairs of weir and dam irrigation schemes (i.e. 10 impacted and 10 control sites) were selected at random from lists provided by the provincial irrigation departments, and a total of 400 households were surveyed. Topographic maps and local knowledge of provincial and district agriculture and irrigation department staff were used to identify control sites.

3.2.3 Survey Methods

At each site, a site survey, a household fishing survey, and a fish biodiversity survey were conducted. The household fishing and biodiversity surveys were carried out twice, in the dry season and during the period of receding water. All surveys were carried out by government livestock and fisheries officers with the active participation of local villagers, and with training and regular quality control by the research team. Results of the study were synthesized and presented back to participating villages.

The site survey was designed to provide general information on the village (population, rice field area, irrigated area), and to quantify habitat availability. Basic data on the village (population, rice field area, irrigated area) were obtained from the

village administration. Perennial and seasonal aquatic habitats were identified from topographic maps and through participatory mapping. Surveyors visited all identified habitats and measured area and depth in the wet and dry seasons. Overall aquatic habitat availability at each site was summarised as the area of riverine (flowing water, such as rivers and streams), lacustrine (standing water, such as reservoirs, natural lakes and ponds) and rice fields.

The household fishing survey covered ten households selected at random from the village list. Surveyors collected data on fishing events (person fishing, time fished and catch in weight) with a one-week recall. The interview method involved use of visual aids to recall (Garaway 1999): bowls of different size and sticks of different lengths helped the villagers in quantifying their catches. Household fishing effort was quantified as time spent fishing by all household members per week. Catch and effort data were recorded separately for reservoirs (where present) and for non-reservoir habitats.

For the fish biodiversity survey, large groups of villagers fished in all local aquatic habitats for a fixed period of about two hours. All fish caught were preserved and identified to species level in the Department of Zoology, The Natural History Museum, London, UK. The number of specimens obtained differed between sampling locations, and species richness was positively correlated with the total number of specimens obtained. Effects of irrigation on species richness were estimated from the full samples, and from the average richness of computer generated re-samples of 30 fish (the lowest number of specimens obtained for a single site). To assess impacts of irrigation on ecological characteristics of fish communities, effects on composition of samples were quantified in terms of proportional abundance of functional feeding groups, and of proportion of rheophilic (flowing water-associated) fish. Classification of species by these characteristics was based on information from FishBase (Froese & Pauly 2004), Rainboth (1996) and Kottelat (2001).

3.2.4 Data Analysis

All survey data were stored in a relational database. Habitat data were aggregated at site level to provide average habitat areas per site in the wet and dry seasons. Household catch and fishing effort data were aggregated at site (village level) and expressed as site averages per household, and per unit aquatic habitat area (average of wet- and dry-season area). The fish biodiversity survey provided site-level data, which were pooled across seasons as no seasonal differences in composition were apparent.

The main impact assessment was based on differences between paired irrigated and non-irrigated sites in the various metrics. A non-parametric bootstrap (Efron & Tibshirani 1993) was used to generate confidence limits for effects. Results are reported as follows: for each variable, the mean value in non-impacted sites is given as a baseline, and the irrigation effect is shown as the mean and 90 percent confidence interval (CI) of differences between the paired, impacted and non-impacted sites (Tables 3.1 and 3.2).

Regression analysis of log-transformed variables was used to explore the role of fishing effort, habitat availability and irrigation impact in determining catch at village level. A regression model of the following form was used:

$$\ln C = \alpha_0 + \sum \alpha_i \ln x_i + \beta_1 D$$

In this equation, C is the catch at village level, xi are covariates (fishing effort, permanent and seasonal water area at village level), D is a dummy variable for impact (0, no irrigation; 1, irrigation), and αi and βi are the corresponding coefficients. Impacts of irrigation development on per-area fishery productivity of habitats were further explored using regression analysis of log-transformed catch (CPUA) and effort (EPUA) per unit area.

3.3 Impact Assessment Results

3.3.1 Sites characteristics

The study covered weir and dam irrigation schemes, with command areas (irrigated land) areas ranging from 17 to 515 ha (average 155 ha) and associated paddy areas varying from 3 to 346 ha (average 93 ha). Weirs had been in operation for an average of 12 years (range 3-35 years), and dams for an average of 7 years (range 3-13 years). As weir schemes and control sites tended to be located higher up in watersheds than dam sites and their controls, the area of irrigation command and overall aquatic habitat was smaller on average (Table 3.1). Village size was unrelated to irrigation type (weir/dam) or impact, varying between 15 and 256 households with an average of 102. Within all irrigation schemes, wet season rice continued to be cultivated as a rain-fed, deep-water crop although supplemental irrigation was applied occasionally. Dry season rice crops were cultivated with lower water levels and sometimes involved higher yielding varieties.

Table 3.1 Effects of irrigation on aquatic habitat areas at village level. Mean area at non-impacted (NI) sites is given as a baseline, and effects are shown as the mean difference in area between paired, impacted and non-impacted sites. Effects in bold are significant at $P < 0.1$

	Riverine habitat		**Lacustrine habitat**		**Rice field habitat**	
	NI	**Effect (90% CI)**	**NI**	**Effect (90% CI)**	**NI**	**Effect (90% CI)**
Weirs						
Dry season	04.6	-1.7 [-4.6, 0.7]	07.5	-2.2 [-10.0, 4.4]	13.5	5.8 [-8.1, 17.2]
Wet season	09.3	-3.3 [-8.7, 3.1]	10.7	-4.8 [-16.4, 3.1]	59.6	-12.3 [-28.3, 3.4]
Dams						
Dry season	15.7	**-13.5 [-33.7, -1.6]**	04.5	**80.9 [14.4, 186.5]**	6.8	**47.1 [25.9, 72.7]**
Wet season	23.1	**-19.8 [-40.6, -5.6]**	05.9	**110.2 [28.7 223.2]**	124.1	2.3 [-60.0 60.7]

Riverine habitat includes rivers, streams and canals; lacustrine habitat includes natural lakes and human-made reservoirs and ponds; rice field habitat includes all areas used for rice cultivation.

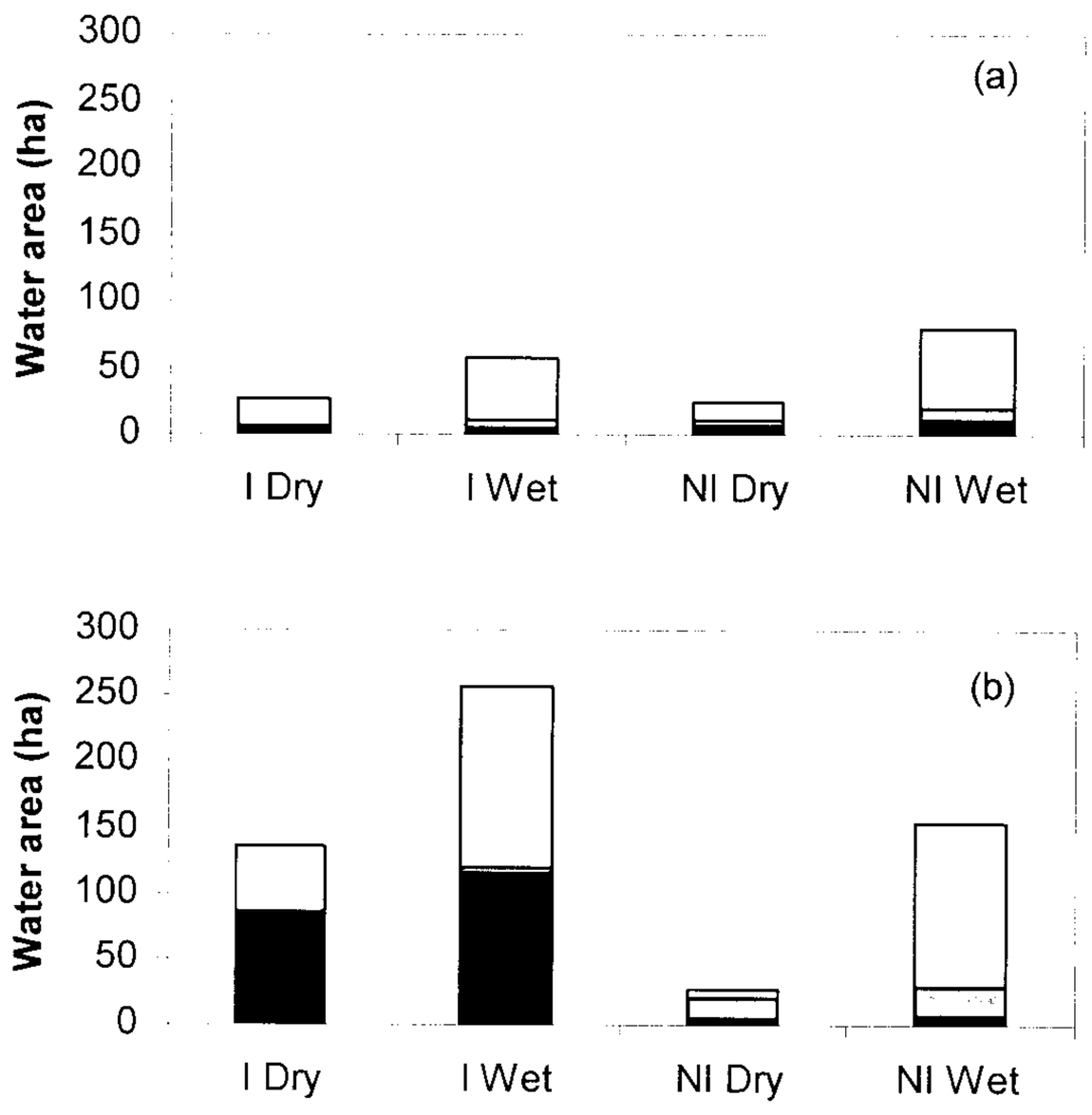
3.3.2 Aquatic habitat availability

Aquatic habitats at all sites comprised a stretch of river (on which the weir or dam was located in the case of impacted sites), variable numbers and sizes of lacustrine waterbodies (natural lakes, wetland and human-made reservoirs and ponds) and rice fields. Total wet season aquatic habitat in non-impacted sites averaged 79 ha in weir and 153 ha in dam control sites (Table 3.1). Dry season areas were much smaller overall and more similar, at 25 ha and 27 ha in weir and dam controls, respectively. Temporary wetland area was two (weir controls) to four (dam controls) times greater than permanent water area, and was dominated by rice fields. Weir irrigation schemes had no significant impact on aquatic habitat areas (Table 3.1 and Figure 3.1a). Dam irrigation schemes were associated with large and significant increases in lacustrine habitat area, and concomitant declines in riverine habitat area (Table 3.1 and Figure 3.1b). Dam schemes also led to a significant expansion in dry season rice field area.

3.3.3 Household catch and fishing effort

Participation in natural aquatic resource use was near universal in all sites, with 83 percent of households fishing during the survey period. In the non-impacted sites, average household fishing effort was consistently about 5 h/week, but household catches were lower in weir controls (0.77 kg/week) than in dam controls (2.07 kg/week). This difference in catch reflects the differences in location and habitat availability already outlined. On a per-area basis, fishing effort was much higher in weir than in dam controls (6.6 vs. 2.9 h/ha/week), while catches were similar. Average household catch and effort in all sites are shown in Table 3.2. Overall household catch and effort were far more variable among than within pairs, suggesting that the paired design had effectively controlled for environmental variation between watersheds.

Figure 3.1 Aquatic habitat areas in the weir (a) and dam (b) sites and associated controls Impacted (I) and non-impacted (NI) sites in the dry and wet seasons. Habitats are classified as lacustrine (reservoirs, lakes, and ponds) (black), riverine (streams and rivers) (gray), and rice paddies (white).



Weir schemes were associated with a significant 36% decline in household catch and a smaller, non-significant, decline of 14% in household effort (Table 3.2). Overall this indicated a moderately negative effect of weir irrigation schemes on fish catches, partly but not fully explained by a decline in fishing effort. No significant overall impacts were detected for dam schemes, although a tendency towards reduced household catch and effort was noticeable (-17% and -13%, respectively). However, the lack of significant overall effect hided very substantial changes that emerged when analyzing the data separately between the newly created reservoir and non-reservoir habitat. Dam schemes were associated with drastic and statistically significant reductions in non-reservoir catch (-51%) and effort (-58%) on a household and per unit area basis. Reservoir catch and effort partially compensated for the reduction in non-reservoir fishing, so that net effects were smaller and not significant. However net impacts may be spatially differentiated, and overall negative impacts may occur downstream of the dam where the reservoir is less accessible.

There were no statistically significant seasonal differences in catch and effort, but average household catches were consistently lower, and the level of effort expended consistently higher, in the dry than in the wet season in all but the dam impacted sites. Catch per unit effort (CPUE) was significantly higher in the wet season than in the dry season in all but the dam impacted sites, where no seasonal effect on CPUE was detectable. Dam schemes thus reduced the normal, seasonal variation in aquatic resources availability.

Table 3.2 Paired comparisons of average household fishing effort (HH effort) and catch (HH catch), catch per unit of effort (CPUE), effort (EPUA) and catch (CPUA) per unit area, and species richness. Mean values for non-impacted (NI) sites are given as a baseline, and effects are shown as the mean difference between paired, impacted and non-impacted sites. Relative mean effects are also shown as a proportion of the NI value. Effects in bold are significant at $P < 0.1$

	Weirs			**Dams, all habitats**			**Dams, non-reservoir habitats**		
	NI	**Effect**	**Rela-tive**	**NI**	**Effect**	**Rela-tive**	**NI**	**Effect**	**Rela-tive**
HH catch (kg/week)	0.77	**-0.28 [-0.50, -0.10]**	**-36%**	2.07	-0.36 [-1.18, 0.27]	-17%	1.80	**-0.91 [-1.89, -0.12]**	**-51%**
HH effort (h/week)	4.84	-0.69 [-1.64, 0.21]	-14%	5.55	-0.72 [-1.91, 0.62]	-13%	4.48	**-2.58 [-4.04, -1.13]**	**-58%**
CPUE (kg/h)	0.15	+0.01 [-0.04, 0.07]	+7%	0.38	0.29 [-0.05, 0.82]	+76%	0.37	-0.04 [-0.17, 0.10]	-11%
CPUA (kg/ha/week)	1.01	**-0.63 [-1.73, -0.01]**	**-62%**				1.26	**-0.75 [-1.49, -0.13]**	**-69%**
EPUA (h/ha/week)	6.62	-1.20 [-3.04, 0.39]	-18%				2.85	**-1.76 [-2.94, -0.66]**	**-61%**
Richness (raw)	12.9	-0.7% [-4.0, 2.7]	-5%	17.1	1.2 [-4.2, 5.8]	+7%			
Richness (standardized)	9.05	-0.50 [-1.80, 0.60]	-6%	8.94	+0.40 [-1.65, 2.21]	+4%			

In addition to the results in Table 3.2 an increase in catch per unit of effort was observed for dam sites in aggregate (although this was not statistically significant). This may reflect changes in the physical environment that facilitate efficient harvesting. In particular, fish tend to accumulate in the stream or river just below a dam where their migratory pathway is blocked. Other modifications of similar effect on harvesting efficiency include cross-drainage culverts underneath contour canals, which concentrate both runoff-water and fish.

Relationships of catch per unit area (CPUA) and CPUE to effort per unit area are given in Table 3.2, aggregated over all habitats other than reservoirs. Catch-effort relationships for weir and dam sites (impacted and controls) had a similar slope but the intercept was significantly higher in dam sites and the associated controls than in weirs and controls. This reflects underlying differences in physical and hydrological site characteristics. Impact status (impacted/control) had no significant effect on the relationship between CPUA or CPUE and EPUA in either weir or dam sites.

Species richness and ecological composition assemblages

Participatory test fishing yielded between 30 and 353 (average 101) specimens per site, representing a total of 124 fish species. Numerically the most common species were the flying barb *Esomus metallicus Ahl*, the climbing perch *Anabas testudineus Bloch*, and the snakehead *Channa striata Bloch*, which together accounted for about 40% of the samples. The latter two species are able to migrate across dry land, and are thus well adapted to colonizing rain-fed rice fields (Rainboth 1996). Average species richness in the full samples was 12.9 in weir and 17.1 in dam controls. In the samples standardized to 30 specimens through computer-generated resampling, species richness was equal at 9 in both weir and dam controls (Table 3.2). No impacts of irrigation on average fish species richness were evident, regardless of whether effects were estimated from full or standardized samples. Confidence limits on impacts were fairly narrow, with all 90% confidence limits within 33% of the mean.

The proportional representation of functional feeding groups was similar in weir and dam control sites, with 27% carnivores, 20% omnivores, 45% planktivores and 8% insectivores. Weir impacted sites were associated with a significant increase in omnivores (+17%), and concomitant reductions in planktivores (-10%) and insectivores (-6%). No significant changes in the relative abundance of feeding groups were detected in dam impacted sites. The proportion of rheophilic individuals was higher in weir control sites (25%) than in dam controls (13%). There was no

significant impact of either weir or dam schemes on the proportional abundance of rheophilic fish.

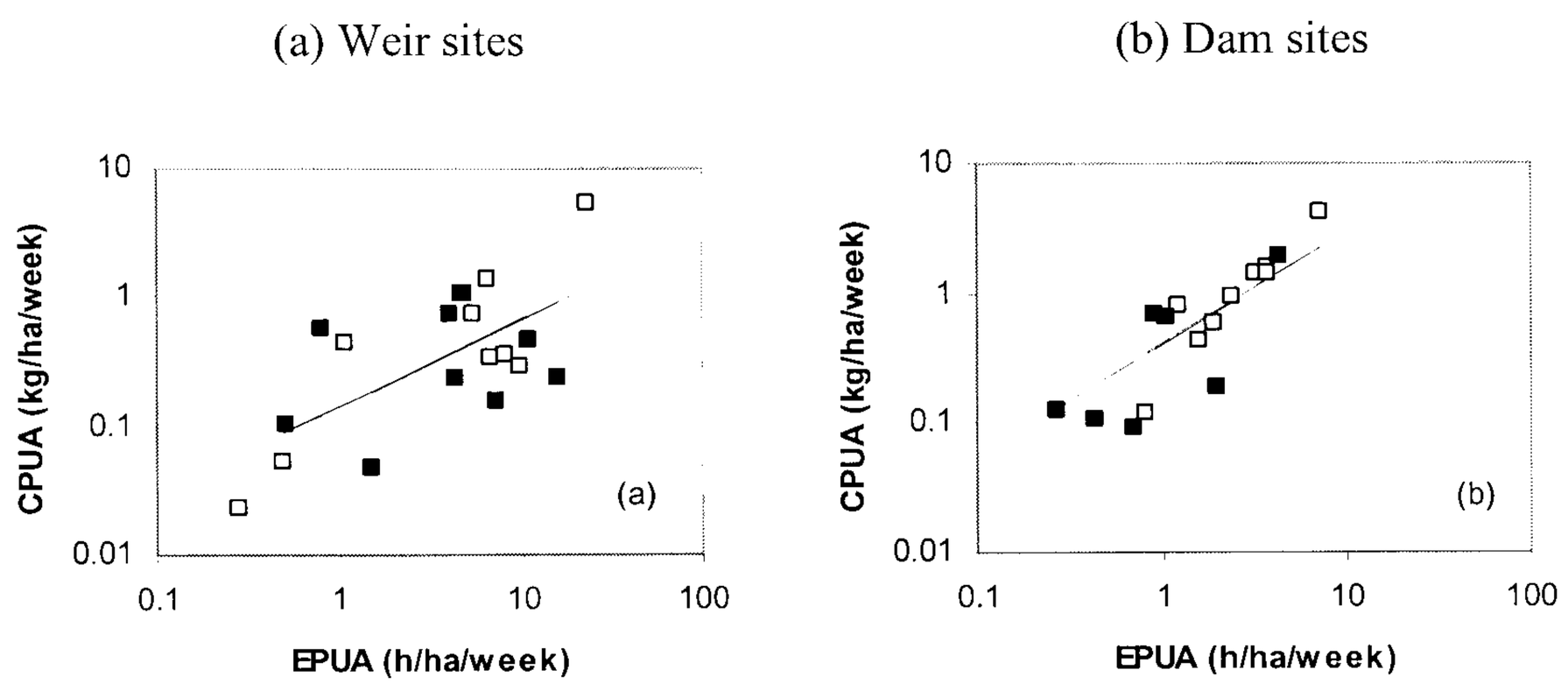
Determinants of fisheries production

Regression analysis of village level fish catch consistently identified fishing effort (total time spent fishing by all households) and temporary wetland area as key determinants of total catch (Table 3.3). The estimated values of coefficient α_3 (0.46 for dam, and 0.61 for weir impacted and control sites) indicated that a 1% reduction in temporary wetland area caused a 0.4-0.6% reduction in village level catch. The coefficient of irrigation impact α_1 was not significant, confirming that effects observed in the paired comparisons were the results of differences in fishing effort and habitat area, rather than a reduction in per-area fisheries productivity of habitats. The same was evident from the relationships between CPUA and EPUA, which showed no systematic differences between non-impacted control and impacted sites (Figure 3.2).

Table 3.3 Parameter estimates (with standard error in parentheses) for the regression models of village level catch (Equation1) Relationships of catch per unit area (CPUA) and effort per unit area (EPUA) for irrigated and control sites are given in Figure 3.2. There is no difference in per-area fisheries productivity of irrigated and control sites.

Effect		**Weirs**		**Dams overall**		**Dams outside reservoir**	
		Full	**Reduced**	**Full**	**Reduced**	**Full**	**Reduced**
Constant	α_0	-1.69 (1.03)	**-2.14 (0.93)**	**-3.07(1.74)**	**-2.71(1.50)**	**-4.75(1.36)**	**-4.49(1.09)**
Effort	α_1	**0.48 (0.25)**	**0.65 (0.20)**	**1.06(0.22)**	**0.96(0.18)**	**1.21(0.22)**	**1.18(0.15)**
Dry season area	α_2	0.15 (0.14)		-0.16(0.19)		0.00(0.15)	
Temporary area	α_3	**0.61 (0.20)**	**0.50 (0.17)**	**0.46(0.23)**	**0.40(0.20)**	**0.54(0.23)**	**0.51(0.19)**
Irrigation	α_1	-0.44 (0.45)		0.17(0.39)		0.00(0.41)	

Figure 3.2 Relationships between fishing effort (EPUA) and catch (CPUA) per unit area in weir (a) and dam (b) sites. Non-impacted controls (open squares) and impacted sites (solid squares)



Declining fishing effort may in itself be the result of increased demand for labour in other activities (particularly irrigated agriculture), and/or a reduction in the actual or perceived opportunity for fishing due to changes in fishable habitat or fish abundance. While the assessment of the relative contribution of each factor was beyond the scope of this study, the main reason for the declining fishing effort was further investigated in the livelihood analysis.

3.3.4 Fisheries in rural livelihoods

Household cash income and levels of asset ownership were low overall in the project area. The importance of aquatic resource use to households was 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 ranged from 0.5 US$/kg for small "trash" fish to 1.5-2.5 US$/kg for larger fish. Household catches consisted of about one third of "small" and two thirds of "large" fish, and the average value was 1.5 US$/kg. Table 3.4 provides an indicative estimate of average household income in the project area,

including the contribution of fish catches. This suggests that in an average household, aquatic resource use accounted for 21% of gross income.

Household fishing effort and catch were strongly related to household size, but only weakly influenced by socio-economic status. 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. Indeed irrigation development may have been focused on villages that were more prosperous and influential in the first place, a possibility the study could not investigate.

Table 3.4 Contribution of aquatic resource use to gross household income

	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%

Note: Market prices and exchange rates of 1999

Socio-economic effects of irrigation development as measured in the household surveys are shown in Table 3.5. 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 showed 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 3.5 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*	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 ownership	1%	**3% [1%, 5%]**
Bicycle ownership	75%	28% [-7%, 63%]
Motorcycle ownership	3%	3% [-4%, +9%]

* The rice index is the average of the following dummy variables at household level:
-0.5 deficient, 0 sufficient, 0.5 surplus

Although definitive conclusions cannot be reached from these limited data, the implications may be that the major socio-economic impacts originate from the increased opportunity cost of fishing. This would have resulted in the transfer of part of the labour force to irrigated farming with a respective decrease in fishing effort. In addition, the effort allocated to fishing has been partly redistributed towards the reservoirs, reducing the effort allocated to exploitation of floodplain aquatic resources.

3.4 Discussion

Discussion here focuses on the quantitative impact assessment results, the methods applied and the lessons drawn for the improvement of impact assessment methodology and approach.

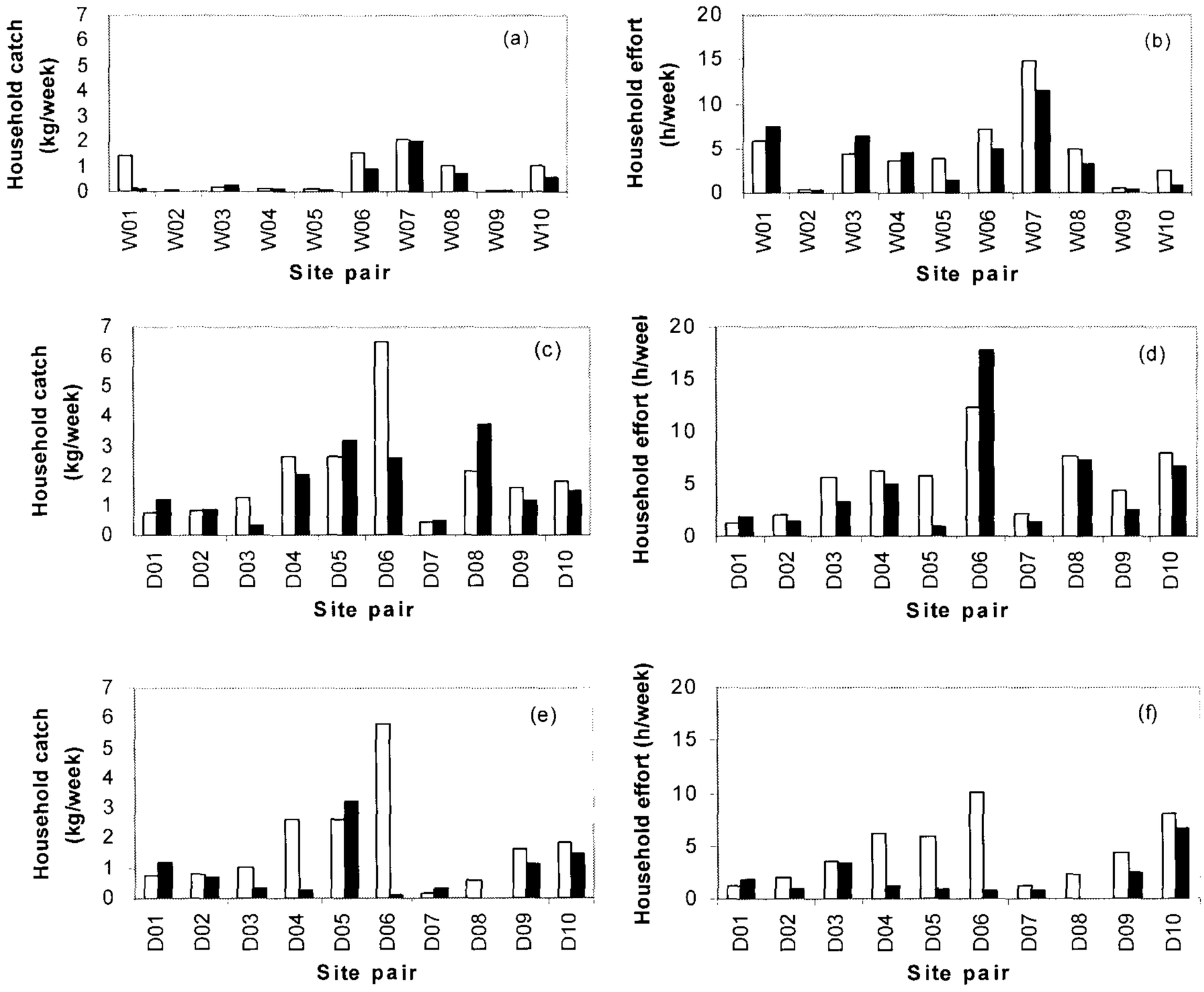
3.4.1 Methodological Critique

Observational studies replicated at the irrigation scheme level are an efficient way of assessing irrigation development impacts on aquatic resources in a rigorous manner

and at relevant spatial scales. They are, of course, more susceptible to biases than experiments (where treatments are allocated randomly to experimental units) or survey sampling (where observational units are selected without reference to impact status) because of the subjectivity involved in selecting control sites (Eberhardt & Thomas 1991). However, fully designed experiments with large scale disturbances are rarely possible (or ethically desirable), and survey approaches tend to require far larger sample sizes to achieve a power similar to that of targeted observational studies. The close correlation of catch and fishing effort between impacted and paired control sites (Figure 3.3) suggests that the selection of controls within the same watershed and with similar village characteristics has successfully reduced environmental variation and increased the statistical power of the impact study. Overall impacts were moderate but consistent.

Although the possibility of an inadvertent bias can not be ruled out completely, neither the location of irrigation schemes nor the selection of control sites was in any way influenced by prior knowledge on the productivity or diversity of fisheries. A more important factor likely to contribute to the moderate level of impacts detected is the fact that impacted sites were embedded within largely intact river systems. This configuration allowed adoption of a rigorous comparative methodology in the first place, but it also meant that colonization of irrigated sites from the surrounding area could raise local productivity and diversity. Cumulative and synergistic impacts are likely to occur as a result of increasing density of small to medium-scale schemes, and repeated interruptions of longitudinal connectivity in rivers and streams. Further studies on such effects are warranted, and could be carried out in the study area once irrigation development has expanded (see also Section 4.1.4).

Figure 3.3 Average household catch and fishing effort in the paired weir (a, b) and dam (c-f) sites effort are shown overall for all aquatic habitats (c, d) and for habitats other than reservoirs only (e, f)



3.4.2 A new light on the impacts of irrigation on fisheries

The quantitative impact assessment results have contributed to enhancing knowledge on the impacts of irrigation on fisheries, both on their holistic nature and magnitude. They provide some unexpected and possibly counter-intuitive results with regard to the current literature on irrigation impacts on fisheries as developed below.

Fisheries can be important even in irrigated rice-based farming systems

The rain-fed rice farming landscapes of southern Laos support diverse fish assemblages (at least 124 species, about 10% of the total estimated for the Mekong basin; Coates et al. 2003) and productive fisheries (with annual average yields of 60kg/ha of wet season water area). These yield figures are broadly similar to those estimated for flood-prone rice systems in Bangladesh (Halls et al. 1999) and natural floodplains (Bayley 1988). Hence rain-fed rice farming landscapes in the study area may be regarding as broadly intact floodplain-like ecosystems.

The importance of fisheries to rural livelihoods is apparent from the fact that 85% of households participated in fishing during the study, and achieved an average catch of 60 kg/household/year. Data obtained in the present study suggest that overall, small-scale aquatic resources are productive and diverse, and not significantly degraded. Hence the importance of small-scale, natural aquatic resources to the rural population should be fully recognised in southern Laos, the wider Mekong region, and generally in most rainfed rice farming systems. This means that assessments of impacts on such resources should be carried out whenever development is likely to have impacts, and the aquatic resources in agricultural areas should not automatically be assumed to be degraded or diminished.

Therefore natural aquatic resources can be productive and diverse even within irrigated rice farming systems. They can continue to play an important role in rural livelihoods, maintain much of their diversity and add considerable value to the use of irrigation water in agricultural areas, both rainfed and (to a lesser extent) irrigated. This value should be quantified particularly in the estimation of water productivity and considered in water allocation decisions. It is thus important to take measures to conserve and enhance natural fisheries productivity and diversity in irrigated rice systems for social and ecological benefits. In the face of increasing pressure on water resources, this can make an important contribution to the conservation of inland aquatic resources in the tropics.

Impacts of irrigation on fisheries in rice-based farming systems can be less negative than commonly perceived

The overall impacts of irrigation development on household catches in weir and dam irrigation schemes have been assessed as only moderately negative and impacts on fish species richness were not significant. The low overall level of irrigation impacts on fisheries productivity and stock diversity in the rice-based farming systems of southern Laos may be surprising, given the substantial impacts of weirs and dams on river flows and longitudinal connectivity of river habitats (Jackson & Marmulla 2001, Welcomme 2001).

Weir irrigation schemes had no significant effect on aquatic habitat areas, but were associated with a significant decline in household fish catches. This decline in catch was only partially explained by reduced fishing effort. Weirs had no effect on fish species richness, but were associated with a moderate, statistically significant increase in the relative abundance of omnivores and concomitant reductions in planktivores and insectivores. Reduction of stream and river flows in the late wet season and dry season was identified as a key mechanism. Weirs also create an obstacle to fish migration, but the importance of this mechanism in small tropical weirs is subject to debate, given that in many cases, there is considerable overshoot at the height of flows (or the weir sites may be completely flooded). In ecological terms, this suggest that weirs affect primarily the extent of local dry season aquatic habitat, and possibly spawning and recruitment where weirs present obstacles to migration.

Dam irrigation schemes significantly reduced riverine habitat area, and increased lacustrine habitat and dry-season rice field area. Dam schemes led to a redistribution of fishing effort towards reservoir habitats in response to new opportunities. Dam schemes also significantly reduced seasonality in both aquatic habitat and resource availability. No significant impacts of dams were detected on fish species richness or the relative abundance of functional feeding groups. The storage of significant amounts of water induces changes that are more complex and far-reaching. Severe

reductions in stream/river flow and the extent of downstream flooding occur in the wet season. However, seepage from the reservoir and the irrigated area tends to increase dry season flows and water levels, above those found in comparable non-impacted streams/rivers and other small water bodies. Dams also create major obstacles to fish migration, as illustrated in the literature review, Chapter 2. In ecological terms, whilst dams reduce spawning and recruitment, results showed that they also increase dry season aquatic habitat and stock survival.

In conclusion, two likely contributing factors are the hydrology of the rainfed rice farming system, and possibly the fact that the schemes assessed were embedded into largely intact river systems. Aquatic habitat in rainfed rice farming landscapes is dominated by rice fields, the hydrology of which is driven by runoff and direct precipitation rather than river flow and water level. Hence the hydrology of the dominant habitat is insensitive to modifications of river flow and its fisheries productivity is likely to be maintained as long as ecological connectivity with perennial habitats is sufficient to allow colonization by fish. This result highlights potential limitations in the scope of river flow rehabilitation efforts, as further developed in Chapter 4, Section 4.2.1.2.

In the study sites the impacts are largely explained by a moderate reduction in fishing effort, most likely reflecting the new economic opportunities of irrigated agriculture and thus increased opportunity costs of time spent fishing. In dam irrigation schemes, there was a strong tendency for fishing effort to be re-directed from rice field, stream and lake habitats into the newly created reservoirs. Neither the moderate overall reduction in catches, nor the more dramatic shift of fishing activities into reservoirs indicate a loss of productivity in traditional habitats given that the per-area catch-effort relationships in habitats outside the reservoir have been maintained. Therefore the reduction of fishing effort is likely to reflect a positive response to new fishing opportunities.

Results per season show that while the wet season hydrology of rainfed paddies may be largely unaffected by irrigation development, two factors might have significant impact on their fish production: i) farming practices that reduce the retention of water in rice fields such as use of irrigation water even in the wet season cycle and ii) lower wet season flows in the river and/or irrigation infrastructure creating obstacles to lateral migration resulting in decreased fish recruitment to paddies from permanent water bodies. For example, fish recruitment to rainfed paddies above the irrigation canals and outside the command area may be reduced as a result of canal embankments blocking fish movement.

Although dam irrigation schemes are associated with an expansion of dry season rice field area, this does not lead to an increase in fisheries production. Dry season rice cultivation is carried out with minimal water storage in the rice fields, which thus provide little aquatic habitat. Even if water storage in rice fields was increased, however, there is unlikely to be significant recruitment of fish into the rice fields. Colonization in the wet season is linked to the natural migrations triggered by monsoon conditions. As colonization is linked to seasonal migrations significant colonization is unlikely to occur in the second, irrigated production cycle.

There was no significant impact on fish species richness from irrigation development. Hence overall, impacts of medium-scale weir and dam irrigation as practiced in the study area on fisheries productivity and diversity were very limited. Irrigation development has neither significantly reduced, nor significantly increased the productivity of fisheries.

Irrigation management can impact fisheries more severely than the irrigation infrastructure *per se*

The results above indicate that the greatest threat to the fisheries productivity of rainfed rice farming landscapes is a reduction in rice field water storage during the wet season, which would result in a drastic reduction of temporary wetland area

suitable as fish habitat. Whereas in the study area, the wet season crop was cultivated in the traditional rain fed way even in irrigated sites, availability of irrigation water can facilitate the intensification of wet season rice production with a concomitant reduction in rice field water storage. This modification in wet season farming practice is likely to have a far more dramatic impact on fisheries production than the development of dry season irrigation as assessed in the present study.

The results obtained here for irrigation development in rainfed rice farming landscapes are remarkably similar to those obtained for flood control and irrigation schemes in the flood-prone rice farming landscapes of Bangladesh. Flood-prone rice farming systems can continue to support productive fisheries within flood control schemes. Therefore small adjustments in the design and operation of flood control structures and creation of perennial aquatic habitat with flood control schemes can dramatically improve production (Sultana & Thompson 1997, Halls et al. 1999).

That is why, unless water is maintained in the paddy between production cycles, the irrigated wet season crop is unlikely to add significantly to annual fisheries production. Of course there may be some scope for rice-fish aquaculture even in irrigated rice fields as long as some areas are set aside for fish habitat (Ruddle 1982, Haylor & Bhutta 1997). A crucial factor in rice field fish production is the maintenance of a sufficient water level, at least in the initial stages of cultivation. This was the case in all sites assessed, where the wet season crop was cultivated in the traditional rain fed way even in irrigated sites. This is not necessarily the case in other Asian countries where farming practices tend to use irrigation water even during the wet season and to drastically reduce storage within the rice field.

Management implications

There are several important implications of these results for the management of irrigation development impacts on fisheries. First, ecological attributes of rain-fed rice farming landscapes are such that they may support diverse and productive

fisheries even within irrigated areas. The value of these fisheries to livelihoods and biodiversity conservation should be assessed, and considered in agricultural and water management decisions. Secondly, irrigation water management and farming practices within irrigated rice farming systems may have a greater impact on fisheries productivity than irrigation infrastructures such as weirs and dams. Management practices that conserve and enhance natural aquatic resource productivity should be maintained and developed where feasible, and may yield ecological and social benefits.

Thirdly, cumulative and synergistic impacts of irrigation schemes should be considered even where the individual schemes appear to have only limited impacts. This study also demonstrates the value of rigorous empirical assessments of irrigation impacts on fisheries to the development of management and policy guidance. In the face of increasing pressure on water resources, such studies can make an important contribution to the conservation of inland aquatic resources in the tropics.

3.4.3 Lessons for impact assessment

The above results have implications in terms of methodological approach as they provide lessons for improving the assessment of impacts. These emphasise the importance of both an integrated assessment across sectors, disciplines and scales, and the disaggregation of impact results. The need for increasing the use of local knowledge and supporting the management of impacts and decision-making are also highlighted.

Integration across sectors, disciplines and scales

The study showed that the linkages between impacts on the biophysical system and impacts on livelihoods are neither direct nor linear. As a result livelihood changes cannot always be fully understood and directly deducted from production changes.

This calls for integration of cross-sectoral analysis and investigation of processes of changes rather than only the diagnostic of impacts.

Results also showed that the critical issue of irrigation impacts on fisheries might not be strictly the severity of impacts in isolation but the overall balance of costs and benefits within and among sectors. The study has clarified the potential determinants of impact to further investigate in other sectors, primarily the irrigated farming practices. From the changes in fisheries opportunity costs it appeared that in irrigated systems, changes in fisheries were likely to be closely related to changes in rice-farming systems development of the whole area and the socio-economic dynamic created by irrigation development (e.g. market, road construction, labour employment, etc.). This means that assessments should include a-priori 'externalities' (off the scale or off the sectoral and disciplinary focus of the study) where these can be significant determinants of impacts (e.g. farming practices) and then analyse the main interactions between the relevant activities.

Although the quantification of impacts is useful for several reasons (e.g. for use in CBA and decision-making as detailed in Chapter 4, Section 4.2.2.1), the snapshot results did not inform sufficiently on the processes underlying the impacts in order to predict all major potential trajectories of change. The literature supported by the current study showed that results of impact assessments (even disaggregated) may be the outcomes of a multitude of factors. In particular, rural livelihoods are a determinant of fishing effort (via opportunity costs, strategies, alternatives, etc.) along with the value of fishing (evaluated or perceived) in rural livelihoods. Further investigations would need to focus on irrigated farming including subsequent effects of the activity on fisheries systems. Because labour allocation and opportunity costs are primarily dependent on other major activities like irrigated agriculture, changes in the livelihood of fishers need to be analysed in relation to changes in these other activities.

The study revealed that impacts on productivity, fishing effort and opportunity cost of fishing cannot be considered independently. Rather than narrowly focusing on one aspect of the impact (e.g. the biophysical requirements of exploited fish species), it is also critical to understand when, where, how and why people fish and who fishes. The study of the different roles of fishing in rural livelihoods by Smith et al. (2005) (see Chapter 2) provides a useful basis for guiding the inclusion of further socio-economic analysis in future assessments (see Chapters 4 to 6). Therefore the holistic view adopted by this quantitative assessment needs to be developed particularly through further integration of the analysis. This will help in demonstrating how the current status of the fishery is determined by the physical and ecological characteristics of the site, the livelihood aspects and the systems of rules pertaining to resource exploitation.

Regarding issues of scales, the linkages between micro, meso and macro-scales were not specifically investigated, and for example the interpretation of results revealed that the socio-economic status of the different villages prior to irrigation could be an indirect determinant of irrigation impact, through selection of villages that may be more influential in project decision-making at provincial or national levels. Cumulative and synergistic impacts are likely to occur as a result of increasing density of small-to-medium schemes at larger scales (e.g. river basin level), leading to repeated interruptions of longitudinal connectivity in rivers and streams. Hence cumulative impacts of irrigation schemes should be considered even where the individual scheme has appeared to have only a limited impact, and further studies at catchment level are warranted to assess these issues.

Importance of a disaggregated analysis

The assessment of the severity of net impacts should be balanced with a disaggregated assessment of the distribution of costs and benefits among and within communities. In turn, social changes may impact on the natural environment,

particularly on resource abundance and diversity (as mentioned in Chapter 2), for example, through changes in exploitation patterns.

The disaggregation of results per category of aquatic habitat was critical to understanding the distribution of impacts and identifying some underlying mechanisms. Impacts were largely explained by a moderate reduction in fishing effort, most likely reflecting the new economic opportunities of irrigated agriculture and thus the increased opportunity costs of fishing. In dam irrigation sites, fishing effort showed a strong tendency to being re-directed from rice field, stream and lake habitats into the newly created reservoirs. This pattern is likely to reflect a positive response to new fishing opportunities.

Neither the moderate overall reduction in catches, nor the more dramatic shift of fishing activities into reservoirs indicate a loss of productivity in traditional habitats, given that per-area catch-effort relationships in habitats outside the reservoir have been maintained. In this rice-base farming context, 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. Clearly, whilst the disaggregation of results per aquatic habitat was informative, the disaggregated analysis should be pursued on a livelihood basis (impact on livelihoods in different locations of the catchment), particularly any change in access rights, opportunity costs and labour allocation.

Use of local knowledge

For such a quantitative and rigorous impact assessment, the use of local knowledge has been limited to the planning and implementation of surveys. Although this represents an important contribution to the assessment, a more extensive use of local knowledge and structured interactions of stakeholders with researchers would have probably enhanced the knowledge and understanding of impacts.

A notable example in the study is that local knowledge would have been particularly useful in understanding the determinants of fishing effort, the distribution of effects, livelihood strategies and other livelihood related issues. For example the counter-intuitive reason(s) determining an increase of fishing effort during the wet season, when fishing efficiency is lower on average and farming labour requirements are higher, given that most fishers are also farmers. Therefore benefits of stakeholders' participation should be developed beyond their contribution to local surveys.

Support to the management of impacts and decision-making

The value of rigorous empirical assessments of irrigation impacts on fisheries to the development of management and policy guidance has been demonstrated firstly by providing an improved understanding of impacts and some key mechanisms underlying these. More specifically, by demonstrating the potential importance of fisheries in rice-based farming systems, the study revealed the importance of managing fisheries even in some irrigated systems such as the rice-based farming systems (see Sections 3.4.1.3 and 3.4.1.4).

3.5 Conclusions

The rigorous comparative assessment of the impacts of dams and weirs on fisheries, in rice-based farming systems of Laos (Mekong region) provided accurate results on the biophysical and socio-economic effects of irrigation in the study sites of Southern Laos. The study also contributed to a better understanding of pathways and mechanisms of biophysical impacts, particularly from the spatial disaggregation of results per type of aquatic habitat.

Several important implications on impacts and methodological approach to assessment can be drawn from the following results:

- Ecological attributes of rice-based farming systems are such that they may support productive fisheries even within irrigated areas. The potential importance of fisheries within irrigation systems supports the need to continue investigations.
- Irrigation water management and farming practices within irrigated rice systems may have a greater impact on their fisheries productivity than irrigation infrastructure *per se*.
- Proliferation of small-to-medium scale irrigation schemes may lead to cumulative impacts in excess of those established here. Therefore cumulative and synergistic impacts of irrigation schemes should be considered at larger scales (catchment, river basin) even where the individual scheme appears to have only a limited impact.

In addition, the Lao case study has provided lessons for the development of improved methodologies for impact assessment. An integrated assessment is required to encompass the multiple and varied impacts and underlying mechanisms across sectors, disciplines and scales. The spatial and socio-economic distribution of impacts calls for a disaggregated analysis. Results showed the potential benefits of increasing use of local knowledge in impact assessment given time and resource constraints. Lastly, the assessment should support the management of impacts and decision-making through information, involvement of stakeholders and investigation of management scenarios.

These inputs add to the identification of strengths and limitations of existing impact assessments through the literature review (see Chapter 2).

Chapter 4 - Assessment of the Impacts of Irrigation on Fisheries

Drawing from the knowledge of impacts gained in Chapters 2 and 3, this thesis defines the assessment of the impacts of irrigation on fisheries as the ex-ante or ex-post evaluation of the impacts induced by the development of irrigation on the fishery system. As justified through the key mechanisms of impacts identified in Chapter 2, the assessment involves analyzing the effects on the biophysical and social components of the fishery system.

In the first part of this chapter, the existing approaches and methodologies are reviewed with emphasis on their benefits and limitations for the assessment of irrigation impacts on fisheries. In the second part, a new impact assessment approach is proposed drawing from: the knowledge of fisheries systems and potential impacts of irrigation (Chapter 2), the results and lessons from the quantitative impact assessment (Chapter 3) and the benefits and limitations of existing methods (Part I of this chapter) (see also Chapter 1, Figure 1.1).

The review in Chapter 2 and the quantitative impact assessment in Chapter 3 have identified several key requirements for the assessment of irrigation impacts on fisheries.

A holistic approach that incorporates specialist assessments

The review of the fishery system showed that in-depth studies are needed to improve the knowledge on its components in irrigated systems, and the implications of its interaction with one or several other components. Since this will not encompass all main mechanisms of impacts of irrigation on fisheries, a holistic approach drawing from the knowledge of specialist assessment is required. This approach should allow

integration of intersectoral and interdisciplinary issues, and the identification of appropriate spatial and temporal scales of study.

Acceptance by stakeholders

Acceptance of the impact assessment by stakeholders (see definition of stakeholders in Part II, Section 4.1.2) is critical to the adequacy and feasibility of the study and its outcomes, in particular the management recommendations. The decision-making should result from a transparent study process and shared decisions on the assessment and management of impacts.

Feasibility in a context of limited data and resources

Lack of data and resources will often dominate the impact assessment studies. These constraints require the use of all available information from both scientific and local knowledge. In this thesis 'local knowledge' refers to both the indigenous knowledge of fishers and the broader knowledge (technical or not) of other local stakeholders including communities and government officials.

Support for the management and decision-making

Assessment results should inform the management of impacts and decision-making of irrigation development. This includes the recommendations of mitigation and enhancement measures to improve the design and implementation of irrigation projects.

The first part of this chapter reviews existing methods and approaches against these identified requirements. Drawing from the results and lessons from the previous assessment (Chapters 2 and 3), an impact assessment approach is proposed in the second part. It aims to address the key methodological issues of existing impact assessments, and to support management and decision-making for irrigation development.

I. Review of existing methods and approaches for impact assessment

The following review of literature focuses on methods and approaches that are relevant to the assessment of the impacts of irrigation on fisheries. This includes the assessment of selected determinants of impact mechanisms (e.g. aquatic habitats, species diversity, opportunity cost of fishing) as described in Chapter 2, and the assessments of outcomes. Various types of methods and approaches are now available, from impact assessment frameworks to specialist assessments (e.g. reductionist and single-issue assessments). As illustrated in Figure 4.1, impact assessment frameworks generally use specialist assessments (biophysical and/or social) and to various extents, they may adopt the following functions: integration, participation, monitoring and evaluation, and management and decision-making.

Figure 4.1 Frameworks of existing impact assessments

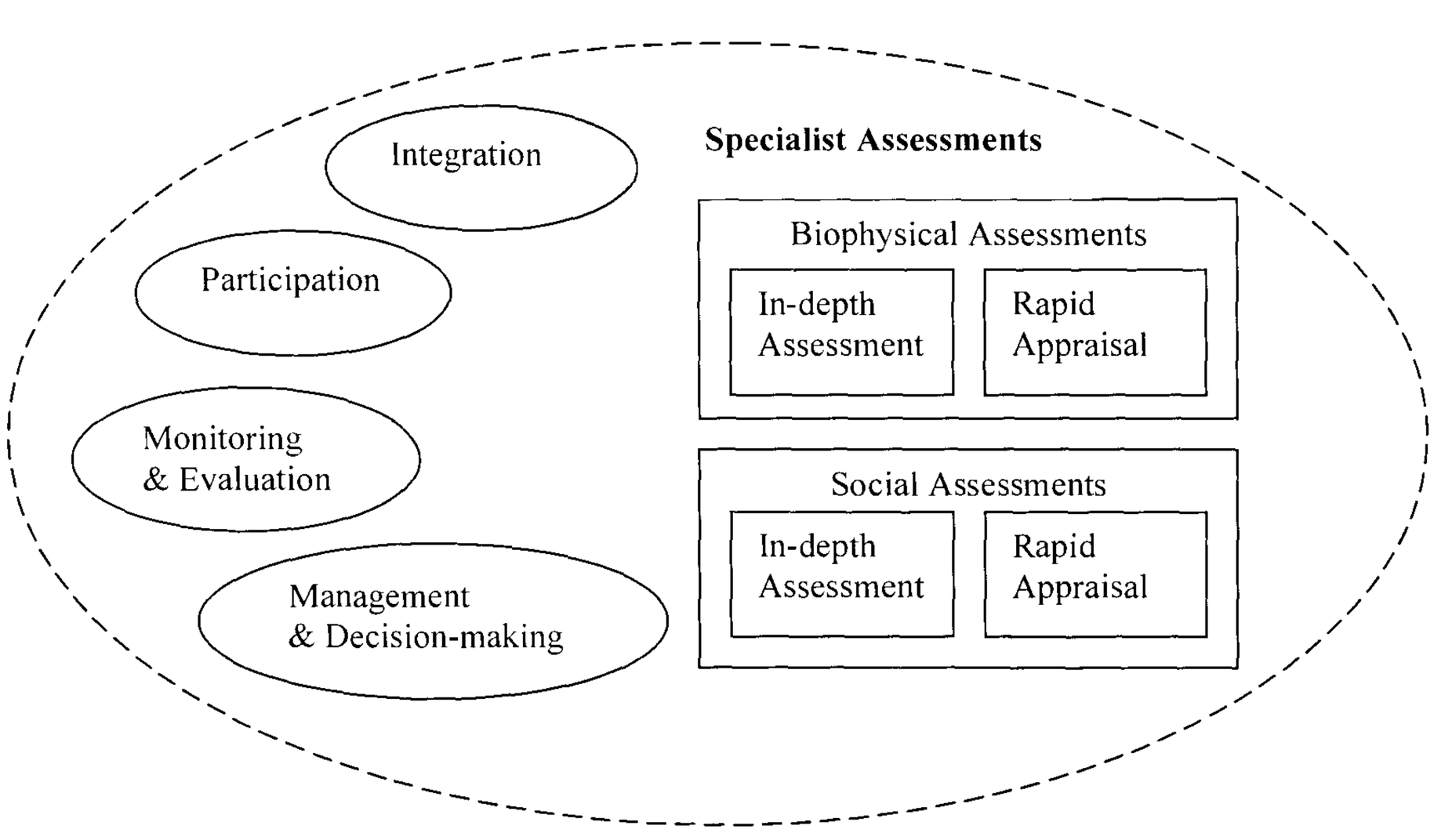
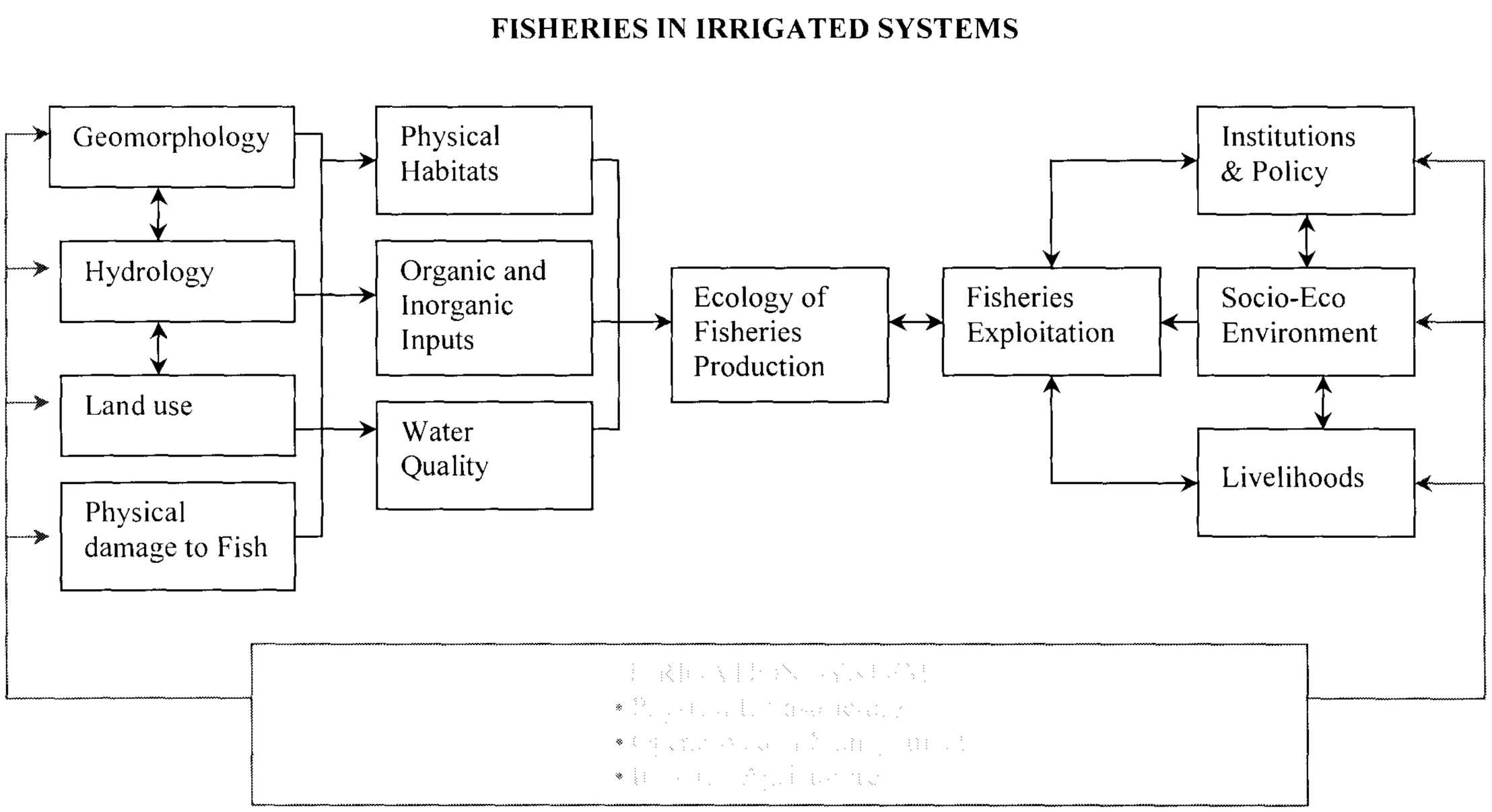


Figure 4.2 illustrates the disciplinary coverage and the components of the fishery system considered. As shown in this figure, the approaches usually apply to the biophysical or social components of the fishery system, and more rarely to both together. The objectives of impact assessments, and their approach and methodology, are reviewed against the general objectives identified below for the assessment of irrigation impacts on fisheries.

Figure 4.2 Coverage of the fishery system by assessment approaches



4.1 Process frameworks for impact assessment

The process frameworks relevant to the impacts of irrigation on fisheries have developed in the context of existing practice for irrigation project appraisal. They generally provide a sequential structure through screening, scoping, assessment and mitigation and/or enhancement, and decision-making on project agreement. Process frameworks usually include some degree of public participation and tend to be more oriented towards practical and management issues in order to support project decision-making. The most common frameworks used for this purpose are Environmental Impact Assessment (EIA) and Social Impact Assessment (SIA).

4.1.1 Environmental Impact Assessment (EIA)

Among the numerous definitions of Environmental Impact Assessment (EIA), Sadler (1996) has proposed a broad conception of "the process of identifying, predicting, evaluating and managing the biophysical, social, health and other relevant effects of development proposals before major decisions are taken and commitments are made". EIAs generally consist of a baseline description of the natural environment, the assessment of potential environmental impacts, and listing of recommendations for management and decision-making on project development. Innovations in the procedures and methods have enhanced the international diffusion of EIA and in comparison to its early phase, the process is now multi-dimensional in purpose, scope and approach (Sadler et al. 2000), and more systematic in its implementation.

The literature on EIA is massive and a range of approaches is now widely used. They take various forms from checklists of possible impacts (e.g. ADB 1987, ICID 1993) to more elaborate networks (e.g. RAMSAR 2000), flow diagrams (e.g. EU 1993, FAO 1995), and matrices and multi-criteria analyses (e.g. Petermann 1996). They place more or less emphasis on public participation during the assessment process (e.g. World Bank 1993, Fell & Sadler 1999).

This section focuses on the impacts of irrigation projects on fisheries and for this purpose, a range of guidelines has been reviewed. The availability, access and wide use of the EIA were the only criteria used in the sampling selection. The objective was to evaluate how fisheries issues are addressed in EIAs and the strengths and limitations of such fisheries impact assessments. Results are summarized in Table 4.1.

Table 4.1 Review of a sample of EIA Guidelines from a fisheries perspective

Source	Fisheries mention and consideration	Method for integration of Fisheries
Environmental Guidelines for Selected Agricultural and Natural Resources Development Projects *ADB, 1987* Environment, agriculture and natural resource management	- Generally or indirectly in: irrigation (hydrology, water quality), forestry (ecology, socio-economic benefits) - Specifically in: watershed development (dams - including fisheries and reservoir management- are one of the Integrated Watershed Development Plan components), land clearing, coastal zone development	▪ List of factors potentially affecting fisheries and aquaculture (e.g., inadequate site selection and/or design, effects of construction and operations phases; etc) ▪ Checklist of environmental effects - Irrigation: project location, design - Fisheries and Aquaculture: natural resources, socio-economic development - Watershed Development - Forestry - Land Clearing and Rehabilitation - Coastal Zone Development
Environmental Impact Assessment Guidelines for Agricultural Development *ESCAP – UN, 1990* - Environment and development studies - Land Clearing Projects (LCP)	- Identification of impacts on fisheries in: Erosion/siltation, pesticides and fertilisers in water, heating of streams - Need to describe potential impacts of upland LCP on downstream fisheries - Description of potential impacts in swamp lands: loss of nutrients, aquatic habitats, biodiversity, increased accessibility of fisheries leading to over-exploitation	Not specific method for fisheries ▪ Process - Impact identification - Impact measurement - Interpretation and Evaluation - Communication ▪ Methodologies Types: checklists, matrices, networks, simulation modeling workshops Other types: ad hoc, overlays, environmental index, cost/benefit analysis
Environmental Guidelines on JICA Development Study for Agricultural and Rural Development Projects *JICA* *Japan, 1992* Agricultural and Rural Development Projects	Significant Environmental Impacts: - Economic activities: destruction or disappearance of grounds for fishing - Institutional and custom related issues: disturbance of existing fishing rights - Biological and ecological issues: reduction of biological diversity - Hydrology and water quality: changes in water surface hydrology, deterioration of water quality affecting downstream fishery and aquatic habitat	Process in Project Cycle - Preliminary Environmental Study: project and site description forms - IEE : Initial and Joint Screening/Scoping (checklists) - EIA - Design for Protection Measures - Implementation - EMP - Monitoring of EI Methodology types: Ad hoc, matrices, networks, overlays
Environmental Procedures The Integrated Approach *European Union, 1993* Environment and Development	- Impacts on fisheries and aquaculture mentioned in 'Receptors of impacts' and 'Environmental impacts' of most checklists for Preliminary Environmental Assessment: irrigation, water supply, forestry, waste disposal and treatment, port and harbour projects, pesticides and fertilisers projects	Environment Appraisal: - Initial Screening - Preliminary Environmental Assessment - Environmental Assessment - Review - Monitoring - Project Evaluation - Institutional practicability

Source	Fisheries mention and consideration	Method for integration of Fisheries
The ICIDEnvironmental Check-List to identify Environmental Effects of Irrigation, Drainage and Flood Control Projects ICID, 1993 Irrigation, Drainage and Flood Control	Not specifically mentioned in the checklist but indirectly included in: - Ecology (rare species, animal migration), - Socio-economics	- Checklist: summary table, description, references - General data sheets - Specialised data sheets - Look-up table showing linkages - Results sheet
Environmental Impact Assessment of Irrigation and Drainage Projects FAO, 1995 Irrigation and Drainage	Aquatic habitats part of the selected Important Environmental Components - Description of biological resources and habitats status at the first stage (gathering information) - Identification of potential impacts due to changes in flood regime and water quality - Environmental Management Plan (EMP) specific to fisheries and aquaculture	Working steps: - Gathering information and consultations - Environment description - Analysis and prognosis of environmental appraisal - Overall environmental appraisal - Recommendations for environmental management 3 types of EIA: Rapid EA (REA), semi-detailed EA (EIA-s) and detailed EA (EIA-d)
Environmental Handbook Documentation on Monitoring and Evaluating Environmental Impacts *BMZ, 1995* Agriculture	- Consideration of various options for fisheries and aquaculture at the planning stage of a dam project - Integration when deciding on dam design - 5 categories of environmental aspects: . adverse effects on aquatic life . environmental impact caused by fisheries and aquaculture (F/A) . socio-economic situation influencing use of resources . effects of F/A on the socio-economic situation - Impact of F/A on environment and socio-economics	- Scope - Environmental impacts and Protective measures - Analysis and evaluation of EI - Interaction with other sectors - Summary Assessment of Environmental Relevance - Computer-aid simulations of both ecological and economic situation Use of a Standard model
Environmental Appraisals for Agricultural and Irrigated Land Development *GTZ, 1996* Agricultural and irrigated land development	Listed in: - Biological imbalances (wetlands and aquatic habitats, freshwater and saltwater systems, fauna) - Conflicts over development activities (reservoirs, water supply, fisheries and aquaculture)	- Identification of environmental changes: matrices, checklists, impact networks - Evaluation of EIA studies - Proposals for EMP 3 types of EIAs - Flexible process integrated into the whole project cycle (planning and implementation) - Predictive negative impact reduced, mitigated or compensated during the planning stage - Quantification of impacts in monetary terms (MCA)
A Guide to preparing an Environmental Impact Assessment (Irrigation Sector) *Overseas Economic Cooperation Fund* Japan, 1997 Irrigation projects	No specific considerations on fisheries	- Screening - Scoping - Assessing - Alternatives and Mitigation - EIA report documentation - Reviewing - Monitoring Environmental Management

The results show that overall few documents specifically mention the impacts of irrigation projects on fisheries. The fisheries sector is represented in a minority of EIA frameworks such as the ones provided by ADB (1987), FAO (1995) and BMZ (1995), and to a lesser extent EU (1993). More often fisheries issues are indirectly addressed through: i) impacts on the ecosystem (GTZ 1996, ICID 1993), including

biodiversity (JICA 1992) and wetlands (RAMSAR 2000); ii) impacts on the physical environment, including hydrology, water resource management, water quality (JICA 1992, ESCAP & UN 1990), and iii) impacts on the socio-economic (BMZ 1995, ICID 1993) and institutional environments (including potential conflicts, as in GTZ 1996).

The general focus is on the ecology and diversity of aquatic resources, in particular biodiversity conservation. In these studies, impacts on fisheries are usually considered as an indicator of ecosystem integrity and biodiversity. Where socio-economic impacts on fisheries are addressed, it is through the contribution of the activity to rural production, employment, income generation and preservation of socio-cultural values, and possibly through resulting conflicts.

Despite the integration of fisheries into the biophysical or socio-economic environment of the project, the methods for impact assessment tend to be reductionist or single-issue. Impact assessments are mainly conducted through the use of dichotomous indicators and dummy variables (presence (0)/absence (1) or yes/no) such as: the presence of a particular fish species, potential impacts on critical aquatic habitats, on effects of water quality change on freshwater fish. This is reflected in the wide use of checklist protocols based on the identification of presence or absence of listed potential impacts. Use of continuous variables as indicators is less common given data constraints except estimates of the economic value of fisheries (e.g. UN 1990, JICA 1992, ICID 1993, FAO 1995, GTZ 1996). More integration has been attempted with the use of matrix and network frameworks (see Table 4.1) but the analysis is usually limited to the identification and representation of impacts on different factors and sectors of the environment, including fisheries.

These assessments tend to rely on outcomes and aggregated results for the project area, and the resulting determination of impacts tends to be descriptive and a static "snapshot", particularly for results issued from checklist frameworks. On the whole the existing frameworks support identification of potential impacts by expert judgment, but provide only limited guidance on quantification of impacts and

integration of information towards a holistic understanding. As a result, assessments may miss the dynamics and likely interactions between the components of the fishery system (see Chapter 2) and the spatial and social distribution of impacts.

Similar limitations have been noted in the identification and selection of mitigation and enhancement measures, when responses are based on identified outcomes viewed independently. In addition, little consideration is given to the cost of management measures and to more feasible alternatives for mitigation and enhancement. A typical example are the fish ladders commonly designed to mitigate fish migration (see also Chapter 2, Section 2.3.1) although their relatively high cost may not justify their generally low performance for tropical fish species (see also Section 4.3.1.3). In addition impairment of longitudinal migration may not be the major cause of decreased fisheries production, and reestablishment of some lateral and longitudinal connectivity downstream of the irrigation scheme may have more benefit for fish recruitment and thus for fish production.

In general the lack of baseline data and studies has constrained impact assessment studies, and as a result, observers note that irrigation projects have often been implemented with minimal fisheries studies (see examples of Yali Falls, Nam Song and Theun-Hinboun dams on the Mekong tributaries, Hirsch 2001). Where fisheries studies are carried out, data used to be collected over a very short period, often during a single season (Hirsch 2004) with the potential biases on impact assessment results (both biophysical and social; see Chapter 2) this implies.

To conclude, fisheries assessments have been insufficiently or inadequately integrated into EIAs, even where conducted for the appraisal of large-scale irrigation projects. These results will be used and further developed in the identification of general strengths and limitations of assessment frameworks (Section 4.1.3).

4.1.2 Social Impact Assessment (SIA)

Social impact assessments are usually similar in structure and sequence to EIAs, i.e. they generally consist of a baseline description of the social environment, the assessment of potential socio-economic impacts, and listing of recommendations for management and decision-making on project development.

A SIA usually measures impacts not only in economic terms but also in qualitative terms when describing social changes. This involves evaluation of the tangible and intangible social and cultural benefits and costs of a project. In practice, SIA describes what types of effects will likely be felt in the communities affected, identifying the groups at risk or that will benefit, and when possible the extent of the impacts (time frame, degree of pervasiveness, proximity indicators, etc.) (Vanclay 2000). To date application of SIA to the impacts of irrigation on inland fisheries has not received much attention. The few social impact assessments widely reported in fisheries were addressed to the marine sector (e.g. NOAA 1994, Health Canada 1999). The review of SIA literature can thus only be general.

SIAs are most often implemented as part of EIA studies. In cases where SIAs are carried out independently, they may overlap with EIA studies although an important difference is that the latter tend to focus on the value of economic products while SIA also emphasizes social processes of impact (Vanclay 2000, Sadler et al. 2000). In addition SIA usually attempts to integrate the perceptions of impacts and wider perspectives of the different stakeholder groups impacted by the project.

In general, SIA promotes collaborative and participatory approaches but experience shows that stakeholders rarely contribute or influence the final outputs of the SIA (NOAA 1994, Health Canada 1999). The major reason identified is the difficulty of the participatory assessment process in particular due to the political consequences of raising social concerns on the project, and its lack of integration into the decision-making (e.g. NOAA 1994).

4.2 Specialist impact assessments

Specialist assessments essentially draw from reductionist approaches. In this thesis a broad definition of reductionist approaches is adopted, referring to approaches that narrowly focus on one or a few selected component(s) of the fishery system. They usually reflect a disciplinary view of the system and as illustrated in Figure 4.2, their assessment may cover one or several components of the fishery system.

4.2.1 Specialist biophysical assessments

In principle, assessing the impacts of irrigation on the biophysical system implies assessing all direct and indirect changes induced by the development of irrigation. This is complex and raises many difficulties such as the assessment of structural and functional changes in the ecosystem, including the differentiation of effects per aquatic species and species assemblage. Ecological studies have thus focused on key determinants of the impacts of irrigation on fisheries, mainly habitat and flow factors that are essential to assure the living functions of aquatic resources (see Chapter 2, Section 2.1.1). Furthermore the identification of aquatic habitat degradation as one of the main threats to the sustainability of fisheries (see Chapter 1, Section 1.2) has strengthened the focus on physical habitats.

There are several established approaches and methods for the assessment of biophysical impacts:

- Qualitative identification and classification of impacts
- Aquatic habitat assessment
- Empirical yield models
- Mechanistic population models
- Information from quantitative impact assessments

Qualitative identification and classification of impacts

Several types of classification exist, mainly based on ecosystem trophic levels (e.g. MacCartney et al. 2000). Assessments such as proposed by Petts (1984) and adapted by Bergkamp et al. (2000) have classified the impacts 'per order' from physical drivers of the ecosystem to the different trophic levels. First-order impacts refer to ecosystem driving variables (flows, water quality, sediment loads, morphology of channel, floodplain and coastal delta). Second-order impacts relate to primary production (plankton and periphyton, growth of aquatic macrophytes, riparian vegetation, delta and coastal vegetation) and third-order impacts on fauna (aquatic species, waterbirds, etc.).

These classifications can be useful for disentangling the biophysical impacts of irrigation on fisheries, from effects on the physical environment to respective effects at each level of the food chain on which aquatic resources depend. The classifications also provide a simplified representation of possible interactions between trophic levels that are of relevance in the assessment of fisheries production (see Chapter 2, Section 2.1.1.3).

Many impact assessment guidelines provide checklists of impacts, generally focused on biophysical impact pathways. Such checklists can help ensuring that all major potential impacts are considered, but they do not provide guidance on how to assess the likely level of impact. The latter is left to expert judgment.

Aquatic habitat assessment

On the assumption that habitat preservation is key to preserving species and ecosystems, habitat assessments aim to quantify the availability of suitable habitat under different scenarios of water resources development. A widely used methodology is to characterize habitat requirements of species in terms of factors such as water depth, flow velocity, temperature, substrate, and availability of food organisms in the form of a Habitat Suitability Index (HIS). The physical habitat

simulation system PHABSIM then allows prediction of the extent of suitable habitat given different levels of river flows (Welcomme 2001).

Empirical models (e.g. Pusey et al. 2000) have been developed for the relationship between fish assemblage structure, and hydrology and habitat. Impacts of disruption in longitudinal habitat connectivity on migratory fish species are also commonly assessed drawing from available knowledge of life histories (Bizer 2000, Jackson & Marmulla 2001).

Environmental flow methods are a set of widely used and increasingly highly developed habitat assessments. The regime and dynamics of the river flow has been increasingly recognized as a key driver of river ecology and associated wetlands (Brizga et al. 2002). The impacts of river flow modifications on ecosystems have received a particular emphasis and a wide range of methods has developed, mostly for rivers without significant floodplain habitat. The main methods identified are the 'instream flow' assessments (e.g. Bunn & Arthington 2003); the 'instream flow incremental methodology' (IFIM) (e.g. Reiser et al. 1989, Stalnaker et al. 1995) in developed countries, a habitat rating approach including habitat hydrodynamic, and 'environmental flows' (Arthington et al. 1992, 2004; Tharme 1996, 2003; King et al. 1999).

For fisheries purposes, such flows are defined as the quantity of water that must be maintained in a river system at all times to protect the species of interest for fisheries or for conservation and the environments on which they depend (Arthington et al. 2004). In practice, environmental flow assessments have tended to focus on some important (in terms of economic value, public interest, or biodiversity) fish species in large rivers. The implication of spatial and seasonal hydrological patterns on fisheries production have also been analysed through the use of geographic information systems (GIS) (de Graaf et al. 2001) and Bayesian network models (Baran et al. 2003).

River flow assessments have provided detailed information on changes occurring in the riverine ecosystem after impoundment of an irrigation scheme, particularly in the diversity of its aquatic resources. However focusing on the river ecosystem alone usually appears a too limited and narrow approach. This is particularly the case in the tropics where the floodplain and other types of water bodies independent from the river, may play a crucial role in the ecology of fish and the production of fisheries.

Empirical yield models

Empirical models have established the relationship between fisheries yield, habitat characteristics and fishing effort. In Sri Lanka, Nissanka & Amarasinghe (2001) developed empirical models for predicting fish yields in lakes and reservoirs on the basis of hypsographic curves (i.e. area-water depth relationships). Other factors like hydraulic retention time and morpho-edaphic factors were found to influence fish yields in tropical reservoirs. Nissanka et al. (2000) have assessed a range of reservoir storage levels that can contribute to fishery productivity. These empirical models have supported the assessment and management of reservoir fisheries.

Mechanistic population models

Mechanistic population models are based on an understanding of biological processes at population level. In floodplain systems, these models provide quantitative predictions of fisheries yields in relation to flooding patterns (e.g. Welcomme & Hagborg 1977, Halls et al. 2001). For reservoirs, assessment models estimate fish populations, including the effects of water level fluctuations on fish yields (Welcomme & Hagborg 1977, Martin et al. 1981, Beam 1983, De Silva 1985).

Quantitative impact assessment

In principle the best quantitative information on impacts can be obtained from 'before-after' or 'impact-control' studies with adequate replication. However such studies are available only for a few systems, notably flood control and irrigation schemes in Bangladesh (Halls et al. 1999), and small- and medium-scale irrigation

schemes in Laos (Chapter 3; Lorenzen et al. 2000). While a detailed and rigorous assessment of all impacts of irrigation on the biophysical factors affecting fisheries is probably not feasible in practice, quantitative assessment of changes that are key to aquatic resource ecology can provide results of high value, especially in supporting the quantifications and valuations required in cost-benefit analyses of irrigation projects. In addition they can provide an empirical base for practical assessments in other comparative locations, and for assessment frameworks (see for example for EIAs, Section 4.1.3).

However, rigorous experimentation, for example the replicated comparison of impacted and control sites, is usually not practical in the field and cannot build on ideal experimental conditions for validation of hypotheses. In this context, observational studies can offer a practical alternative but their limitations (mainly the subjective bias in the selection of sites; see Chapter 3, Section 3.4.2) have to be considered in the interpretation of the quantitative results. Quantitative results are thus needed in principle but in practice, the resources required may impair the feasibility of the impact assessment, and alternative methods such as empirical relationships may have to be sought.

4.2.2 Socio-economic assessments

The social and economic assessment of the impacts of irrigation on fisheries has been overlooked in the past irrigation project appraisals that show an overriding focus on irrigation engineering and hydro-ecological assessments. The development of socio-economic assessments is more recent (e.g. WCD 2000) and mainly results from the increased recognition of irrigation impacts on fisheries production and the livelihoods of people dependent on these.

Socio-economic assessments of irrigation impacts aim to ensure that irrigation projects contribute to processes in society that will use resources efficiently,

maximize welfare and reduce poverty. Objectives include enhancement of rural livelihoods and improved equity in the distribution of benefits (e.g. use of the equity principle developed in WCD 2000). The distribution of impacts is thus another important feature of the socio-economic analysis, and this implies identifying who will lose or gain from these changes in order to optimize the performance of the project.

The most commonly used methods are cost-benefit analysis (CBA), socio-economic profiling, and more recently livelihoods analysis. Socio-economic assessments are usually both quantitative and qualitative for inclusion of tangible (e.g. assets such as land, fishing gears, nutritional intake) and intangible costs and benefits (e.g. cultural identity, social values, sense of being marginalized or empowered to make wider choices).

Cost-benefit analysis and valuation of fisheries

Cost-benefit analysis is still the most widely employed technique for both appraisal and ex-post evaluation of irrigation projects and indeed, the origins of this technique are closely associated with the history of investment in dams for irrigation and hydropower (Curry & Weiss 2000). The analysis determines whether in aggregate for a scheme, costs are balanced by benefits over time for the national economy. Ultimately this technique aims to inform decisions on the value of the investment compared to alternative projects or project designs. Whilst of merit in attempting a monetised and aggregate comparison of costs and benefits for the national economy, the approach has four main limitations of relevance to the impacts of irrigation on fisheries.

First the comparison of costs and benefits can never be comprehensively inclusive. Although the need to include externalities such as the impacts on the environment as well as direct costs and benefits is recognized, practical difficulties in quantification and valuation may lead these to be neglected. In fisheries, conventional economic

valuations are generally derived from the value of the production and respective economic effects only (employment, post-harvesting, etc.) (see the global review conducted by Neiland 2003). Environmental and social benefits are usually not valued and these excluded 'intangibles' will inevitably carry less weight in decision-making. For example, the modifications to or loss of the natural river environment supporting fish stocks and human interactions with these stocks can challenge or eliminate traditional and culturally important fisheries (Jackson 1991). This can also apply to other 'downstream' livelihoods such as floodplain grazing and flood recession farming. As a result, scientists and practitioners have observed that analyses of dam schemes tend to underestimate costs (particularly to the environment and to fisheries) and overestimate benefits (Adams 2000a, 2000b; WCD 2000).

Secondly, standard methods take no account of the incidence and distribution of costs and benefits. Accompanying social and environmental impact assessments (see Sections 4.2.1 and 4.2.2) may be carried out, but detailed differentiation of impacts between locations and communities or groups is rarely comprehensive. Thirdly, the aggregate comparison of a "snapshot" of costs and benefits inevitably promotes a "blueprint" style approach to project design and management in situations where an adaptive and reflexive approach may be more appropriate. For example results of CBA in ex-post evaluation may lack explanatory power.

Lastly, the use of discounted cash flow analysis raises concerns about the long-term valuation of natural resource stocks, biodiversity and user costs for future generations. While during the assessment (usually at the irrigation planning stage), the value of preserving natural inland fisheries is often estimated to be lower than the benefit gained from increasing crop production, future generations might have to bear the costs of degraded capture fisheries. This cost could reach high levels where the resilience of the natural ecosystem is likely to be irreversibly threatened (e.g. in highly polluted waters).

Socio-economic profile

The aim is to compile information that will reveal the sources and extent of socio-economic differentiation within the potentially affected population. Socio-economic impact assessments can rarely build on ideal experimental conditions and a rigorous assessment of baseline conditions is often impossible, for example when project implementation or social and/or economic changes have already occurred in the project area. The socio-economic profile presents the physical (location), demographic and economic characteristics of the area. A preliminary profile of the area can be prepared using secondary information, direct observations and reconnaissance field visits, and discussions with stakeholders and key informants (e.g. local government officials, merchants, school teachers, NGO representatives, etc.).

More refined information can be gained using methods of wealth ranking or other participatory and/or rapid rural appraisal techniques. Often socio-economic profiling and livelihood analysis are combined (Neiland 2003) but this is not necessarily always the case. For the assessment of irrigation impacts on fisheries, socio-economic profiles are useful to draw the baseline and support a comparative analysis of pre- and post-project situations.

Livelihood analysis

Core concepts of the livelihood analysis are that the assessment must be people-centred, holistic and dynamic in seeking to understand and build upon processes of change. It must consider linkages between activities at macro and micro levels and the importance of the policy and institutional environment in influencing chosen livelihood strategies and outcomes. Livelihood analysis originates in part from analyses of the differential capability of rural households to cope with crises, and variation that stems from different patterns of asset holding. This emphasizes the need to understand the policy and institutional environment in which households operate and the 'vulnerability context'. The most vulnerable households will be those with low resilience (the ability to recover from stress or shocks), and high sensitivity (the

magnitude of the effect of an external shock) (Allison & Ellis 2001). Smith et al. (2005) have provided a framework for analysis of rural livelihoods, modified from Alison and Ellis (2001) (Table 4.2).

Table 4.2 Framework for Analysis of Rural Livelihoods

Assets	**for which access is modified by**	**in a context of**	**resulting in strategies**	**composed of activities**	**with outcomes in terms of**
Natural e.g. land, water, fish stocks, forest Physical infrastructure, tools and buildings Human skills, knowledge and health Financial income flows, savings, credit Social kinship networks, associations, trust, access to wider institutions	Social relations: - Gender - Class - Age - Ethnicity Institutions: - Customary - Land & water tenure - Markets Organisations: - Associations - NGOs - Local admin. - State agencies	Trends: - Population - Migration - Technological change - Relative prices - Macro policy - National & world market trends Shocks: - Climatic - Market - Disease - Conflict	Livelihood strategies	- Fishing - Cultivation (non-market) - Cultivation (market) - Livestock - Other hunting and gathering - Rural manufacture - Rural trade - Services - Farm labour - Non-farm labour - Migration - Remittances - Other transfers	Livelihood security: - Income level - Income stability - Seasonality - Vulnerability Environmental sustainability: - Soil & land quality - Water - Fish stocks - Forests - Biodiversity
Resource endowment	**Institutional and policy environment, and vulnerability context**		**Household choices and resource allocation**		**Outcomes**

Smith et al. 2005, modified from Alison and Ellis 2001

Techniques of livelihood analysis include the characterization of social groups and strata using various participatory techniques (e.g. group discussion and wealth ranking), or more formal household surveys. In the assessment of irrigation impacts on fisheries, the livelihood analysis is particularly important in understanding the exploitation patterns of fishing and the role the activity is playing in rural livelihoods and strategies, and how this may change with the development of irrigation.

4.2.3 Holistic assessments

In the literature, holism appears more often as an objective and a principle rather than a specific methodology. The holistic approach has generally been pursued through the integration of all components relevant to the topic through a variety of ways. Literature refers mainly to the integration of disciplines and/or sectors and activities, for example, Integrated Natural Resource Management (e.g. Campbell et al. 2001, Sayer & Campbell 2003, Harwood & Kassam 2003), 'bridging the disciplinary divides' (e.g. Kinzig 2001), and 'coupling' or 'merging' social and ecological systems (Carpenter & Cottingham 1997). Now that the need for holistic approaches has been widely acknowledged, the major concern is not whether holism is relevant but how to implement it. In practice, holism has most often been defined by default where insufficient integration of factors from several disciplines (e.g. biophysical, demographic, socioeconomic, behavioral) or sectors (e.g. irrigated agriculture, fisheries, forestry, and domestic use) led to failures in understanding and solving "*real-world*" problems (e.g. Liu 2001).

'Environmental flow assessments' (see also Section 4.2.1.2) have developed 'holistic methodologies' (Tharme 1996, Arthington et al. 2004) but this holistic approach is taken from a river flow perspective and does not cover the entire fishery system and interactions between its components as described in Chapter 2 (Section 2.2.5). As a result livelihood impacts are deduced from ecological consequences of river flow modifications and this does not take into account the various functions of fisheries in rural livelihoods and the processes that determine labour allocation decisions (and hence fishing effort) in the wider socio-economic context. As for socio-economic assessments of irrigation impacts on fisheries, these have rarely clarified the implications of fisheries production in both the overall context of rural livelihoods and socio-economic development likely to be induced by irrigation (Smith et al. 2005).

In principle holistic methodologies have the capacity to further incorporate advanced single-issue techniques (such as hydraulic and habitat modeling tools) as they become available, as well as their consideration of multiple ecosystem components (Tharme 2003). This capacity is particularly useful for the assessment of irrigation impacts on fisheries and this will be further developed in Part II (Section 4.2.2.1) of this chapter. Such approaches and guidance for practical application are still rare although attempts towards more integration between disciplines are noticeable (e.g. WCD 2000). Apart from the 'Guidance Manual on the Management of Impacts of Irrigation Development on Fisheries' (Lorenzen et al. 2004) derived from this research, no holistic impact assessment has been identified that specifically applies to the impacts of irrigation on fisheries.

The spatial distribution of impacts raises issues in both the boundaries of assessment and the spatial analysis of impacts within these limits. The ecological boundaries defined in ecological studies do not necessarily match the scale of potential impacts of irrigation on the ecosystem. Depending on the scale of the irrigation scheme and its spatial distribution (e.g. through the canal network), effects can extend far beyond the irrigation project command area and its respective hydrological catchment. This was the case in Sri Lanka with the impacts of the Kirindi Oya irrigation project on the lagoons in the neighbouring catchment (see Chapter 6).

The spatial boundaries of assessments above or below the irrigation scheme do not necessarily extend up to the catchment (or beyond). Within selected boundaries, downstream changes have often been overlooked or much less studied (e.g. due to the remoteness of the area or a lack of interest, WCD 2000). In addition the linkages between upstream and downstream effects are rarely analyzed or may be misinterpreted. For example, irrigation benefits for fisheries upstream of a project area do not necessarily add to the benefits downstream, and similarly for the costs. This may be due, for example, to the migration of fish, the mobility of fishers, resettlements and redistribution of lands induced by the project.

In livelihood analysis, assessments that focus only on an immediate micro-level can overlook households' opportunities and constraints raised in the economic environment at meso and macro-scales, as well as wider trends or shocks. In particular, neglect of markets and their influence on livelihoods and poverty can lead to failure in identifying livelihood opportunities and constraints arising from market processes and development. For example, irrigation development is likely to stimulate the social and economic development of the area, with potential increase of employment in other sectors. This is likely to increase the opportunity cost of fishing with a possible decrease in fishing effort.

4.3 Critical conclusions on existing impact assessments: strengths and limitations

Reductionist and process assessment frameworks are available for the study of biophysical and social impacts of irrigation on fisheries. To various extents they have provided background knowledge of relevance and utility to the assessment of such impacts. The literature review has identified the strengths and limitations of existing impact assessments with respect to the impacts of irrigation on fisheries.

4.3.1 Reductionist *vs.* holistic?

While the techniques and methods provided by reductionist hydrological and ecological assessments can be powerful in assessing particular issues relevant to biodiversity conservation, aquatic resource ecology and fisheries production, they may present significant limitations when assessing the impacts of irrigation on fisheries. The following disciplinary gaps and uncertainties have been identified:

- Contrasting with the focus on the species level and respective habitat requirements, ecological changes emerging at ecosystem or species assemblage level have been much less studied. This would imply considering compensatory mechanisms of stock increases or catches in multi-species and

multi-gear fisheries (e.g. in fish population models), as will be the case in most tropical river-floodplain fisheries. It is however recognized that the integration of compensatory mechanisms and interactions between species and between fishing gears, would highly complicate the assessment of all incremental, synergistic and antagonist effects induced by the development of irrigation.

- There is a significant dearth of quantitative assessment of the magnitude and duration of impacts.
- In comparison to biophysical assessments, social studies that have applied to the impact of irrigation projects on fisheries have generally been neglected.
- The valuation of fisheries and the assessment still faces difficulties in reflecting all use and non-use costs and benefits of fisheries, and proposed methods are generally difficult to implement (mainly because of high data requirements).
- The perceptions and social significance of change induced by the impacts and the reflexivity of stakeholders' reactions (e.g. anticipation of change in fishing grounds such as reservoir creation; anticipation of change in fishing efficiency at bottleneck points) are rarely considered.

Holistic assessments of the impacts of irrigation on fisheries are still rare although attempts towards more integration between disciplines are noticeable. While there is a need for more integration, such impact assessments attempt to be cross-sectoral and cross-disciplinary, in particular when the integration of SIA in EIA is achieved. Existing assessment frameworks do not provide systematic guidance on the identification of boundaries and of spatial differentiation within them. The review of literature has thus shown that in most cases, both reductionist and holistic assessments are desirable to improve the understanding of impacts and their assessment.

4.3.2 Participation of stakeholders

Whilst participation is usually limited to local partnership and data collection in specialist assessments, participation of stakeholders (also called the 'public') is a regular feature of process frameworks. However experience of participation is still limited and literature of participation applied in impact assessment frameworks relatively weak. That is why the scope of the review on participation has been broadened to other studies (see Section II.4.1.2).

4.3.3 Feasibility in a context of limited data and resources

While impact assessments are often carried out in a context of limited data and resources, available knowledge tends to be under-exploited. Various types of knowledge of the impacts of irrigation on fisheries (e.g. local knowledge of fishers, results obtained in other comparable catchments) could increase the knowledge on the impacts and potentially improve their assessment and management.

Where the methods proposed by assessment frameworks are not adequate (e.g. a too superficial EIA checklist method *vs*. in-depth assessment requiring too many data), means for increasing the use of available knowledge (including local knowledge) and for seeking alternative methods have rarely developed. Attempts to optimize the use of knowledge could also improve the feasibility of the assessment. For example, ranges of average fish production per category of aquatic habitat are available and can provide a strong basis for cross-checking predictions usually made from theoretical calculations.

EIA and SIA frameworks have not been systematically tested and validated before wide-scale dissemination. They often face limitations when addressing local constraints, in particular the lack of data and resources, and as a result the feasibility of these frameworks has often been under question (e.g. Sadler et al. 2000, Vanclay

2000). Although a regularly specified component of EIAs, monitoring and evaluation are not much applied in practice, although they may provide substantial support to improving the performance of the assessment, in particular where data are insufficient and assessment results uncertain. For example, surprising and unpredictable effects (e.g. voluntary migration of populations, sudden ban on fisheries by religious groups as for example in Sri Lanka, Chapter 6) may result from the implementation of an irrigation project or may happen in the course of its existence.

4.3.4 Inadequate support to the management and decision-making

Although more oriented towards management outcomes, standard frameworks usually lack means for achieving the following objectives.

- Adequate representation of fisheries issues (in particular due to the difficulties in valuation of fisheries and of ecosystems services, see Section I.4.1.2) and giving them a proper weight in the management and decision-making of irrigation projects.
- Clear identification of objectives of assessment frameworks and management recommendations and in particular, the potential divergence between the objectives of increased fisheries production and conservation (see Chapter 2, Section 2.2.5) is rarely addressed.
- Assessment of trade-offs between competing demands, typically when deciding on reservoir water allocation to satisfy the needs of irrigated farming and/or fishing, or when deciding on the degree to which fisheries development may be facilitated in irrigation canals and how access will be managed.
- Achievement of a true participation and a broad based acceptance of management measures across sectors (particularly by farmers and fishers) and institutional levels (e.g. by communities, and local and national level

officials). This may also involve means for resolving conflicts because diverging views and interests may emerge in decisions on assessment and management of impacts.

- Although it will be too late to make drastic changes in the infrastructure design, identification of specific needs for the sustainability of fisheries (e.g. the timing for water release to facilitate fish migration; the maintenance of minimum water levels in reservoirs) may improve the overall performance of existing irrigation systems. For this purpose ex-post assessments can support the improvement of irrigation operation and management with regard to the development or sustainability of fisheries.

Specialist assessments generally provide little interpretation or support for the use of results in management and decision-making. Within the fisheries sector, the objectives of fisheries production and ecosystem conservation are usually approached independently although consideration of their particular interdependence (as developed in Chapter 2, Section 2.2.5) may have important implications in the management of aquatic resources. For example, maintaining river flows to preserve or enhance the livelihoods of fishers downstream of a dam in a context where the river does not contribute much to fisheries production (see for example in Sri Lanka, Chapter 6).

In contrast with reductionist assessments that are not primarily designed for providing management results, process frameworks have put more emphasis on management purposes. However fisheries tend to be under-represented and analysis of the trade-offs in the management of irrigation water generally neglects the needs of fisheries. In addition, participation needs to be enhanced (see Section 4.3.2) and attempts should be made to build consensus on management decisions.

II. An Approach for Impact Assessment: Adaptive, Participatory and Integrated Assessment (APIA) of the Impacts

The lessons drawn from the literature review (Chapters 2 and 4, Part I) and from the previous impact assessment (Chapter 3) have informed the development of the approach. The assessment of the impacts of irrigation on fisheries is proposed through a sequential process that is outcome and management oriented. Its particular features are that it is an integrated, participatory, adaptive and composite assessment. Although adopting a holistic approach, the assessment focuses on the impacts of irrigation on fisheries production and rural livelihoods (as justified in Chapters 1 and 2).

4.1 Features of the approach

In seeking to achieve the objectives defined above, the approach has been assigned several key features as discussed below.

4.1.1 Holistic and integrated assessment

In this thesis, holism is taken to refer to the objective of broad coverage and understanding of issues, viewing the problem under study as a whole and in its wider context, rather than a specific methodology.

A holistic approach is called for here because, as illustrated above (Section I.4.2), the biophysical and socio-economic systems under study involve multiple actors and causal factors. Impacts can be interconnected or obscured by other processes of change. They can also result from multiple causal factors that act in synergy, in competition or by compensation (see for example Chapter 2, Section 2.2.5).

Analytical boundaries are not easy to define because the impacts of concern can spread across socio-economic sectors and research disciplines, and across spatial and temporal scales. Interactions between chains of cause and effect can be difficult to disaggregate and predict with accuracy, not the least because of the adaptive reactions of stakeholders.

As indicated in Section 4.2.4, the major current concern is how to implement a holistic approach. In APIA, integration of the following factors is sought: of the inputs from disciplinary specialists (e.g. hydrology, irrigation engineering, fisheries ecology and socio-economics), for analysis across sectors (agriculture, fisheries and alternative land uses and employments) and across the hierarchy of governance and institutions (from communities to local and national government).

The first objective is to achieve the minimum required degree of integration for building the overall picture of the impacts of irrigation on fisheries (in terms of locations, sectors, stakeholder groups or different time and space scales), and the general distribution of costs and benefits. This should prevent missing any critical issue or opportunity lying in the interaction between activities, actors, scientific disciplines, locations or time periods. The assessment will aim to be comprehensive in the identification of key issues raised by irrigation impacts on fisheries and selective in the identification of detailed investigations wherever this is necessary.

Mechanisms of spatial distribution of impacts and temporal variability of the main causal factors will probably not be fully identified at the onset of the assessment. Hence spatial and time scales for the assessment may initially be set based on a-priori assumptions and preliminary assessment results, and then refined as understanding of the issues of most significance is gained. The spatial study scale of an irrigation project can be a-priori the catchment area (the hydrological unit of most irrigation projects) but wider scales of study may be required, for example, where the irrigation system extends beyond the catchment (e.g. via canals) and where effects are likely to be felt across catchments.

In any case, critical linkages between micro, meso and macro-scales have to be kept and clarified, for example, so that studies at river basin scale can exploit the results obtained at the catchment scale when assessing cumulative impacts. In addition the participatory assessment across institutional levels (see Section 4.1.2) will probably need interpretation and adjustment of project results in the context of the national issues raised from governmental representatives.

Across time scales, different trends and dynamics, e.g. seasonal patterns of activities also need to be considered. For example, long-term effects on the ecosystem may not be revealed during the analysis, and the consequences of drying-up a reservoir on fish stocks can be felt more strongly in the following years. In some cases, a positive impact in the current year (increased catches when the reservoir has been dried up) can turn out to be negative the following year (due to the resulting stock depletion in the reservoir). Spatial and time scales selected for the assessment thus need to be kept under review as part of an adaptive approach (see Section 4.1.3) throughout the assessment process.

4.1.2 Participation by stakeholders

Here stakeholders are defined as the persons, groups and organizations with a valid interest in the impacts of irrigation on fisheries. This includes all those whose livelihoods are connected to it (e.g. fishers, farmers, manufacturers and suppliers of equipment, traders and processors), those who are affected or benefiting from the impacts, and those who influence the management and decision-making on irrigation and fisheries. Stakeholders are found across the institutional levels, from the community of villagers to the local and national (including decision-makers and policy-makers) representatives of the government.

Rationale

The rationale of a participatory approach to the assessment of the impacts of irrigation on fisheries is discussed through identification of the benefits of stakeholder participation, the methodological requirements and the potential risk and constraints associated with its implementation. General strengths and limitations of participation have been extensively reported in the literature (e.g. Campbell & Salagrama 2000, in the fisheries sector). Table 4.3 summarizes the key aspects referring specifically to the assessment of irrigation impacts on fisheries, and these are also discussed below.

Representation. As actors in the problems of irrigation impacts on fisheries, stakeholders of relevant sectors are involved in attempting to solve these within the assessment process. The aim is to convert stakeholders from being part of the problems to an agent in their resolutions (as further developed below). Inter-sectoral representation is particularly important in this case because fishers are often left out of irrigation management decisions and as a consequence, they usually do not have much influence over the management of water and aquatic resources. Adequate representation could also help in correcting the usual neglect and underestimation of the significance of fisheries in rural livelihoods.

Adequate representation of fishers typically requires giving a 'voice' to fisher groups in discussions or negotiations with farmers and other water users, and enhancing expression of their interests and concerns. However expression of diverging interests or revealing issues that had lain hidden has the potential for creating conflicts. Representation of the fisheries sector may not be straightforward because the fisher groups are rarely homogeneous and often differentiated in access to resources and social influence. Lastly power and influence of other stakeholder groups (e.g. farmers) might impede or block reaching a balanced contribution of representatives.

Table 4.3 Main benefits and associated risk or constraints of participation to the assessment of irrigation impacts on fisheries

Benefit	Methodological feature	Main associated risk or constraint
1) Representation		
Selection of representatives	Conflicting views	
Give voice to fishers	Enhance expression of interest	Impeded by more powerful
2) Shared knowledge		
Integration of fishers knowledge	Awareness creation	Confusion, knowledge management
	Enhance knowledge creation	Need for translation
	Increase-improve knowledge	Miscommunication
	Integration of multiple views	
3) Shared analysis		
Multi-sectoral issues	Collective learning, analysis	Slow down the process
	Holistic and integrated approach	
Whole range of institutional levels	Communication between institutions.	Bias, power
Integration of issues of different scales		Confusion, lack of consensus
4) Consensus building		
Uncertainty of scientific outputs	Share responsibility	Disagreement, need for negotiation
Irreducible value judgment	Societal choices, preferences	Potential for conflict creation
Part of the problem-solving	May influence behaviour change	
5) "Ownership" of outputs		
Identification of management options	Favour sustainability of options	
Aid to decision-making	Inform, transparent decision building	

Shared knowledge. Local knowledge is captured and exploited for two main purposes: to increase and improve overall knowledge of impacts in the area under study, and to promote a shared construction of knowledge across a range of sectors and institutional levels. The importance of fishers knowledge has been acknowledged in the literature, and this is primarily supported by the fact that fishers are de facto managers (Baelde 2001, Neis et al. 2001). The limitations of specific scientific assessments (as developed in Chapter 2) can also gain from local knowledge where this can fill knowledge gaps, or complement information from surveys, for example on fishing techniques used, aquatic habitats available (including their access), or migration patterns of different species. Expression of local knowledge can also improve understanding of the values and priorities of different affected groups and act as a trigger to further construction of shared knowledge and analysis (see below).

Construction of shared knowledge involves accessing and using the various forms of knowledge expressed or displayed by stakeholders of different sectors, at different institutional levels. Adequate communication skills (including translation and workshop facilitation) are important because the data and information have to be sufficiently understood by the stakeholders. However communication and collaboration between stakeholders and scientists can be hampered by narrow professionalism or socio-cultural barriers. Furthermore the combination of the two distinct forms of knowledge is clearly not straightforward (Neis et al. 1999, Neis et al. 2001). For example, inputs from local knowledge may need evaluation before inclusion in the scientific inquiry, not the least because of its potential for being highly subjective and biased. In general, participatory experiences have shown that information can be perceived and used as a source of power and influence in the decision-making (e.g. Irland & Vincent 1974).

Shared analysis. Throughout the assessment multiple perceptions and perspectives of the impacts will be revealed, often differing and sometimes conflicting. Given pre-conceptions and biased perceptions of reality, the challenge is to achieve a convergence in the definition of key issues, objectives of assessment and ways to solve the identified issues. The approach thus needs to establish a common understanding building towards convergence of opinions to the extent possible. Stakeholder contribution to assessment of impacts may imply facilitating the development of local capacity.

The approach must also show the ability to translate a wide variety of data and information, from stakeholder perceptions of an issue to detailed technical assessment results. Capacity building may again be required since stakeholder should understand at least the main principles of the analysis to ensure their contribution and interaction. While the integration of local knowledge may enhance the impact assessment capabilities and performance (e.g. by raising critical livelihood issues as in Sri Lanka, see Chapter 6, Section 6.1.5), it is clear that results inevitably carry stakeholder

judgment. This will add to the traditional 'professional judgment' of technical and scientific impact assessments.

Consensus building. A shared understanding of the perceptions and priorities of other groups can change attitudes and promote consensus in the definition of key problems, management objectives and possible solutions. Indeed simply initiating or improving the representation of fishers in negotiations with farmers and other water users can be of value in correcting past sources of bias. In addition where affected communities are not only appraised but given the opportunity to participate in the assessment and subsequent management of their social and environmental context, they may adapt in reasoned ways to changing circumstances. This can result in positive or negative outcomes for the process.

Therefore the approach seeks to establish a broader caucus and hopefully consensus for matters of societal preference and value judgment. However this complicates the specification of management objectives and selection of preferred outcomes. For example, socio-cultural barriers can impede negotiation with different stakeholder groups, as in case of low ranking fishers. In extreme situations, the process may reveal incompatible interests, and conflicts that are non-resolvable.

Enhance 'ownership' of management options. Consideration of values and stakeholder priorities is required because the choice of management measures is ultimately (partially or fully) the result of societal preference. The features above have the potential to enhance the acceptance and 'ownership' of management options and recommendations, improving their implementation and sustainability (for example, through greater compliance with regulation, reduction of enforcement costs or contribution to costs). The sharing of responsibilities and uncertainties can significantly increase the sustainability of management measures. This form of ownership often needs to be established across a range of institutions and levels of decision-making in particular, where the mitigation measures promoted locally (e.g.

increased allocation of water for fisheries; reduction of water pollution by farming, cities and industries) have implications in the management of the whole river basin.

In order to simplify the presentation of the summary table (Table 4.3), the main risks and constraints of participatory approaches have been presented per type of methodological feature. However these can overlap for example, where power influences from farmer groups decrease fisher representation, and thus lower or annul the other benefits of participation (shared knowledge, analysis and ownership of outcomes). In general, the overarching significant constraint of a participatory approach is that it is likely to increase the resources (time, budget) and skills (e.g. communication, translation, workshop facilitation) required for the assessment and outcomes may not justify the investment. Ultimately discouragement may prevail in the face of the challenges to be overcome.

Appropriate degree of participation

Despite the challenges revealed in the previous section, the importance of the benefits of stakeholder participation usually calls for an increase of its use. As with the holistic approach, the key issue will be how to implement the approach in order to gain from it while minimizing the risk of losing because of it. This study suggests emphasizing the selection of the appropriate degree of participation as the first means to optimize the use of participatory approaches in impact assessments.

Literature shows that participation of stakeholders can range from their contribution as sources in extractive processes of data collection, through processes that complement and inform the assessment and management by state authorities, to processes in which stakeholders participate fully and are genuinely empowered in influencing the setting of objectives and decision-making (e.g. Biggs 1989, Pretty 1995, Abbot & Guijt 1998, Guijt & Gaventa 1998, Leeuwis 2000, Allen 2001). Participatory processes at this latter end of the spectrum are considered by many practitioners to be the most promising means to address complex resource

management challenges in rural areas. However both the debate and the development of optimal modalities are still ongoing.

The APIA approach attempts to achieve a 'genuine participation', defined as the interactive, creative and continuous contribution of stakeholders throughout the impact assessment process, from identification of key issues to selection of management measures and decision-making. This involves responsibility, and a strong and genuine commitment of stakeholder representatives throughout the process. In the typology of participation proposed by Biggs (1989) and Pretty (1995), this corresponds respectively to a 'collaborative' participation or an 'interactive' participation compared to lower levels (consultation only) or higher levels (self-mobilisation) (Table 4.4).

The appropriate degree of participation will also depend on the local context, the resources available, and the significance of the problems under study. Whilst the target should be 'genuine participation' local constraints may inhibit achievement of this level. As indicated above, a frequent consequence is the large increase of resources required by the participatory assessment, typically where stakeholder skills are low and require capacity building programs. Iteration (see Section 4.1.3.2) should help in evaluating the appropriate degree of participation and adjusting it during implementation if this becomes critical to the assessment.

In APIA, workshops are used as the principal fora for participation. Stakeholder representatives are invited to a series of workshops covering the sequential process of impact assessment. National representatives are expected at least in the final decision-making phases. The role of each participant is clearly defined at each stage of the process, particularly with regard to the selection, weighting and application of decision criteria. The aim is to create an enabling environment for interaction between scientists and stakeholders and support a process that is open to self-criticism, reflection and evolution towards negotiated agreement and possibly conflict resolution.

Table 4.4 A typology of participation: how people participate in development programmes and projects

Typology	*Characteristics of Each Type*
1. Manipulative Participation	Participation is simply a pretence, with 'people's' representatives on official boards but who are unelected and have no power.
2. Passive Participation	People participate by being told what has been decided or has already happened. It involves unilateral announcements by an administration or project management without any listening to people's responses. The information being shared belongs only to external professionals.
3. Participation by Consultation	People participate by being consulted or by answering questions. External agents define problems and information gathering processes, and so control analysis. Such a consultative process does not concede any share in decision-making, and professionals are under no obligation to take on board people's views.
4. Participation for Material Incentives	People participate by contributing resources, for example labour, in return for food, cash or other material incentives. Farmers may provide the fields and labour, but are involved in neither experimentation nor the process of learning. It is very common to see this called participation, yet people have no stake in prolonging technologies or practices when the incentives end.
5. Functional Participation	Participation seen by external agencies as a means to achieve project goals, especially reduced costs. People may participate by forming groups to meet predetermined objectives related to the project. Such involvement may be interactive and involve shared decision making, but tends to arise only after major decisions have already been made by external agents. At worst, local people may still only be coopted to serve external goals.
6. Interactive Participation	People participate in joint analysis, development of action plans and formation or strengthening of local institutions. Participation is seen as a right, not just the means to achieve project goals. The process involves interdisciplinary methodologies that seek multiple perspectives and make use of systemic and structured learning processes. As groups take control over local decisions and determine how available resources are used, so they have a stake in maintaining structures or practices.
7. Self-Mobilization	People participate by taking initiatives independently of external institutions to change systems. They develop contacts with external institutions for resources and technical advice they need, but retain control over how resources are used. Self-mobilization can spread if governments and NGOs provide an enabling framework of support. Such self-initiated mobilization may or may not challenge existing distributions of wealth and power.

Source: Pretty, 1995

4.1.3 Adaptive Approach

Such objectives assigned to the integrated and participatory approaches (as described above) will probably not be achieved at once in view of their respective constraints

and limitations. An adaptive approach is thus needed as a flexible and learning response to the complexity and inevitable uncertainty raised by the integrated and participatory assessment.

Adaptive approaches have initially developed for the purpose of managing natural resources, essentially with the 'adaptive management' proposed by Holling (1978) and further developments of the approach e.g. in marine fisheries (Walters 1997). Adaptive approaches commonly recognize the need to engage in a learning process in response to the complexity and uncertainty that characterize natural resources systems. The aim is to improve management and decision-making. Various forms of adaptive approaches are now available, e.g. for the assessment and management of the environment (some EIAs, e.g. World Bank 1993, Hughes 1998) and in fisheries ('adaptive learning', e.g. Garaway & Arthur 2004). The principle of adaptation has also been applied to scientific research ('adaptive research', e.g. Collinson & Tollens 1994).

More precisely, the adaptive approach is useful in APIA for:

- assessing the relevance and significance of the APIA approach, and evaluating its operation, performance and impact;
- adjusting the degree of assessment to the resources available, with possible variation of emphasis in assessment of issues;
- if necessary adjusting the degree of integration and participation throughout the assessment (as described in Section II.4.1.2);
- responding to creative knowledge potentially derived from the integrative and participatory assessment;
- responding to emerging events, unexpected outcomes and unpredictable stakeholder reactions;
- adapting assessment results to the needs of management and decision-making;
- allowing an incremental improvement of the APIA approach throughout replication and multiplication of case studies.

The progress and outcomes of the impact assessment should be continually monitored and evaluated, and feed-back mechanisms should correct or improve the process and the outputs produced by it. The structured and sequential process allows adaptation at each stage of the assessment. The following methods are used for implementation of the adaptive approach as developed below: i) monitoring and evaluation and ii) iteration and learning.

Monitoring and evaluation

The progress and outcomes of the impact assessment will be continually monitored and evaluated. A prior condition is that the APIA process should be transparent and open to regular critical examination. An evaluation framework is suggested in Table 4.5, based on the widely used concepts of logical framework analysis (Poate 1996, Wiggins & Shields 1995). It provides a structure for systematic evaluation of APIA, first to check the relevance and significance of the approach (i.e. whether it fits the identified requirements while implementing it) and then to evaluate its operation, the performance of its key features and its impact locally and globally. Throughout further implementations, the framework should also support incremental refinement of the approach.

Indicators and means of verification are proposed. The number of indicators is preferably limited due to inevitable constraints on time and resources. A possible option is that stakeholders and scientists agree on a set of quantitative (e.g. the number of stakeholders attending the workshops) and qualitative indicators (e.g. poor, average or good understanding of issues). Tools for evaluation and sources of information are suggested: direct observations, workshop questionnaires, documents, informal and regular review of the process, peer review of research outputs. The evaluation framework will be tested during the first case studies (Chapters 5 and 6).

Table 4.5 Evaluation framework

Structured evaluation	Indicators	Means of verification
Impact		
National & international	Wider uptake & adoption potential of approach	Peer review Acceptance and use
Project specific	Changes in water & fishery management within the project area	Monitoring and evaluation of implementation
Performance (Outputs)		
Identified research needs	Clear specification to fill critical knowledge gaps Importance	Peer review Uptake and resource allocation
Management recommendations	Relevant and feasible Justify costs of impact assessment	User acceptance & adoption Study team & workshop assessments Peer review
Impact assessment results	Accurate & comprehensive Management oriented Understandable & usable	Study team & workshop assessments Peer review
Performance (Key features)		
Adaptive	Adaptation to resource constraints Response to outcomes & lessons Reaction to unanticipated outcomes	Study team & workshop assessments
Participatory	Commitment/genuine involvement Integral use of local knowledge Representation of interest groups Communication & conflict reduction	Study team & workshop assessments
Holistic & Integrated	Inter-sectoral & disciplinary analysis & recommendations Comprehensive spatial & temporal coverage Diagnosis of complex causal pathways Synergistic & innovative outcomes	Study team & workshop assessments Peer review
Composite assessment	Cost-effective use of available data Ability to resolve critical questions & knowledge gaps	Study team assessment
Operation (Activities)		
Workshops	Number, conduct & completion to schedule	Study team observation & assessment
Impact assessment	Coverage & analytical tools/methods	Study team & workshop assessments
Secondary data collection	Data adequacy: coverage, authority, accuracy, level of disaggregation	Study team & workshop assessments
Primary data collection	Data adequacy: coverage, authority, accuracy, level of disaggregation	Study team & workshop assessments
	Cost-effectiveness of collection	Study team assessment
Operation (Inputs)		
Workshop participants	Number Representativeness for sectors & levels of governance	Attendance records Assessment of spatial, temporal & sectoral coverage of issues
Study team	Disciplinary coverage Expertise & skill levels Utility of inputs	Workshop assessment/participant questionnaires Relevance to outputs
Materials & Logistics	Workshop facilities, location & duration	Study team assessment Participant questionnaires

For example, the selected degree of participation will be assessed in relation to the local context, the resources available, and the significance and complexity of the

problems under study. It will be justified with subsequent consequences in the outcomes of the process, and this can be a negotiation at the start of the process. For example, evaluation might show that the lack of local participation did not allow expression of fishers' interests and led to potential underestimation of fisheries issues in the assessment. Capacity building may thus be required, in turn necessitating an increase in time and resources, and the risk of delaying the production of assessment results.

Iteration and learning

Iteration provides feed-back mechanisms to facilitate incorporation of evaluation results and subsequent lessons back into the process, preferably directly while implementing it but also possibly after implementation. Direct incorporation is necessary for identification and adjustment of the degree of integration (e.g. for time and space scales) and of participation, as justified above (in Section 4.1.2).

Learning from experience is thus inherent to the approach. For implementation in the APIA approach, several types of learning capabilities will be needed:

- learning to cope with imperfect knowledge and unpredictable outcomes;
- learning to recognise and integrate different values and priorities;
- learning to cope with the dynamic process of change initiated by the implementation of the approach itself.

To follow up on the example developed in the discussion of monitoring and evaluation, if evaluation shows the need to increase resources to provide capacity building and ensure a genuine participation, iteration mechanisms will either increase resources directly, or in the case that this is not possible, the expected degree of participation will have to be lowered. Impact assessment must record the change in participation with implications in the process, for example in this case, the likely decrease of commitment and ownership of stakeholders. The lesson is that further

studies should plan and allocate higher resources to participation if justified (as discussed above in Section 4.1.2).

Future use of the approach can exploit the lessons drawn from the first implementations in Laos and Sri Lanka (see Chapters 5 and 6). In general, outputs and lessons from the adaptive approach will be exploited for improvement of the APIA approach through an incremental process. Each application of the approach in various country case studies can thus be used as a learning experience that aims to improve the approach for the specific context and possibly to draw more generic lessons.

4.1.4 A composite assessment

Lastly implementation of the key features defined above requires a composite assessment for the following purposes:

i) To exploit the relative strengths and complementarities of methods or data sources in a given situation. This is also justified by the need to tackle strengths and limitations specific to each technique, typically when looking for complementarities between reductionist and holistic assessments (see Section 4.1.1). For example, while CBA compares the economic performance of engineering options, ecological modeling predicts fish populations in the water bodies resulting from these engineering options.

ii) To enhance the capacity for providing new perspectives and insights on the impacts of irrigation on fisheries.

iii) To support the adaptive approach when seeking to make optimal use of available resources and knowledge.

For these purposes, the assessment seeks to capture and combine different types of methods (analytical tools, empirical models, conflict resolution techniques, etc.), different sources of data and information from stakeholders, scientists and possibly other relevant representatives. This requires firstly a good and updated knowledge and understanding of facts relevant to the assessment, and secondly a selective capability for independent or combined use of these relevant sources of knowledge.

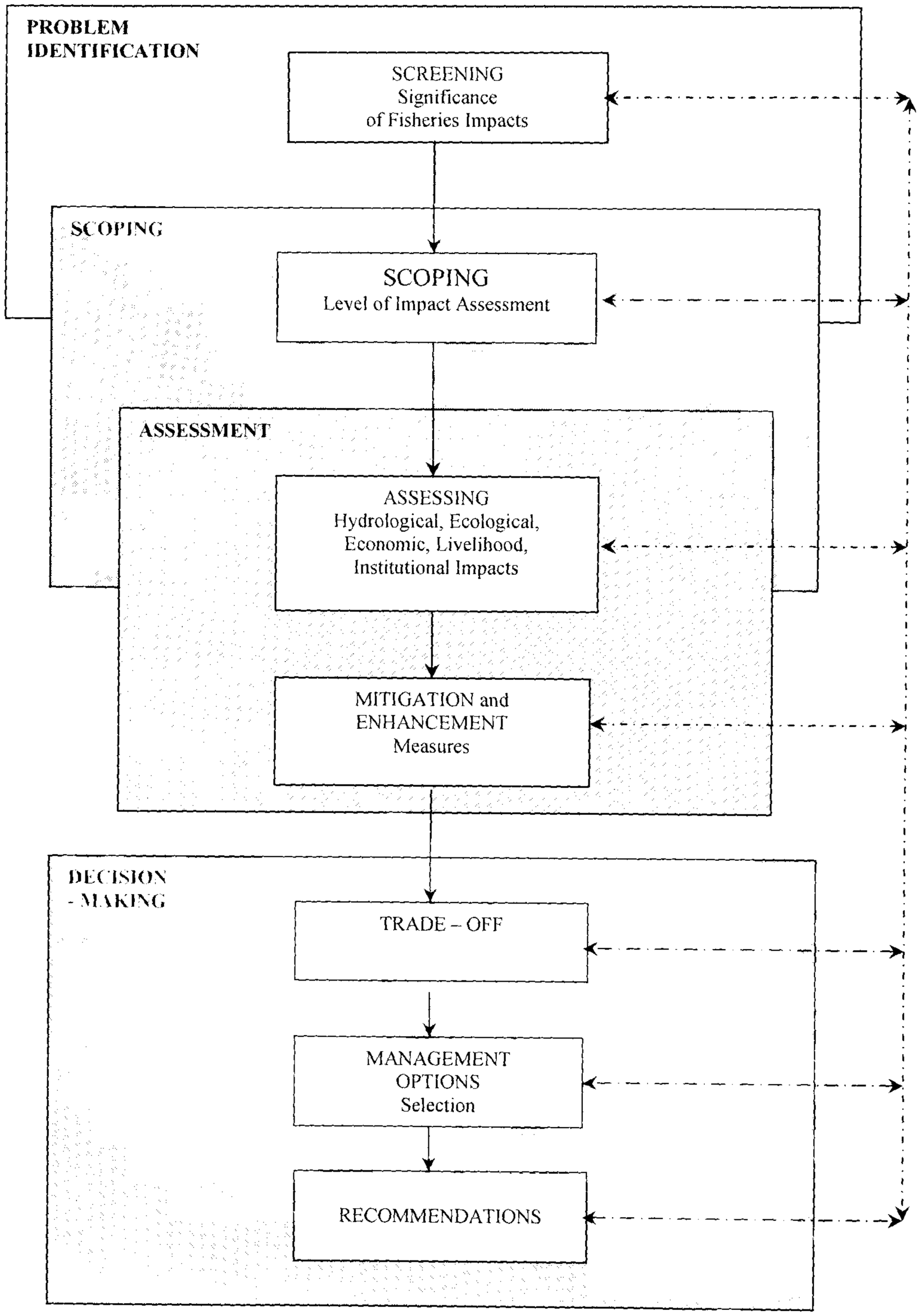
4.2 Stages of APIA

Despite possible limitations identified in the literature review (Chapters 2 and 4, Part I), the concepts and methods of EIA are clearly relevant to the impacts of irrigation development on fisheries. An EIA can provide a structured and sequential process, which can be sufficiently flexible in its implementation to accommodate the range and complexity of concerns identified above, while ensuring management oriented outcomes. A further advantage is that where the concepts of EIA are widely used and understood the prospect for fisheries assessments to be routinely integrated into appraisals of irrigation investments will be enhanced.

Following conventional practice for environmental impact assessment the approach involves stages of preliminary assessment, screening, scoping, impact assessment and identification of mitigation or enhancement options (Figure 4.3). This should be followed by monitoring and evaluation of the measures taken when implemented. The main stages of the approach are:

1) Preliminary assessment, screening and scoping
2) Assessment of impacts
3) Decision-making and management of impacts

Figure 4.3 Diagram of APIA stages



The sequence of screening, scoping and impact assessment phases should be seen as overlapping and often iterative in practice, particularly at the first stages when prioritization of issues and focus of assessments need to emerge from a possibly wide range of issues. Continuous monitoring has to refine the operation of the approach, checking its structure, activities and functioning, and tailoring it to local conditions and responding to challenges as they arise. Performance and impact will also be frequently evaluated in terms of the quality and utility of outputs, with iteration and refinement to improve these as necessary.

4.2.1 Preliminary assessment, screening and scoping

To ensure comprehensive coverage and involve all stakeholders the approach starts with a preliminary assessment of the likely impacts of irrigation development on fisheries for the case under investigation. First stakeholders (as defined in Section 4.1.2) are identified, and representatives are selected and invited to the series of workshops organized within the process of impact assessment. During the first phases of the process (e.g. scoping), this is ideally paralleled by a stakeholder analysis that includes initial determination of both likely impacts for different groups and the role and influence of these groups on management and decision-making (MacArthur 1997, ODA 1995).

Based on available data and knowledge, a preliminary assessment establishes whether an irrigation project is likely to have any substantial impact on fisheries that would call for a thorough impact assessment. Based on the preliminary assessment, screening determines whether an impact assessment is justified given the nature and importance of the possible impacts on fish production, livelihoods and biodiversity identified (including potential importance in the future). It should reflect a holistic view of both possible impacts and the perceptions of stakeholders. The outcomes of screening can thus be to proceed with a comprehensive impact assessment, to proceed with a more focused assessment of particular issues (both to be refined in terms of

actual coverage by the subsequent scoping stage) or to decide that no further work concerning impacts on fisheries is necessary.

The preliminary assessment may involve a combination of:

- identification of potential impacts on fisheries, livelihoods and biodiversity through use of rapid assessment tools and checklists and review of the results at the first workshop with stakeholders;
- initial description and prediction of impacts through a workshop in which experts or knowledgeable stakeholders give descriptive, or possibly numerical rankings, of the importance and magnitude of possible impacts;
- reconnaissance field visits and community or stakeholder interviews in the field;
- comparison with similar projects in comparable environments and with reference to available empirical information from secondary sources.

It will not be feasible to investigate all possible impacts in detail because resources (budget, time scale and expertise) will always be limited. The purpose of scoping is thus to define the issues to be assessed and the level of analysis needed for each, subject to resource constraints. This is achieved through specification of the study focus and elimination of irrelevant and insignificant issues, for example by preventing non-essential data collection or concentration of resources on one issue (e.g. impacts on a single species) while neglecting others. Since the scope of the assessment must optimize the production of assessment results, trade-offs between the required level of assessment (number of key issues considered, degree of accuracy of the prediction, level of management) and the resources available will be considered. Scoping is thus an important step in ensuring the feasibility of the study.

Scoping will primarily rely on the preliminary assessment for information, but should continue throughout the impact assessment as the study scope may need to be adjusted to take account of new information or changing circumstances. It should also complete the establishment of contact with, and participation by, all relevant

stakeholder groups. A workshop at the scoping stage thus involves reaching agreement on: the most critical issues, including the degree of urgency and irreversibility of change; the spatial boundaries for the areas affected; the physical and socio-economic processes to be considered, and their interactions and time horizons; and the level of assessment needed for each of these.

4.2.2 Assessment of Impacts

The impact assessment focuses on the key issues identified during scoping, and involves four activities.

1) Description of the project.
2) Description of the baseline situation; analysis is descriptive and summative with the aim of documenting a basis for evaluating project impacts.
3) Evaluation of project impacts through comparison of 'with' versus 'without' irrigation scenarios over time for the affected area. The possibility of change independent of irrigation should not be neglected, but in practice this usually involves comparison of the baseline with a predicted future (ex-ante appraisal) or reconstructed past situation (ex-post evaluation).
4) Identification and appraisal of mitigation and enhancement measures and long term management requirements.

The approach will capture various sources of information and utilise different types of knowledge (from scientists, stakeholders, and policy-makers), at different phases of the assessment process. Guidelines for the most relevant and fisheries specific tools and analytical techniques have been compiled in a "Guidance Manual for the Assessment of the Impacts of Irrigation on Fisheries" (Lorenzen al. 2004).

The assessment aims to establish the main processes of change underlying predicted or observed impacts on fisheries and dependent rural livelihoods, and any sources of conflict. The interrelationships between attributes are explored to identify how the

attributes are connected to possible (or observed) outcomes. Major impact pathways i.e. significant mechanisms linking causes and effects, are explored and the degree of change irrigation development may create in the identified system is judged. These relationships and causalities are analysed over time and space to the extent possible (in relation to scoping results). Through regular feedback the assessment seeks to determine why impacts may arise as observed or as predicted. For this purpose, the assessment must be sufficiently dynamic in tracking the varied and multiple possible pathways that could be the root cause of the impacts.

Assessment procedures should include the identification of mitigation and enhancement measures to support the management of irrigation impacts on fisheries and decision-making.

4.3 Conclusions

This chapter has proposed an approach to improve the assessment of irrigation impacts on fisheries, drawing firstly from the knowledge of the nature, magnitude and mechanisms of impacts (Chapters 2 and 3), and secondly from the review of existing methods and approaches relevant to the assessment of impacts of irrigation on fisheries (Chapter 4, Part I). The following key requirements were identified for the literature review.

i) While process frameworks provide useful starting points for holistic approaches, the holistic understanding and assessment of fisheries needs to be developed. Substantial knowledge can be drawn from existing specialist assessments, in particular on biophysical impacts. Specialist assessments also need to be continued primarily to fill key knowledge gaps and provide quantitative assessment results.

ii) The participation of stakeholders in the assessment and management of impacts should be enhanced. Literature and experiences on participation are

extensive, and have the potential for increased application in impact assessment frameworks.

iii) In a context of limited data and resources, impact assessments should better optimize the use of existing knowledge (including local knowledge) in order to increase the feasibility of assessment studies and process frameworks.

iv) Assessment results should support the identification of management measures, and improve the representation of fisheries in irrigation management decisions

While exploiting the strengths of existing assessments, the approach attempted to address their key limitations with respect to the impacts of irrigation on fisheries. The resulting approach is an adaptive, participatory and integrated assessment (APIA) supported by a sequential process that is outcome and management oriented.

The propositions of this chapter were tested and validated with evaluation of experiences in Laos (Chapter 5) and in Sri Lanka (Chapter 6). This contributed to improvement and refinement of the approach through an incremental process.

Chapter 5 - Testing and Evaluation in Lao PDR: Ex-Ante Impact Assessment

The impact assessment approach proposed and developed in Chapter 4 was first tested and evaluated in Laos. An integrated and participatory ex-ante assessment was carried out for a planned dam irrigation project. In this chapter methods and activities are described for the assessment of the baseline situation, evaluation of impacts and identification of management options based on mitigation and enhancement measures. Implementation of the approach is evaluated for its operation, performance and impact, noting that for this first case study, emphasis was given to the refinement and improvement of the approach. Conclusions are finally drawn from the results and discussion of the assessment and evaluation of the approach.

5.1 Methods and activities

The impact assessment was carried out over ten weeks from October to December 2001, during the early construction phase of the scheme. The assessment was carried out in a sequential process built around a series of stakeholder workshops and following the sequence defined and justified in Chapter 4. Methods and activities are described below. The author designed the case study and was present to manage and observe all activities throughout. A local study team was built with the local partner (the Regional Development Committee of Southern Laos, RDC) and consisted of one permanent and two part-time field officers, and one part-time supervisor.

5.1.1 Project selection

In practice, the selection of an irrigation project for appraisal should be made by the participants of the process, primarily the policy-makers and key stakeholders. For this pilot case study, the following criteria of selection were aimed at enhancing the feasibility of the study: the well-established working relationships with local partners (particularly RDC) in Southern Laos, the scale of the scheme (medium-scale), the accessibility of the site (at least road access) and the availability of secondary data.

In the province, three large-scale irrigation projects were under construction at the time of the study. The three dam projects started in 2000 and construction was planned to take three years. Within the district, priority for this study was given to Huay Thouat project since a previous study covered this area and irrigation impacts on fisheries were quantitatively assessed (see Chapter 3) in one of the impacted villages (Thouat Nua). This selection ensured some available knowledge of the area thereby decreasing the risk of non-feasibility for this first case study.

5.1.2 Data sources

Key sources of secondary data included the results of a quantitative, replicated fisheries impact assessment of small to medium scale dam irrigation schemes (Chapter 3; Lorenzen et al. 2000), and detailed analyses of the role of fisheries in livelihoods (Garaway 1999). Each of these studies was carried out in the Savannakhet plain near the case study site, providing quantitative information based on long-term and spatially replicated surveys.

Prior the testing, a livelihood analysis was carried out with the team of experts in order to study the baseline context in the project area. Informal surveys were carried out in a few villages and used methods of wealth-ranking, labour use, diagramming,

and semi-structured groups and household interviews. Results informed on the background of household livelihood assets in the catchment area (Smith et al. 2001).

Specific information for the project site and concerned villages was drawn from district and provincial records (e.g. population, rainfall, planned irrigated area, crop area and production per village and per household) and cross-checked with data from the technical feasibility report of the Huay Thouat project (Anon. 2000a).

5.1.3 Overview of activities

A sequence of eight workshops was arranged, corresponding to the stages of the assessment process described in Chapter 4 (Figure 4.2). The sequence of workshops has been organised in order to match each phase of the impact assessment process (see Chapter 4, Figure 4.1), from problem identification to decision-making. The characteristics of these workshops (content, participants, objectives, activities and outputs) are summarised in Table 5.1. Workshops were used as a mean to enhance participation of stakeholders throughout the implementation of the impact assessment process. Prior to the testing, the international team conducted a short and rapid appraisal of livelihoods and possible livelihood impacts (Smith et al. 2001).

Table 5.1 Planning and content of workshops and parallel surveys

No. Date	Objectives	Activities	Outputs	Surveys
WS 1 19/10	▪ Validation of stakeholder identification • Understanding of assessment study • Understanding of impacts • Screening: introduction	▪ Introduction of selected stakeholders • Introduce study and series of workshops with preliminary planning • Perceived impacts listed by groups • Classification of impacts per category • Mapping on the board to discuss potential linkages and interactions	▪ Final list of stakeholder representatives • List of potential impacts • Classification • Assignment of responsibilities for secondary data collection	• Preliminary investigation: Rapid appraisal in 4 villages • Meetings with stakeholders (villagers and government

WS 2 26/10	• Screening: continued • Validation of preliminary assessment results	• Introduction of workshop (plan & objectives) • Present results of preliminary investigation (literature review, meeting and rapid appraisals) ▪ Discussion and review of preliminary results	▪ Results on perceived significance of impacts • Decision on impact assessment to conduct (or not)	officers)
WS 3 02/11	• Scoping	• Introduction of scoping • Present assessment method and activities	• List of key issues • Identification of assessment activities in relation to available resources	
WS 4 09/11	• Synthesis of first phase (Problem identification) • Assessment: first phase	• Presentation of first results • Plenary and group discussions on results • Plenary discussion for identification of remaining gaps • Planning and agreement on responsibilities for remaining activities • Workshop evaluation	• First assessment results • Identification of remaining gaps • Assignment of responsibilities for following activities	
WS 5 19/11	• Assessment: second phase • Management introduction	• Presentation of assessment results per issue by study teams • Groups discussions for definition of data collection for baseline assessment and prediction	• Review of first phase: evaluation results • Baseline assessment results • Impact assessment activities defined • Assignment of responsibilities for activities	• Assessment: Rapid appraisal in 15 villages • Meetings with stakeholders (villagers and government officers)
WS 6 27/11	▪ Impact assessment finalised ▪ Management of impacts (1st part)	• Group and plenary discussions on assessment results • Group and plenary discussions on possible mitigation and enhancement measures • Workshop evaluation	• Conclusions on assessment results • List of adequate mitigation & enhancement measures	
WS 7 05/12	• Management of impacts (2nd part)	• Scenario building per group • Selection of evaluation criteria • Selection of scenarios per group • All participants suggest and agree on recommendations • Conclusion on study implemented at local level	• List of selected management options • List of preliminary recommendations for the management of impacts	• Meetings with stakeholders (government officers)
WS 8 11/12	• Introduction of study and purpose • Exchange and discuss with national officers, results obtained at local level	• Opening ceremony by provincial and national officials • Introduction of study and workshop plan • Stakeholder analysis for national officials • Presentation and discussion of assessment results and management measures proposed at local level • Plenary discussion on local level results	• List of impacts perceived at national level • Finalised stakeholder analysis • Finalised impact assessment results	• Meetings with stakeholders (government officers)
12/12	• Trade-off analysis • Support decision-making	• Identification of evaluation criteria • Selection of scenarios per group • All participants suggest and agree on recommendations • Workshop evaluation • Conclusion on the whole study	• List of adequate scenarios • Preliminary list of recommendations	

5.1.4 Stakeholder identification and analysis, and capacity building

An initial list of stakeholders was defined in consultation with local partner organizations (the Regional Development Committee and the Division of Livestock and Fisheries, and the Agricultural and Forestry Division). This included: i) the villages benefiting directly from or affected by the irrigation scheme across the project area; ii) the district and provincial level officers from the following institutions: the Department of Planning (Ministry of Planning), the Department of Irrigation (Ministry of Irrigation), the Division of Livestock and Fisheries, and the Agricultural and Forestry Division (Ministry of Agriculture), and iii) the engineering company responsible for project design and construction (Table 5.2). One or two representatives of each group were invited to the series of workshops.

The participation of villagers to the workshops was discussed with the local team. Time spent in workshop communication and capacity building was anticipated to be significantly higher if inviting villagers. The village surveys and informal interviews (see paralleled surveys, Table 5.1) were aimed at representing villagers' perception of impacts and issues. Lastly as villagers themselves, the district officers were anticipated to reflect (at least partly) their communities' interest. One villager was still represented due to his strong interest and commitment for enhancing fisheries in the area.

National representatives of the government were expected to be mainly involved in the final phase of the process (management and decision-making), they were kept informed about the workshops and key outcomes throughout the process. Results of the stakeholder identification were presented at the first workshop, for discussion and identification of any non-represented groups. Involvement of the provincial meteorological agency was suggested because of its role in hydrological data collection, a representative was invited to the next workshops.

Observations during the first workshop revealed the strong need for building capacity and enhancing participation. Usually aimed at supporting project design and stakeholder identification, a stakeholder analysis (ODA 1995) was used here primarily to enhance participation. Workshop participants were asked to define their interest in the study, and their perceived importance and influence in the process. According to ODA definitions, 'importance' refers to the degree to which the stakeholder is considered a focus of a decision to be made and 'influence' refers to the level of power a stakeholder has to control the outcome of a decision. Importance was ranked from 1 (lowest) to 3 (highest importance). Since participants felt a wider range of scoring was required to represent the different levels of influence, this was ranked from 1 to 6 (highest influence).

Table 5.2 Stakeholder identification and analysis. Expression of interest and self-evaluation of importance and influence (scoring) by workshop participants

Stakeholders	**Interest**	**Importance** Score from 1 lowest to 3 highest	**Influence** Score from 1 lowest to 6 highest
1) Villagers	Need expertise on fisheries and potential for enhancement in available water bodies after irrigation	3	2
2) District officers . Irrigation . Livestock & Fisheries . Crop	Important study because rice and fish are very important in Laos. Interest in receiving training to learn how to increase the production of rice and fish. Opportunities to work together for people involved in rice/fish related activities	3 3 3	3/2 4 3
3) Provincial officers . Agriculture & Forestry . Irrigation . Hydrology . Livestock & Fisheries . Crop . Planning	. Improve human resources skills particularly on rural survey/design techniques . Require expertise on mitigation of irrigation impacts and on the proper design of irrigation schemes . Need expertise in hydrology, water quality, chemistry to study the potential impacts on fish . Very high interest in this study because it addresses questions and issues raised in their regular work . Integration of different Government Sections. Particular interest in rice-fish culture . Need to improve knowledge on the management of natural resources for people in provinces, districts and villages	2 3 2 3 2 2	4 4 3 4 3 5
4) Private company	. Information on the impacts of Huay Thouat project on fisheries	3	3
5) National officers . Planning . Livestock & Fisheries	. Interest in following-up this study, in particular to develop extension activities and study implications in fisheries development (including fish processing). . Need expertise on reservoir fish management and fish breeding, in particular. Interest in following-up this study.	3 3	4 5

The main interests in contributing to the impact assessment study focused on improving skills and better understanding irrigation impacts on fisheries through inputs and support from experts. This revealed the potential duality of interests between the impact of project and the benefits of participating in the study and its process (this was also noticed during the village interviews). Increased communication on the purpose of the study was pursued during the first phase of the assessment. This was also important in defining possible pathways of impact (see also Section 5.3.3).

The majority of participants ranked average or high importance for the topic and approach of the study (2 and 3), particularly at community and district levels. National level officers also felt part of the study. The perceived influence depended on the sector of relevance (e.g. higher influence from Fisheries section ranked 4) but the main factor was the institutional level, national level officers having more influence in the decision-making (4 and 5).

The stakeholder analysis clarified the stakeholders' perception of the study and their expectations from the assessment and what commitment they may be prepared to make. Beyond enhancing participation, the stakeholder analysis also informed on the perception and expectations of the study (and destination of the work). The exercise also clarified how do stakeholders perceive each other in the discussions (by group and plenary). This also revealed that enhancing participation might need to be achieved through various ways (balancing representation, giving a 'voice' through facilitating expression of concerns, etc.). For example, villagers although of low influence in the decision-making, were recognized as very important for the study and thus should be adequately taken into consideration. This result was acknowledged by the national representatives.

Two types of exercises were designed to start building capacity.

1) Identification and classification of impacts

Four teams (3-4 persons per group) were organised per scale level and across disciplines, i.e. the villager representative joined the Champhone district officers, Savannakhet provincial officers formed the three other groups. Each team provided a list of potential positive and negative impacts. The variety and multiplicity of impacts raised the need to structure and classify these. Since the sectoral and disciplinary perception of impacts dominated, the following categories were suggested and agreed by participants as a mean to facilitate their understanding (Table 5.3): 1) hydrology and aquatic habitats; 2) fish ecology and resource use; 3) livelihood; 4) governance and institutions. Each category was assigned a color and each impact was classified and indicated on a card of the respective color. Each team presented the impacts on a series of coloured cards and results were discussed in a plenary session.

Table 5.3 List of all impacts of irrigation as identified by the working groups in the screening workshops

Impact	**Hydrology Aquatic Habitats**	**Ecology and Resource use**	**Livelihoods**	**Institutions**
Positive	. flooded area . increase of water availability in the wet season and close to the reservoir and canals throughout the year . storage of water in reservoir . 'F.R.I.E.N.D.S.' (Flood protection, Rain remission, Irrigation, Electricity, Drainage, Storage of Water)	. increase fish population . stocking / raising fish . increase fish production in reservoir . increase fish habitats	. increase rice production (second crop during dry season) . increase jobs in village . increase villagers income . use of fertiliser (more efficient in irrigated paddy fields) . increase area for grazing . better living conditions . increase agriculture production (vegetables, fruits, other crops) . increase domestic water supply	. enhancement of social ties between stakeholders

Negative	. flooded area . decrease of water availability downstream the irrigation scheme, especially in the river and floodplain . decrease water quality	. destroy forest . destroy wildlife . move wildlife . block fish migration . decrease fish biodiversity . decrease fish population downstream . decrease fish population in general	Decrease area: . for land use . for grazing . for paddy fields due to canals construction . increase inputs for agriculture . changes in jobs . resettlement of some villages	. lack of leadership for resource use management

As indicated in Table 5.3, some impacts were defined either as positive or negative depending on:

- their intensity e.g., decreased water levels in ponds and reservoirs can increase fish catch (+) but extreme drawdowns can deplete fish stocks (-);
- the location of impact e.g., negative downstream and positive around the reservoir;
- the timing and seasonality of the effect e.g., the increased availability of water during the wet season (+) and the reduced river flow in the river downstream (-);
- the socio-economic category of impacted people e.g. poor and landless downstream of the catchment (-) vs. wealthy benefiting from irrigation development (+);
- the sectoral activity of impacted people e.g., farmer (+) versus fishers (-).
- A combination of the above factors. For example, reservoir creation was perceived as both positive (by fishers, farmers) and negative (by re-settled villagers) across sectors and even within the fisheries sector since the nature of impact also depends on the location of the village community (e.g. far or close to the reservoir).

The high number of impacts identified by participants, their variety and the different orders of impacts (direct and indirect), showed an acute perception of the diversity of the impacts of irrigation on fisheries as exemplified above. Some impacts overlapped different categories (e.g. the increase of fisheries production in the reservoir had

impacts on the ecology of aquatic resources and also on livelihoods) and these were mentioned in each respective category.

2) Potential linkages between impacts: a map of interaction

The colored 'impact cards' were displayed on a board to visualize the potential interactions between the different categories of impacts. All participants contributed to suggestions for the potential position of each card on the board, based on its linkages with other impacts. For example, irrigation decreases catches in the floodplain downstream but increased farming labour requirements and rice production, and potential development of the area bringing new livelihoods opportunities (shops, etc). It was interesting to note that fishing was perceived to remain an important activity (though decreasing) in all different scenarios. This exercise gave a representation, diagrammatic visualisation of possible linkages between impacts of different orders and in different sectors.

During and at the end of the exercises, the understanding of impacts and study objectives by workshop participants was assessed through direct observation and workshop questionnaires (see further details in the Evaluation Section 5.3.2.1). Results confirmed that the assessment process could be pursued with enhanced participation from stakeholders.

5.1.5 Screening and Scoping

Screening aimed at establishing whether Huay Thouat irrigation project was likely to impact fisheries significantly. The significance of impacts was assessed through collection of secondary information and a preliminary investigation as described below (see also Table 5.1).

The area of focus (dam location, command area, likely impacted area) was first identified through a mapping exercise with the district officers from irrigation,

livestock and fisheries, and crop units. For the preliminary investigation four villages were purposively selected to be spatially representative of the impacted area, from the dam site to the tailend of the catchment. The reconnaissance field visits established contact with villagers, and provided location specific information on fish ecology and biodiversity, fishing activities (location, gears, and seasonality), livelihoods and institutions. During each visit field walks and direct observations were made, and semi-structured group and key informant interviews were conducted.

The key questions that addressed potential impacts on fisheries production, rural livelihoods impacts and biodiversity were:

1) Are natural fisheries important in the village?
2) Are fisheries or access to fisheries likely to be impacted?
3) Is the project likely to impact fish migration and fish species diversity?
4) How were the forest and wildlife in the project area before dam construction?

Similarly these questions were addressed to the participants through group discussions (organized per institutional level) during the screening workshop. The significance of impacts perceived by villagers and by workshop participants were presented and summarized in a table (see scoping results, Table 5.4). During the scoping workshop, participants identified the most significant impacts they perceived. Key data and critical information required for the impact assessment were defined, and responsibilities for data collection (and analysis to a lesser extent) were assigned to the respective stakeholder representatives (see Section 5.1.2).

Impact assessment methods and activities were designed on the basis of both the estimated significance of impacts in each main category (production, livelihoods and biodiversity) and the resources available for the study.

5.1.6 Assessment of impacts

As designed in Chapter 4 (Section II.4.2.2), the impact assessment included the description of the irrigation project and the baseline situation, the prediction of project impacts, and the identification and appraisal of management requirements (including mitigation and enhancement measures). The assessment first maintained a broad scope covering the identification of aquatic habitats, their productivity, fishing practices and effort, and labour use and livelihood opportunities within the affected area. The baseline situation was described and while identifying the main likely issues likely to arise after implementation of the project, the scope of the impact assessment was progressively tightened.

Secondary data collection was continued after the preliminary assessment (see screening and scoping). Information was generally scarce and scattered in different offices and departments. Typically the main source of information available i.e. the technical feasibility report of the Thouat project by the Vietnamese Institute of Irrigation Technology was available only in the capital Vientiane and in Vietnamese language. The report had to be translated in Lao and secondly in English during the screening and scoping stages (preliminary assessment).

To compensate for the general lack of information, other sources of knowledge were sought in particular empirical information from similar studies in comparable environments. The results of the previous quantitative assessment in the same area (Chapter 3 and Lorenzen et al. 2000) were thus exploited, as well as the surveys by the international team prior to implementation of this case study (during the design of the approach and preparation of its implementation), in particular (Smith et al. 2001) (see also Section 5.1.2). While clarifying the main issues, further gaps were identified and collection of secondary data subsequently continued.

Collection of primary data (started with screening) was pursued by district officers to further analyse specific issues (e.g. the main aquatic species caught by fishers;

migration of different fish species). This was done through additional field visits covering the 15 villages but data could not be fully exploited due to a lack of consistency and reliability. The quality of the data collected was relatively poor in terms of consistency and reliability, and was the result of limited professional capacity for this work. Therefore primary data were limited overall and could not allow more detailed analyses. Throughout implementation, progress on assessment activities and preliminary results were presented and discussed during the stakeholder workshops. This allowed validation of results and eventually completion and refinement of these.

5.2 Results

5.2.1 Background

The biophysical and socio-economic contexts of the country and the province have been introduced in Chapter 2. Here presentation focuses on the case study area, i.e. the district of Champhone in Savannakhet province (southern Laos), one of the 6 plateau provinces adjacent to the Mekong river. Relatively low lying (elevation from 50 to 200m above sea level), the area is fertile and suitable for a variety of crops including rice, vegetables, maize, and cassava.

The site of the proposed project was Huay Thouat, a small watershed at the edge of the Xe Champhone wetland area (Claridge 1996). Pre-project, there were 1,240 hectares of farmed land within the project area, of which 990 ha were used for wet season rice cultivation with yields of 1.9 to 2.5 tonnes per hectare. There was little dry season cropping. Surplus labour was considered to be available in the area and able to contribute to the development of irrigated agriculture.

The irrigation system was designed for a command area of 1,020 ha, distributed over 15 villages. It will serve 880 households, with a total population of 5,830. Drawn from calculations from the topographic map, the catchment of the Huay Thouat river has a total area of 63 km^2 including 43 km^2 above the dam, which will be located upstream of the confluence with the Champhone river. The reservoir was designed to retain 13 million m^3 (about 70% of the total available volume) and to have a surface area of 474 ha at full storage level (Anon. 2000a). The aim of the proposed project was to increase agricultural production by extending the farmed area and by developing a dry season crop. Construction commenced in late 2000 and was in progress during the period of the impact assessment.

5.2.2 Screening

The reconnaissance surveys confirmed the general characteristics of fisheries and livelihoods given by previous studies carried out in the same province and district (Garaway 1999, Lorenzen et al. 2000) including the quantitative assessment (Chapter 3). The Xe Champhone wetland area fisheries contributed very significantly to livelihoods, and the population living in the study area appeared relatively homogeneous and comparable to those investigated by the previous studies.

More precisely on the impacts of irrigation, results showed that concerns on negative potential impacts were relatively low because villagers emphasised the benefits the dam would provide to livelihoods. Within a large consensus villagers perceived the impacts to be positive in aggregate, primarily because the irrigation project would increase the availability of water (particularly during the dry season) and therefore the opportunities to fish, in the reservoir, irrigation canals, and rice fields.

On possible negative impacts only a few concerns were expressed, such as the loss of paddy land to irrigation infrastructure, the impact on the poor at the tail-end of the catchment and the possible decrease of some migratory fish species. The villagers did

not perceive these as significant because the benefits of irrigation would outweigh possible negative impacts from reduced wet season flows and obstruction of fish migration. Nonetheless uncertainties about the significance of the distribution of impacts (particularly the effects on the poor) and the effects on aquatic biodiversity did warrant an impact assessment.

Box 5.1 Results of reconnaissance surveys: informal interviews of key informants in four villages in the project area.

Question 1: Are natural fisheries important in the village?

Fisheries are important or very important, because all households are fishing during the whole year and their food subsistence is based on rice and fish. They can get some income from fish but not much compared to rice and not regularly.

Question 2: Are fisheries or access to fisheries likely to be impacted?

Irrigation impacts on fisheries are perceived as overall more positive than negative.

- Irrigation will bring more water during the dry season and provides more places to fish.
- Fishermen will save time because they won't have to go too far to fish, except for Vang Mao village.

However some worries raised from negative impacts:

- Some villagers lose paddy area because of reservoir and canal construction,
- Less water downstream the dam,
- Fish may have no place to migrate to during the dry season.

Question 3: Is the project likely to impact fish migration and fish species diversity?

Although there will be less water downstream the dam, fish could migrate from the reservoir to the canals and the paddy fields. The majority of villagers didn't perceive any major problem with fish migration and fish population. They would have more fish because more water and more places to fish. However water scarcity has been mentioned. During the dry season, Thouat river downstream the dam dries out and water level of Champhone river is very low (about 40 cm).

Question 4: How were the forest and wildlife in the project area before dam construction?

Most villagers didn't know the area. The ones who knew it made the following comments: "wildlife will have to move to other forests; destruction of forests might reduce rainfalls in the long term".

5.2.3 Scoping

Scoping aimed to establish achievable targets in the defined local context and select the levels of assessment most appropriate to available resources (time, human resources and finance). This also meant defining adequate study boundaries and

matching data sources and methods. Time constraints implied extensive use of available information, in addition to the implementation of rapid appraisals.

Table 5.4 Scoping results: Evaluation by local level stakeholders of the likely significance of impacts on hydrology, ecology, livelihoods and institutions against local resources in the respective government institutions.

	Hydrology, irrigation, and drainage	Ecology and aquatic resource use	Rural livelihoods	Institutions, rules
Significance of impacts				
. Villagers	2	2	2	3
.Workshop participants	1	2	2	2 (+)
Average	**2 (-)**	**2**	**2**	**3 (-)**
Local resources				
. time	2	2	2	2
. staff	2	2	2	2
. budget	1	1	1(-)	1
Average	**2 (-)**	**2 (-)**	**2 (-)**	**2 (-)**
Level of impact assessment	**2**	**2**	**2**	**2**

Note: Scoring from 0 (neutral) to 3 (highest), (+) and (-) indicating intermediary levels.

In evaluation it was judged that the balance of available local resources and the significance of impacts allowed an intermediate level of impact assessment. Although the average result may indicate a lack of ability to discriminate and evaluate the significance of potential impacts, the exercise gave indications on governmental opportunities for resource allocation. It showed that the decentralization of the government is giving more responsibilities and duties to lower institutional levels (mainly at the provincial level), although the budget might not be allocated in adequate proportion.

Therefore, where time and staff were available (as mostly the case), financial issues would often constitute the major bottleneck in implementation of impact assessment studies. This raised the potentially critical need to implement the approach in a context of relatively low resources and the stronger need to tighten the assessment to feasible expectations particularly in terms of financial resources. This exercise of scoping revealed the main potential bottlenecks in further institutional uptake.

5.2.4 Assessment

5.2.4.1 Baseline Situation

The aim was to establish a baseline or benchmark scenario from which to be able to predict likely changes with the introduction of irrigation. The natural resource system, the fisheries production and use of aquatic resources, and livelihoods, were assessed in the project area and at larger catchment level if relevant. Collection of information and analysis first focused on the baseline situation but could overlap with the prediction of impacts.

The natural resource system

The natural environment and aquatic habitats within the future command area and over the catchment were identified through participatory mapping and direct observation during reconnaissance surveys. Results showed that much of the upper Huay Thouat catchment is forested, while the area immediately above and below the dam is agricultural land. Water resources in the area are extensive but highly seasonal. In the wet season, the water resources include 990 ha of rainfed paddy fields, the Thouat river, and the much larger Champhone river into which it flows, and its associated oxbow lakes and depressions. In the dry season, only the Champhone river and its oxbow lakes retain water and thus provide fishing opportunities. Villages and cultivated land are concentrated in the lower Thouat catchment, within easy reach of these fisheries.

Wet season paddy production relies heavily on rainfall and surface runoff from upstream rice fields. The predominant irrigation practice is a cascade of basins with water flowing from basin to basin. The paddy fields are located in the beds of river valleys but the land level is higher than the water level of Xe Champhone therefore the natural flood recession can not be used for cultivation. Hence water resources in the area are extensive but highly seasonal and the river dries out during the dry season in many years. Quality of water is good and the Thouat river is clear. Land is

available to expand the cultivated area but cultivation techniques are not developed. Rice, the main crop, is produced only once a year due to the lack of water resources in the dry season.

Fisheries production and use of aquatic resources

In the project area fishing activity was concentrated in the Xe Champhone floodplain (below the Huay Thouat catchment) and in the rainfed rice fields. The natural aquatic habitats play a major role in fisheries production. Much of the cultivated area in the lower Huay Thouat catchment is within reach of the Xe Champhone wetlands, an area rich in oxbow lakes and seasonally flooded depressions which supports a productive inland fishery. Aquaculture was little developed in the area, contributing less than 10 percent of the total fish production.

Previous study (see Chapter 3) showed that even within irrigated rice farming systems, natural aquatic resources can be productive and diverse and they contribute significantly to the livelihoods of the poor. The characteristics of capture fisheries made them well suited for exploitation by households who are also farmers. Aquatic resources harvested include fish, shrimps and snails, obtained from permanent water bodies and seasonally flooded areas including paddies.

The production of fisheries in the different aquatic habitats identified on the pre-irrigation project maps could not be estimated during this short term study. Therefore comparative empirical data on fisheries production available for most habitat types and geographical areas were used. Empirical data relevant to the case studies are summarized in Table 2.2, Chapter 2. Productivity of river-floodplain systems has been broken down into river and floodplain (including natural floodplain and rainfed rice fields) components based on comparison of yields achieved from river basins with different levels of floodplain development.

All production estimates were cross-checked with consumption and market estimates and discussed with stakeholders. Baseline estimates for production are given in Table 5.6 below.

Rural livelihoods

The local economy was characterised by a relatively homogeneous population of households, clustered in largely independent villages, and engaged primarily in subsistence agricultural production. This was centered on paddy rice cultivation but with hunting, fishing, and gathering of non-timber forest products playing an important role in livelihoods. Occupational specialization in villages was low, and income from farming usually supplemented by other productive activities, micro-enterprise, casual labour, or permanent or part-time government employment (Smith et al. 2001). Women bore a significant burden of agricultural work as well as other household tasks. Table 5.5 summarises the status of household livelihood assets.

Drought or floods and their impacts on the wet season rice crop are the main sources of vulnerability for households, primarily with effects on livestock disease and human labour force (Smith et al. 2001, Hopkins 1995). The wealth ranking exercises conducted during the prior survey by the international team (Smith et al. 2001) found that the access to sufficient cultivable land and adequate family labour for cultivation, to secure a level of rice self-sufficiency or surplus were regarded by the villagers as the most important determinants of household food security and well-being.

Availability and characteristics of water and aquatic resources within walking distance of the village, and/or restriction on use, were important determining factors of total catches and more important than socio-economic differences between groups. Villagers also tended to be constrained in their access to fisheries by what is available in their immediate vicinity because fishing (in particular with 'passive' gear) is often combined with other activities that require household members to be in or near their village or rice-fields thus limiting time to travel to water bodies further away. Women generally fish in closer proximity to their homes.

Table 5.5 Household livelihood assets in the Huay Thouat catchment area

Assets	Status and key issues
Natural	• land variously developed as rice paddy and swidden fields (shifting cultivation), or maintained as forest for gathering wild plants and animals, fuelwood, and occasionally timber • fisheries provided by streams and rivers, seasonally flooded rice fields and depressions and perennial ponds and lakes • comprehensive assessment of how wider trends in population growth, agricultural development and commercial logging are affecting sustainability of land use, forests and livelihood security is lacking
Physical	• access to infrastructure and public services is highly variable but generally poor • in Champone district 57% of villages have year round road access, 25% have only dry season access, and 17% have no road access; 54% have an improved water source (UNDP/ILO 1999)
Human	• levels of health and education are poor, particularly for women (World Bank 2003b) • nationally, the rural literacy rate for those 15 years and older is 79% for men and 49% for women; in rural areas the average number of years of schooling for those aged 15-49 is 5 for men and 4 for women (National Statistical Centre 1999) • in Champhone district 57% of villages have a permanent health volunteer and 3% a permanent doctor; 28% have a complete primary school; 70% receive visits from agricultural extension workers and 14% from veterinarians (UNDP/ILO 1999) • significant indigenous technical knowledge of fisheries as well as of other wild foods and non-timber products from forest areas
Social	• strong inter-household cooperation and support, especially within kinship groups and in reciprocal labour exchange for peak farm tasks (Randall Ireson 1995). • customary access and ownership rights usually exist for fisheries and forests, although disputes and uncertainty over rights may exist • relatively low socio-economic differentiation between households and common reliance on shared fisheries and forests creates the potential for effective community management of these (Garaway 1999)
Financial	• low household savings • limited access to credit • sale of surplus fish catches can be one of few readily available sources of cash income for poor households

Source: Smith et al. 2001.

Use of seasonal labour was found to follow a similar pattern in each of the three villages surveyed. Rice cultivation is the most labour intensive activity, and peak household labour requirements occur during the periods of rice transplanting and rice harvesting. Care of livestock and collection of wild foods also occur throughout the year. Women tend to spend more time on the collection of wild foods than men, and for both men and women more time tends to be devoted to this activity during the wet season when more foods are available. Women are also engaged in growing

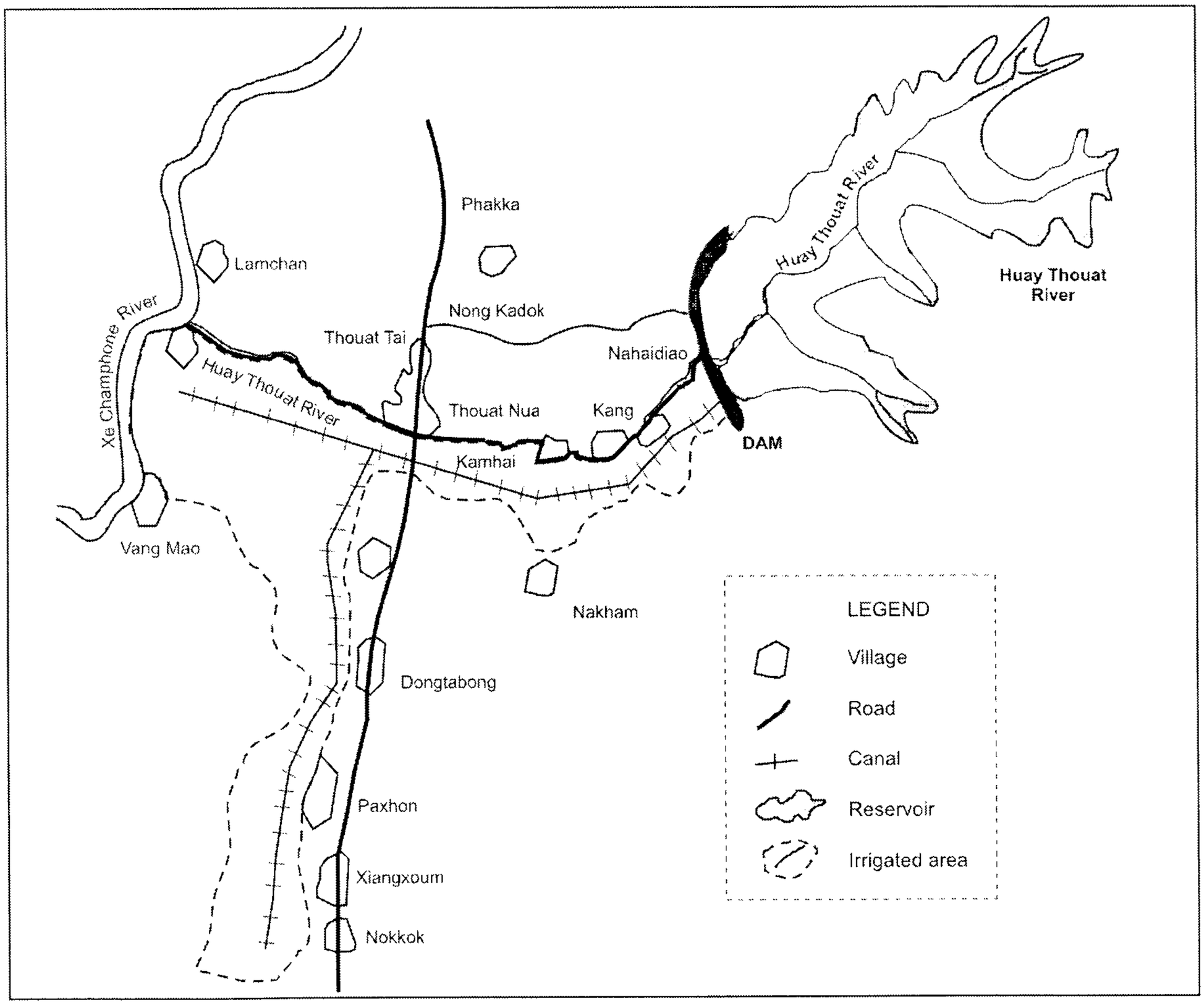
vegetables throughout the year, whereas for men this is more seasonal particularly if their responsibilities are mainly for seedbed or plot preparation (Smith et al. 2001).

5.2.4.2 Prediction of Huay Thouat project impacts

Impact on aquatic habitats and their connectivity

The irrigation system was added to the baseline map and respective changes in aquatic habitat availability and connectivity were showed on the maps (Figure 5.1) established and discussed with stakeholders.

Figure 5.1 Sketch of the planned Huay Thouat irrigation system and impacted area



The main changes predicted were:

i). An overall reduction in annual discharge of the dammed river due to evapotranspiration of irrigation water, and seasonal redistribution of flows resulting in lower wet season and higher dry season flows (from irrigation return flows and seepage).

ii). Relatively little change (less than 3 percent) in the seasonally flooded area comprised of rainfed rice fields (990 ha) (which is dominated by rainfed paddies and therefore not directly linked to river flow) and river Thouat floodplain (about 48 ha). This is contingent on the continuation of rainfed paddy cultivation in the wet season, as any reduction in paddy water storage would reduce their value as aquatic habitat.

iii). The creation of new dry season aquatic habitat in the form of a reservoir and irrigated rice fields. The reservoir will form a permanent water body with a maximum surface area of 474 ha, although the average area is likely to be lower at around 200 ha. The surface area will be well in excess of the seasonal floodplain area lost below the dam. Changes in aquatic habitat area will have direct implications on fisheries production as indicated in Table 5.6.

iv). The Xe Champhone river and associated wetlands, which dominate current dry season habitat, will be largely unaffected. The contribution of the Huay Thouat river to Xe Champhone discharge below the confluence was estimated as less than 2 percent based on relative catchment areas.

v). The loss of longitudinal connectivity of the Huay Thouat river at the dam site. Possibly reduction in lateral connectivity due to raised irrigation canals which may create barriers to fish migration into paddies situated above the command area, and reduced wet season river flow.

vi). A seasonal redistribution of remaining river flows, with a strong reduction in wet season flow and a moderate increase in dry season flow due to irrigation return flows and seepage.

Impact on fisheries production and the exploitation of aquatic resources

Projections of impacts on fisheries production were estimated by multiplying aquatic habitat areas (pre- and post-project) with empirical productivity estimates (Table 5.6).

Table 5.6 Estimated impact on fish production in the Huay Thouat catchment, assuming maintenance of rain-fed rice cultivation in the wet season and complete loss of mainstream river and associated floodplain production. See Table 2.2 for origin of productivity estimates.

Habitat	Catchment Area (ha)	**Before Project**			**After Project**		
		Area (ha)	Productivity (kg/ha/year)	Production (t/year)	Area (ha)	Productivity (kg/ha/year)	Production (t/year)
Rice fields*	6,300	990	60	59	990	60	59
Thouat River		0	0	2	0	0	0
Floodplain		48	80	4	0	60	0
Reservoir		0	100	0	200	100	20
Total		1,038		65	1,190		79
Change					**152**		**14**

Notes: * Rice fields contribute to fish production only during the wet season since water levels are low and natural recruitment onto this area is negligible (no migration) during the dry season.

Fisheries production in the Huay Thouat catchment as estimated from habitat and empirical productivity data is comparable to the expected consumption by local households (53 t/year, 880 households (district records) x 60 kg/ha/year). As shown in the biophysical impacts (see above), overall habitat and production are dominated by rain-fed rice fields, and this production is likely to be sustained unless connectivity is lost between perennial habitats and rice fields, or water retention in the wet season is reduced. Fisheries productivity of dry season irrigated rice fields is assumed to be negligible because of the low level of water and the quasi-absence of natural fish migration from perennial water bodies to upstream habitats.

Sustaining natural fish production in the Huay Thouat catchment on the current scale is thus highly dependent on the continued role of rice fields as seasonal fish habitat. The main threats to this role of rice fields are changes in agricultural practices that usually reduce water retention, and loss of ecological connectivity of rice fields with permanent water bodies. Availability of irrigation water reduces the need to store

water in rice fields, and allows intensification of wet season rice production with concomitant increase in the use of agrochemicals. Reduction in rice field water storage and/or extensive use of pesticides would drastically reduce if not eliminate fisheries production from rice fields.

While it is unclear to what extent the change in river flows and longitudinal connectivity will reduce fisheries production from the river and its seasonal floodplain, estimation shows that production from the river is only about 6 t/year in total. A sensitivity analysis based on the estimated impacts on fish production (Table 5.6) shows that only in the worst case scenario where the reservoir fisheries would not produce at all (e.g., in the unlikely case that people do not use it for fishing), this would incur a 6 t/year loss of production. Therefore even a complete loss is likely to be outweighed by a gain of about 20 t/year from the new reservoir. The net effect of irrigation development on production is thus likely to be positive in aggregate (+14t/year) or slightly positive if the reservoir produces only 10 t/year (+4t/year).

Irrigation infrastructure and water management may restrict fish migration from permanent water bodies to rice fields, due to low water availability in critical habitats along the migration routes, or physical obstacles to migration such as raised canals. Both impacts can be mitigated against (see Section 5.2.6). The extensive survey of fisheries impacts or irrigation schemes in which a traditional wet season rice crop was maintained (Chapter 3) found no evidence for effects on yield beyond those explained by changes in flooded area and fishing effort. This suggests that impacts on connectivity are not generally severe.

The aforementioned impact study in Laos (Chapter 3) indicated slightly lower (by 10-20%) fishing effort and yields in irrigated areas as compared to non-irrigated controls. Returns to fishing effort were slightly, but not significantly higher in irrigated areas. This suggests that fishing effort in irrigated areas declined slightly as a result of socio-economic rather than physical and biological factors and that fishing effort was partially redistributed from river-floodplain and rice field locations to the reservoir.

Estimated effects of irrigation schemes on fishing effort and catch showed a significant reduction of the fishing effort (-60%) and catches (-53%) in the floodplain and rice field areas. These effects were partially compensated by the increase of fishing effort and catches in other water bodies and particularly in the newly created reservoir.

To conclude impacts on fish production outside the Huay Thouat catchment are likely to be insignificant given the low contribution of the Huay Thouat to overall habitat and discharge in the Xe Champhone basin (less than 2%). In addition expected agricultural productivity gains from these practices must offset the concomitant loss of fisheries production to be beneficial overall. However, irrigation schemes are being developed in many locations of the basin and cumulative impacts may be significant in the future and should be assessed.

Impact on rural livelihoods

Results on fisheries production and exploitation show that opportunities for fishing in the dry season is likely to increase because of available aquatic habitats in the dry season (reservoir, rice fields mainly), new perennial water bodies, return flows and seepage from the irrigation system can compensate for the reduction of floodplain area. Travel to reservoir fisheries can be facilitated by service roads constructed along irrigation canals. This would facilitate access to fisheries during the dry season particularly when fishing is to meet own consumption needs rather than to produce surpluses for sale.

The baseline results indicate that the majority of households in the project area practiced fishing as part of a diversified subsistence livelihood, farming being a major activity. Prediction of impacts of livelihoods of fishing households must be assessed with respect to likely changes in farming and with differentiation among and within households (mainly gender). Prior surveys (Smith et al. 2001) show that the major impact of irrigation on labour use is the introduction of a dry season rice crop.

Transplanting and harvesting are the peak periods for labour use and will reduce the time available for other activities in these periods. In aggregate, fishing effort was expected to decline (as observed in Chapter 3, and by Lorenzen et al. 2000 and Smith et al. 2001), because of the increased labour requirements of irrigated farming and increased wage rates and demand for labour in local farm and non-farm labour markets.

Households with inadequate labour to work on their own land in these periods may engage in reciprocal labour sharing arrangements with relatives or neighbours (more frequently with relatives), or may hire casual labour. Respondents suggested that there is an increasing tendency to hire labour compared to practice in the past although this cannot be quantified. Prior survey results also show that by reducing the area of land available for free grazing in the dry season irrigation also resulted in some increase in labour required to care for livestock, in particular the time required to tether animals in grazing areas or to supervise grazing (Smith et al. 2001).

On the other hand, the period of the year during which fishing can be practiced in rice paddies and nearby water bodies will tend to be extended, and thus women may be able to fish for a greater part of the year. This is particularly the case when passive fishing methods can be used in association with work in rice fields. The impact on labour allocation to fishing is thus potentially complex and depends on the location and fishing characteristics of water bodies that have been modified or created by irrigation. For example, the creation of a reservoir is likely to provide both a convenient and preferred location for fishing by men, and to a lesser extent for women. Overall, access will be improved, particularly during the dry season, and importantly access to fisheries for the landless and marginalised should be maintained.

At the catchment and project scale level, the positive impact on fisheries production in aggregate is likely to contribute to livelihood enhancement. Households were expected to benefit from irrigation development overall. As farmers or farm labourers they would gain the direct benefits of irrigation, and as fishers the majority would

benefit from the new reservoir fishery and other improved opportunities for fishing in the dry season.

The lack of project area specific data made detailed prediction of livelihood impacts difficult, but it follows from the relative homogeneity of the rural population and overall positive changes in production potential discussed above that damaging livelihood impacts were not expected for the majority of households. However there is still a need to pay attention on the minority of people marginalized by irrigation and likely to be negatively affected in their livelihoods (not benefiting from farming and negatively impacted in their fishing activity).

However impacts will be differentiated between locations and households, and mainly depending on the access to the aquatic habitats, the socio-economic category, and the seasonality of the effect. In addition impacts are likely to be differentiated along gender lines because as indicated in the baseline information (Section 5.2.4.1 and in Smith et al. 2001), men are more mobile than women and their fishing activity has different characteristics and patterns (location, gears and time spent).

Concentrations of migrating fish created by the Huay Thouat dam infrastructure, will improve the efficiency of fishing effort, particularly for household situated nearest to the reservoir. In the wet season, travelling time to fishing grounds will be reduced for most fishers. Women in particular, tend to fish in the rice paddies or nearby water bodies such as flooded drainage channels or other low lying areas. In the dry season fishing is inevitably limited to perennial streams or ponds and thus will often involve greater traveling, and is more likely to be practiced by men than women.

In conclusion, impacts for individual households will depend on a range of variables including the location and fishing characteristics of water bodies visited, the fishing methods used, the importance of fishing in a livelihood strategy, household resource endowments, and the level of social and economic development of the area. Aggregated impact of the Huay Thouat project did not raise any major concern at the

time of the study. However disaggregated assessment and monitoring will have to be carried out during the implementation of the irrigation scheme.

5.2.5 Opportunities for mitigation and enhancement

A range of mitigation and enhancement measures were considered in the workshops. Most participants tended to emphasise the development of aquaculture, perceived to be the most important measure to mitigate negative impacts from irrigation, through the following measures:

- the use of ponds near canals in borrow pits from irrigation construction;
- the development of rice-fish culture in paddies;
- the implementation of a fish station near the reservoir to produce the fingerlings required for stocking in the reservoir.

Workshop results revealed the large overestimation of the fisheries production expected from fish farming in the newly created reservoir. The project technical report set the objective of 10-20 tons per year (Anon. 2000a) although no detail on its implementation and feasibility was provided raising questions on the adequacy and viability of mitigation measures planned for fisheries. Workshop participants suggested providing 3,500 fingerlings per ha (that is 1,600,000 fingerlings in the 480 ha reservoir) from a fish farm built for this purpose although comparative experiences show that neither the production target, nor the fingerlings input target were feasible in the present context. These ambitious expectations from fish farming resulted from a strong optimism and belief in technical solutions and in aquaculture production, and these were widespread throughout the country. As a result the economic and financial viability of the irrigation project was over optimistic and this initially impeded the exercise of looking for compensation measures.

The research team suggested that maintenance of a rainfed wet season rice crop is likely to be most critical for sustaining fisheries production in the area. This could be

achieved through adjustments in the irrigation system design and management, as presented to and discussed with the stakeholders.

Lateral connectivity could be maintained through the design of 'fish friendly' cross-drainage culverts, which is a simple and potentially important measure. Cross-drainage culverts of Huay Thouat irrigation system had been designed for a flow of 1-2 meters per second which exceeded the maximum short-term swimming speed of most fish species (mostly below 0.5 m/s, Clay 1995) when migrating upstream at times of high rainfall and flow. Larger culverts would reduce flow velocity and improve connectivity, but are more expensive and require regular maintenance to remove debris.

Restoration of the longitudinal connectivity through the 9 meter high dam is difficult to achieve. It is also doubtful whether this would provide significant production benefits as many species are likely to maintain separate self-sustaining populations above and below the dam. This was regarded as a low priority. However there might be trade-offs between maintaining habitats in the river downstream of the dam.

Augmentation of river flow with "environmental" releases during key migratory periods may be required to allow fish migration into rice field habitats and stream. This issue should be assessed once the scheme is operational. Drainage channels may become key migratory pathways within the irrigated rice field system, as long as channels are designed without fall structures. In addition, fishponds for private aquaculture are likely to be created in the command area and will provide additional dry season habitat for wild fish unless they are drained completely.

Institutional rules should be established to restrict fishing at narrow pathways or bottlenecks in the irrigation infrastructure such as culverts. Migrating fish are likely to concentrate in these locations and the resulting high efficiency of fishing may be a threat to the survival of some migratory species.

Although all participants agreed in principle on these measures, the suggested modifications in engineering design likely to mitigate impacts on fisheries were unlikely to be adopted because they contradicted established practice, and project design plans were already completed. In this context, such measures would require strategic assessment and consideration much earlier in the planning and design process.

Although the search for realistic solutions was encouraged through broadening the scope of mitigation and enhancement measures, the focus on fish farming was perceived as the major solution to the impacts of Huay Thouat project on fisheries. As a result, discussion on potential feasibility and performance of other recommendations has been limited.

5.2.6 Summary and conclusions

The case is an example where irrigation is being introduced in an area with rich fishery resources, and where fishing plays an important role in the livelihoods of most rural households. The net impact of the irrigation project on fisheries production was predicted to be slightly positive. This unexpected and perhaps counter-intuitive result is the consequence of two main factors.

i). Natural fish production is to a large extent derived from rainfed rice fields, and can be sustained within the irrigated system provided that the rainfed wet season rice crop is maintained.

ii). The reservoir fishery that will be created should be sufficient to at least compensate for production losses arising downstream in the river and its associated floodplain.

The overall impact on the livelihoods of people living in the project area is also predicted to be positive. The majority will gain benefits from irrigated farming and

the stimulus this provides to the local economy whilst fishing, which is their second most important activity, will not be adversely affected in aggregate and may be enhanced. However, these aggregated positive results hide possible differentiation of the impacts among sections of the communities affected. If the project proceeds such differentiation by location in the catchment, socio-economic status and gender should be monitored to ensure that the interests of vulnerable groups are safeguarded. Most at risk will be landless or land deficient households, more heavily dependent on fishing but more remote from the reservoir, particularly if they are less able to exploit new labour market opportunities.

Although irrigation development may help to stimulate the rural economy leading to new livelihood opportunities, the semi-subsistence and backward nature of the rural economy will persist for some time making it essential that this contribution by fishing is sustained. At the same time fisheries can continue to play the role of a safety net for the poorest sections of the rural population, and some management efforts could be directed to supporting the emergence of more commercialized fishing activities.

5.3 Evaluation of the APIA approach

The operation, performance and impact of the impact assessment were evaluated on the basis of the framework developed in Chapter 4 (Section 4.1.3). For this first case study, emphasis was given to iteration and learning to ensure that the design was able to detect weaknesses and any merging tension, and at the same time to integrate the lessons and extract heuristics for improvement of the design. Direct observations, study team assessment and workshop evaluation after each phase of the process (problem identification, impact assessment, management and decision-making) were the main means of evaluation.

Evaluation of the operation, performance and impact of the approach was based on the framework presented in Chapter 4 (Table 4.5). The indicators suggested in the generic framework were refined in consultation with stakeholders in the workshops. The sources of information and means of verification of these indicators included direct observation by the study team, assessments by interviewed stakeholders, and anonymous workshop participant questionnaires.

5.3.1 Operation

Implementation of the approach was evaluated in terms of the adequacy of required inputs and activities completed.

1) Inputs

The venue for workshops held at the partner office in Savannakhet town was accessible for community (1-2 hours trip for villager and district representatives) and local agency representatives (provincial representatives were based in the same town). The local team was limited in terms of number and skills (2-3 officers from RDC partner, plus occasional contribution from governmental officers, at district and provincial levels), in addition to changes of team members during the process with the respective loss of capacity building. Short-term inputs were provided by international experts in the fields of aquatic resource ecology, agriculture, irrigation management, socio-economics and institutional analysis. This includes the prior livelihood rapid appraisal (Smith et al. 2001).

On average, the workshops reached 90-100% attendance (i.e. 20-25 participants). Any absentee was replaced by a colleague informed on the major outputs from previous workshops. All institutions were represented at each workshop, except the engineering company representative who attended only three workshops including the most important ones (first and final). Besides having a tight schedule for project

construction, the lack of incentive (on the contrary rather reluctance) in assessing potential impacts of their project may explain the low representation of the company.

Some participants proposed to widen the range of stakeholders including representatives of the following sectors or division: finance, trade/market, 'community development'. Whilst these contributions were not estimated critical to justify their late involvement and increased resource allocation, relevance of a broader sectoral representation could be considered in further implementations.

2) Activities

The combination of workshops and secondary and primary data collection increased knowledge of the impacts in a context of poor information overall.

Workshop conduct and outcomes were continually monitored and evaluated through the use of individual post-workshop participant questionnaires and direct observation by the research team. Questionnaire results (see Section 5.3.2.1) showed that participants highly valued their contribution to the workshops, particularly because they could express their ideas and comments, and contribute to the decisions taken throughout the process. However, some participants experienced difficulties in perceiving all issues and multiple consequences across sectors and across key scales. In addition to regular observation, evaluation results showed that the frequency of the workshops had to be increased substantially from five planned to eight actually implemented. The purpose was to strengthen and improve primarily the understanding of the study method and outputs, and the inter-sectoral communication and understanding (see below).

The workshops promoted participation (and thus inputs from local knowledge) and interaction between stakeholders as well as the understanding of common issues and problems. Workshops were thus maintained as the core means for implementation of the approach with the stakeholders and policy makers.

5.3.2 Performance

The performance of the approach was evaluated in terms of its effective demonstration of the key features and objectives of its design, and the relevance and utility of its outputs.

5.3.2.1 Features

1) Holistic and integrated

The net impact results from a balance of positive and negative effects could only be covered by an integrated approach. The focus on aquatic habitats for example the river (negative impact) or the reservoir (positive impact) would not reflect the overall impact of the project. Similarly the focus on one sector, for example fisheries, would have overestimated the negative effect of irrigation by discounting the general improvement of rural livelihoods that result from agriculture development and its trickled down effects on employment, infrastructure, and welfare.

The inter-sectoral integration has also shown the importance of the timing and seasonality of the impacts on rural livelihoods. The overall impact on the livelihoods of people living in the project area is also expected to be positive. The majority will gain direct benefits from irrigated farming, and fishing which is their second most important activity will not be adversely affected in aggregate, and may be enhanced. The integration of sectors and disciplines has thus improved the analysis and interpretation of impact assessment results.

The integration also provided evidence of the most important aquatic habitats to maintain. Beyond their productivity or species diversity characteristics, attention should also be paid to the particular aquatic habitats that play an important role in the livelihoods, here the Huay Thouat river-floodplain and paddy fields but also the larger Champhone river-flooplain.

Results from workshop evaluation showed that all participants recognised the benefits of an inter-sectoral integration. They perceived that linkages between sectors had been usefully created during the assessment process, through plenary debate and group discussions (organised per sector or across sectors). Although villagers' knowledge was by nature more holistic, district officers had a good knowledge of village life and were generally villagers themselves, sectoral specialisms and sometimes narrow perception of problems constrained the inter-disciplinary and inter-sectoral understanding of issues. Exercises were thus designed in response such as the classification of impacts by sector or discipline (e.g. impacts on hydrology, ecology, aquatic resource exploitation, livelihoods and institutions, see Section 5.1.4) and reassembling into a holistic understanding, illustrating the variety of potential linkages between impacts.

The integrated assessment has revealed the differentiation of impacts per sector/discipline and across the catchment. Results contributed to building new perspectives on the impacts of irrigation on fisheries showing that the net impact of irrigation on fisheries production and rural livelihoods is likely to be positive. The factors contributing to this unexpected result originate from both the biophysical environment (rich in fishery resources) and the livelihood characteristics (fishing mainly associated with farming, and activity spread in a variety of waterbody types: rice field, rivers and streams, floodplain), in addition to the creation of a reservoir fishery.

In terms of spatial scale, the assessment covered the project command area and catchment level, upstream, downstream and near the scheme. However it is acknowledged that the assessment of cumulative impacts of the series of irrigation schemes implemented along the Champhone river is a priority for further research. For this purpose, the Huay Thouat study would be able to inform strategic assessments on potential areas of concerns (location in the river basin, socio-economic categories of people, etc.). Temporal coverage was not extensive due to poor historical information but sufficient to predict the likely impacts in the near

future. This emphasizes the need for monitoring and evaluation during project implementation to inform further assessments.

2) Participatory

The level of participation achieved i.e. genuine participation was assessed in terms of representation of stakeholders groups throughout the assessment, the shared knowledge and analysis, consensus building (or reasons for remained conflicts), and the ownership of outputs, as developed below.

• **Representation of stakeholder groups.** Given the high level of attendance, stakeholders from the relevant sectors and institutional levels (see Section 5.1.2) were satisfactorily represented at all workshops, apart from the building company. Views and concerns were expressed by each participant from community to national level. However the voice of the villager and district representatives had to be enhanced by specifically allocating time to express their concerns and interests and by regularly checking their understanding. The importance of representation in the outcomes throughout the assessment was demonstrated. For example, the positive or negative qualification of impacts sometimes depended on stakeholder perception, understanding and/or interest (e.g. the perception of flooded area or reservoir creation).

Although the ex-ante assessment could not ensure that no group or interest was inadequately (insufficiently or not at all) represented, all issues covered by the stakeholders and scientists confirmed the proper coverage of the range of concerned stakeholders. While most villagers in the project area were both farmers and fishers, they showed a more holistic view of impacts. This was also the case of representatives from the Planning department where awareness of the needs for integrating fisheries in the planning, operation and management of irrigation and agriculture was increasing. Direct observation and workshop evaluation results (see

Box 5.2) showed that participants became aware (some governmental officers were already aware) of the need to enhance inter-sectoral communication and coordination.

• **Shared knowledge.** Typical inputs from local knowledge included identification of fishing grounds (see Figure 5.1), fish species exploited, migration routes in mapping exercises and during rapid appraisal results. The different spoken languages (Lao, Vietnamese and English) and the heterogeneity of skills (particularly between institutional level: community compared to provincial level) impeded the direct sharing of knowledge. Workshops were communicated in Lao and English, and a provincial officer translated Vietnamese to the company representative(s).

The need for capacity building was recognised in early stages (see Section 5.1.4) and exercises were designed to improve the understanding. Information and results were presented into a common user-friendly format, and through a regular flow throughout the process. Working groups were first organized by sectors to facilitate exchange and enhance confidence. Observation and first questionnaire results (Box 5.2) revealed that participants felt they had too much information (particularly scientific results) to understand and digest in a relatively short time.

While understanding of the study method and objectives improved, understanding of impact assessment and management measures was required. Therefore capacity building was needed throughout the process. Communication between participants increased rapidly (as observations were supported by questionnaires results, Box 5.2 to 5.4) and working groups were arranged to mix sectors and/or institutional levels. Overall building common understanding of the assessment and its outputs was resource consuming particularly to enhance understanding, and validate and translate the diverse knowledge of different groups.

• **Shared analysis.** Analysis was shared among stakeholders and scientists through various ways: mapping exercises, small group discussions, presentations of group representatives and plenary discussions. All results obtained by the international

researchers were translated in an accessible form to the extent possible, with indication of how problems were solved (or not solved) and how decisions were made including the range of assumptions made. However participants felt they had too much information to digest throughout the assessment process, particularly at the initial stages. This was supported by direct observations and workshop evaluation results. Therefore a strong and continuous capacity building was maintained, and evaluation workshops and direct observations checked that stakeholders could proceed from one step to the other.

Feedback and analysis to and between stakeholders were maintained throughout the process through the large use of group and plenary discussions (see Table 5.1) and direct observations. For example, the debate on the validity of shrimp value assumptions was subsequently followed by a sensitivity analysis on a range of values. Between stakeholders, the exchange focused on understanding each sectors' needs and supporting each other in building a common understanding. For example, the project map drawn by the irrigation engineer was used to locate potential barriers for fish migration in addition to water management needs for irrigated farming e.g., diameter of culverts and implications in the velocity of water and distribution of water; height of spillway and implications on fish migration and capacity of the reservoir.

• **Consensus building.** Despite the heterogeneity of their skills and employment, participants expressed convergent concerns and interest, and no tension emerged throughout the assessment. This facilitated agreement on final impact assessment results and recommended mitigation and enhancement measures.

• **Ownership of outputs.** This objective was difficult to achieve since relatively large resources were allocated to improve the contribution of stakeholders during the impact assessment process, the first step for ownership of outputs. Yet this was an important lesson for further implementation in a context of overall lack of skills, and for institutional uptake. It must be noted that national officials expressed a strong will

to build on institutional uptake through training on the impact assessment approach and ownership of outputs in the near future (see Section 5.3.3).

Overall the level of genuine participation revealed difficult to achieve due to a general lack of skills from stakeholders and adequate understanding of the study revealed a major constraint. This major barrier to high level participation was managed through adaptive mechanisms as detailed in the next section.

3) Adaptive approach

In this first pilot testing, emphasis was given to the adaptive process in order to refine the approach and respond in a timely manner, in addition to the required production of outputs. For this first testing, the learning component of the approach was highly exploited. It produced numerous and continuous lessons, both to refine and adjust the approach, and to improve its outputs. The outputs were thus a combination of provisional and iterative results.

The progressive increase of the frequency of workshops was decided as a result of regular evaluation and iteration. This substantially slowed down the process and stakeholder involvement proved to be time and resource consuming. Expertise increased to support the production of assessment results. Overall results confirmed the need for continuous guidance and training by the researcher/facilitator. This raised tensions between participation and production of outputs. As demonstrated above the most critical need was to find the adequate balance between the production of assessment results and the requirements for a genuine participation of stakeholders, and to allocate resources between capacity building and assessment activities. For example, the strong constraint was the overall low technical skills. Despite these strong constraints, more resources were allocated to attempt achieving a genuine participation: the frequency of workshops was significantly increased (from 5 to 8) and capacity building was pursued and reinforced throughout the assessment.

The objective was thus to provide the critical information required for the assessment and save time for training the stakeholders. The increased frequency of workshops resulting from this decision had to be regularly traded-off with the reduced time allocated to the assessment. On the other hand, the quality of the prediction could be preserved with an increased technical support from the study team and particularly from the international research team (see also Section 5.3.1). Reallocation of resources was in favour of enhancing stakeholder participation

The adaptive approach also allowed reacting to emerging issues and unexpected outcomes. For example stakeholder understanding had to be enhanced through various exercises and a stakeholder analysis expressing interest, power and influence of each representative at all institutional levels. Thus many actions and decisions had to be taken in a short time for rapid and regular iterations. The high probability for unexpected outcomes (understanding and commitment of participants, inter-sectoral discussions, etc.) required simultaneous learning and reaction.

Along with the iterative improvement of APIA implementation, the design of the approach has also benefited from the adaptive process. Lessons were first drawn by diagnosing the constraints and difficulties of the local context and evaluating the outcomes in the light of respective constraints. The approach has thus improved through direct iteration and through integration of the lessons for further implementation of case studies (the next test case being Sri Lanka, see Chapter 6). Evaluation results (developed in this Section 5.3.2) demonstrated the overall feasibility of the APIA approach even where skills are relatively low and resources are limited, such as in Laos.

4) Composite assessment

The composite character of the assessment was evaluated in terms of use of different types of knowledge (scientific and local), types of data (secondary and primary), and methods and techniques.

i) Scientific and local knowledge: scientific inputs were discussed with stakeholders (see also local knowledge), resulting in a combination of expert analyses and workshop stakeholder inputs, simple and more elaborated inputs. This also allowed cross-checking of data.

ii) Secondary and primary information were drawn from formal (surveys, questionnaires) and informal methods (interviews, observations). Notably empirical information from prior studies, and comparative empirical data from other water bodies (Chapter 3, Lorenzen et al. 2000, Smith et al. 2001, Garaway 1999) were extensively exploited to compensate the lack of primary data.

iii) A variety of methods and techniques were used including participatory mapping, a fisheries balance, and empirical relationships.

5.3.2.2 Outputs

The impact assessment approach has delivered outputs in terms of prediction of Huay Thouat project impacts on fisheries, management recommendations, and identification of key research priorities and lessons gained for improving the approach.

1) Impact assessment results

Impact assessment results were evaluated in terms of prediction capability, scientific quality and contribution to general knowledge of irrigation impacts on fisheries.

i) Prediction capability: impacts were predicted positive in aggregate across the project area. In addition these results emphasise the need to monitor the impacts during implementation and operation of Huay Thouat project, in particular the distribution of impacts by location in the catchment area and by socio-economic category. Therefore attention needs to be retained on future concerns, including biodiversity impacts and the likely cumulative impacts on

the larger Champhone river, and the livelihoods of the poor and landless people far from the reservoir.

ii) Scientific quality: the coverage of results (across locations, sectors and disciplines) and degree of accuracy was sufficient at this stage to highlight the main issues of concern in future development of the Thouat irrigation project. However further detailed assessments may be needed in the near future, as identified below as key research priorities.

iii) Contribution to general knowledge: results were primarily specific to the Huay Thouat project and confirmed most results obtained in prior studies (in terms of the relative homogeneity of socio-economic categories, social ties, patterns of fishing, and distribution of fishing effort).

iv) Utility to inform the management and decision-making.

2) Management recommendations

Management recommendations were evaluated in terms of their adequacy and feasibility, and their contribution to general knowledge.

i) Adequacy and feasibility: although a variety of measures was proposed by the study team, stakeholder participants tended to focus on technical measures, in particular aquaculture production. There was a need to increase awareness that aquaculture may not be sufficient to compensate for production loss and a need to look for a range of options, primarily avoiding negative impacts (such as blockage of fish migration in culverts) where possible. Lastly the identified engineering measures likely to mitigate impacts on fish migration would require consideration much earlier in the planning and design process.

ii) Contribution to general knowledge: the large bias detected during the assessment should be considered in the design and evaluation of management measures. Estimations of the technical feasibility report should be put under scrutiny or review of estimations. This showed the need to provide estimates that are reasonable, as subsequently provided in the Guidance Manual by

Lorenzen et al. (2004). Most importantly, the management of Huay Thouat impacts should consider the large bias and adjust mitigation measures. However the recommendations were not sufficiently taken up by the participants.

3) Further research priorities

Further research priorities have been identified in several areas:

i) Assessment of biodiversity and ecosystem integrity, and evaluation of flows and pathways to sustain fish migration

ii) Monitoring the significance of the re-distribution of fishing effort and catches on the livelihoods of fishers, as indicated by the assessment results (Section 5.2.4.2). This would depend on a range of variables including the location and fishing characteristics of water bodies, the fishing methods used, the function of fishing in livelihood strategies, and the level of social and economic development of the area (Smith et al. 2001). Since a range of livelihood impacts were likely to result from the implementation of the irrigation scheme, an analysis in terms of labour allocation and access to water bodies tried to investigate this further.

iii) Impacts at larger scale particularly at the river basin level with integration of cumulative impacts.

5.3.3 Impact

As this was a pilot testing of the APIA approach the evaluation of its impact can only be tentative and preliminary. Changes in irrigation design and planned implementation and management could not be assessed through monitoring and evaluation of implementation, and no subsequent changes in water or fishery management were expected to take place immediately as a result of the assessment. Despite this the impact assessment of Huay Thouat project has increased awareness

on the potential issues: the likely positive outcome should not prevent detailed monitoring and particular attention should be paid on particular locations and poorer category of households, and on the bias resulting from overestimated benefits from reservoir fish farming.

Beyond the impact assessment results, the knowledge and understanding on the impacts and on prediction capabilities gained throughout the implementation of the approach increased the skills of the workshop participants. Awareness of the benefits of the approach also increased, in particular its inter-sectoral and participatory characteristics. Governmental officers at national and provincial levels showed a strong interest in taking further steps after project completion and recognized the need to conduct impact assessment studies on a regular basis. They were willing to learn the approach with view to uptake its implementation in the future.

Further applications will benefit from the improved approach, allowing to act earlier in the project development process (planning stage). Although specific, the process results helped refining the design of the approach, particularly the adaptive approach (the need to design systematic iterative and evaluation procedures) and the capability of quick responses to needs for improvements and adjustments.

5.4 Conclusions

An adaptive, participatory and integrated approach for the assessment of the impacts of irrigation development on inland fisheries was pilot tested through an ex-ante assessment of the impacts of the Huay Thouat project in Laos. Implementation of the approach had two objectives: 1) the prediction of impacts of Huay Thouat project on fisheries and the production of preliminary recommendations on the management of impacts, and 2) the testing of applicability and feasibility of the approach, and development of its design. The study was thus concerned with key processes rather

than just the definition of recommendations and the following conclusions refer to both objectives.

5.4.1 The impacts of irrigation on fisheries

The net impact of the Huay Thouat irrigation project on fisheries production was predicted to be positive in aggregate. The assessment showed that this result is essentially due to favourable baseline conditions, biophysical and livelihood related. The case is an example where irrigation is being introduced in an area with rich fishery resources, and where fishing plays an important role in the livelihoods of most rural households and where fishing takes place in various places including the Mekong and other large rivers. Rainfed rice fields dominate the Thouat floodplain habitat and their contribution to fisheries production will be largely unaffected as long as current cultivation patterns with significant storage of water in the rice fields during the wet season are maintained.

The overall impact on the livelihoods of people living in the project area is also expected to be positive. The majority will gain direct benefits from irrigated farming, and fishing which is their second most important activity will not be adversely affected in aggregate, and may be enhanced. However, these aggregated positive results hide some differentiation of the impacts among sections of the communities affected. If the project proceeds such differentiation by location in the catchment, socio-economic status and gender should be monitored to ensure that the interests of vulnerable groups are safeguarded. Most at risk may be landless or land deficient households, more heavily dependent on fishing, but more remote from the reservoir. Sustaining fishing for some time is thus recommended while the socio-economic development likely to be triggered by irrigation decreases the dependence of fishing as a source of livelihood.

5.4.2 The APIA approach

The Laos case study was the first implementation of the approach and therefore represented a strong test for its robustness. The main challenge was to involve in a relatively short-time (8 weeks) the stakeholders with relatively low skills in the impact assessment. While the assessment involved the analysis of multiple and varied problems raised by the likely impacts of Huay Thouat irrigation on fisheries, local scientific and technical capacity for the impact assessment was very limited. Consequently the process relied heavily on increased capacity building and on guidance from the international research team.

Despite these constraints and difficulties, the impact assessment approach provided predictions of likely impacts of Huay Thouat irrigation scheme and suggested recommendations for mitigation and enhancement measures. The need for monitoring and evaluation of project implementation and operation has been identified.

In particular, the adaptive approach was extensively exploited to improve the APIA approach in its generic and specific characteristics and outcomes. The benefits of APIA were demonstrated in terms of impact assessment results contributing to a better understanding of the impacts of irrigation on fisheries, the improved design of the approach and the identification of future research and management perspectives.

Appendix

Box A.5.1 Evaluation questionnaire and results (percentage of participant responses) for the first phase (Problem identification)

1. Understanding

1.1 Before continuing the impact assessment process, have you reached a sufficient understanding on:
- the nature of irrigation impacts on fisheries (multiplicity, complexity, interconnections)?:
- he impact assessment process?:

1.2 Do you have any comments?

2. Perception of impacts

2.1 Do you think that the potential problems identified for Huay Thouat project justify the implementation of an impact assessment process?

2.2 Do you have any comments?

3. Information use

3.1 Was the information understandable, suitable and in a sufficient amount to take the decision to proceed for an impact assessment?

3.2 Do you have any comments?

4. Participation

4.1 Do you feel that your participation has been fully and equally integrated at the different stages of problem identification (screening and scoping)?

4.2 Do you have any comments?

5. Linkages between sectors

5.1 Has the common work with most stakeholders' representatives (from different sectors, at different levels, with villagers) been more beneficial in providing the first outputs than a sectoral approach?

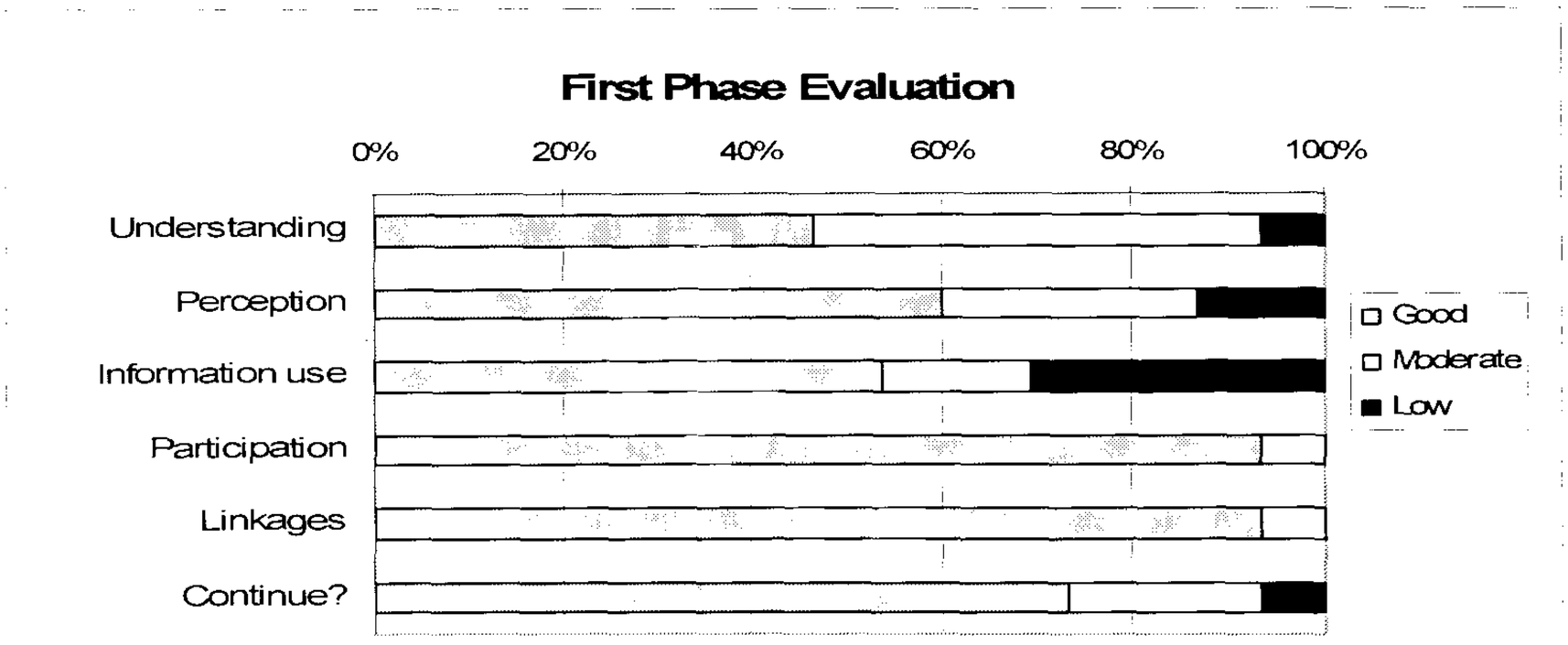
5.2 Does it stimulate the creation of linkages between sectors?

5.3 Do you have any comments?

6. Feasibility to continue the impact assessment process with regard to local conditions

6.1 Did we concentrate enough on what is achievable considering available Lao resources? (human, financial, etc)

6.2 Do you have any comments?



n=21

Box A.5.2 Evaluation questionnaire and results (percentage of participant responses) for the second phase (Assessment of Impacts)

1. Situational Assessment

1.1 Evaluate your understanding of Situational Assessment (please tick): Good Medium Low

1.2 If low or medium, what didn't you understand?

1.3 Do you think the workshop participants provided sufficient and appropriate lists of data to collect and analyse?

1.4 Do you agree with the responsibilities assigned to each stakeholder?

1.5 Do you have any comments?

2. Prediction of Impacts

2.1 Evaluate your understanding of Prediction of Impacts (please tick): Good Medium Low

2.2 If low or medium, what didn't you understand?

2.3 Do you think the workshop participants provided sufficient and appropriate lists of data to collect and analyse?

2.4 Do you agree with the responsibilities assigned to each stakeholder?

2.5 Do you have any comments?

3. Mitigation and Enhancement

3.1 Evaluate your understanding of Mitigation/Enhancement (please tick): Good Medium Low

3.2 If low or medium, what didn't you understand?

3.3 Do you think the workshop participants provided sufficient lists of potential mitigation and enhancement measures?

3.4 Do you have any comments?

4. Participation

4.1 Do you feel that your participation has been fully and equally integrated at the different stages of Impacts Assessment and Mitigation/Enhancement?

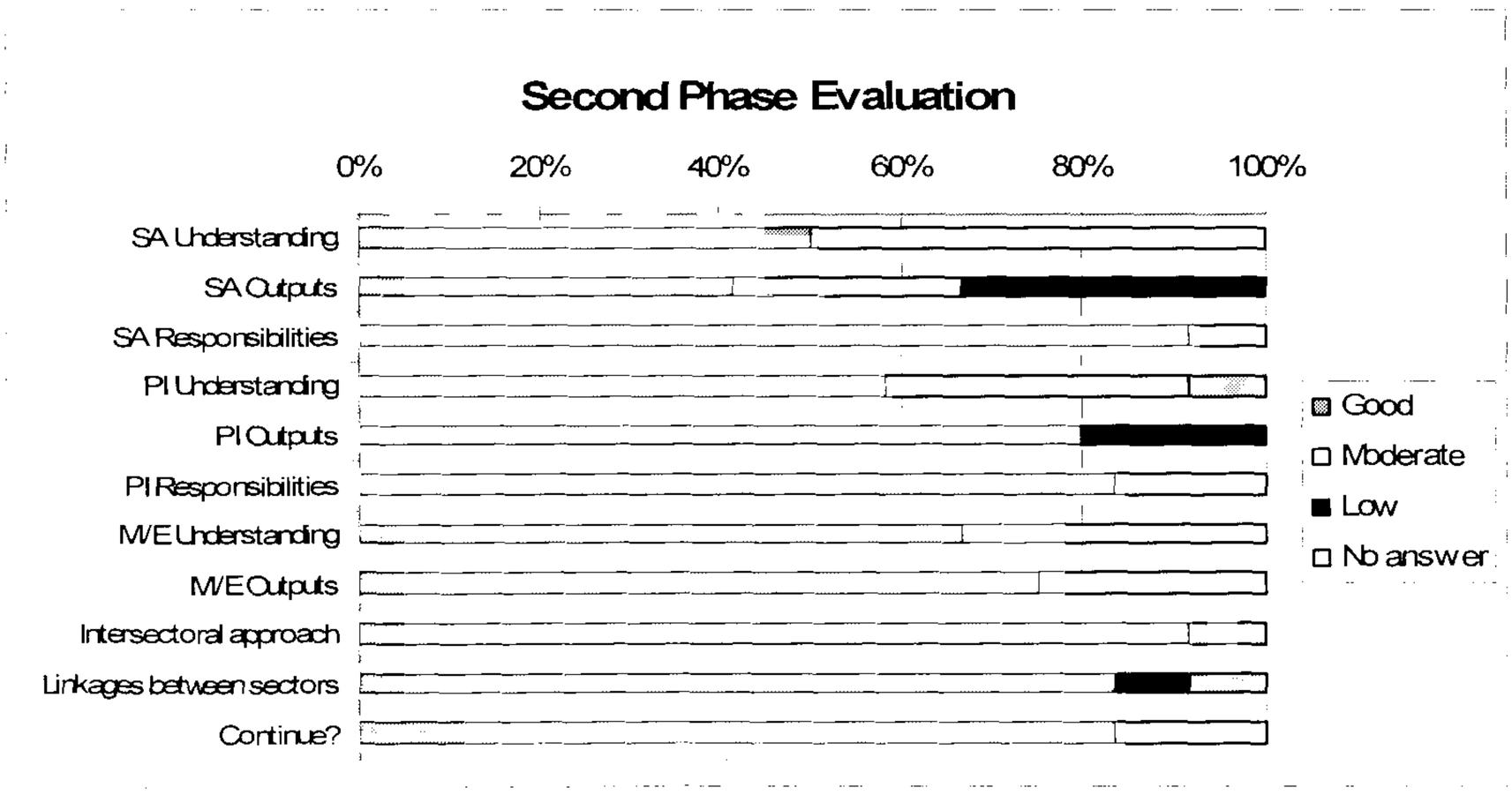
4.2 Do you have any comments?

5. Linkages between sectors

5.1 Has the common work with most stakeholders representatives (from different sectors, at different levels, with villagers) been more beneficial in providing Assessment phase outputs than a sectoral approach?

5.2 Does it stimulate the creation of linkages between sectors?

5.3 Do you have any comments?



n=22

Box A.5.3 Evaluation questionnaire and results (percentage of participant responses) for the final workshop

Questionnaire 3

Please tick when Good Medium Low options are given.

1. Irrigation Impacts on Fisheries

1.1 Evaluate your understanding of the nature of Irrigation Impacts on Fisheries (impacts are multiple, complex, varied and interconnected): Good Medium Low

1.2 If low or medium, what didn't you understand?

2. Impact Assessment process

2.1 Evaluate your understanding of the Impacts Assessment process: Good Medium Low

2.2 If low or medium, what didn't you understand?

3. Screening

3.1 Evaluate your understanding of Screening: Good Medium Low

3.2 If low or medium, what didn't you understand?

3.3 Do you think the workshop participants provided sufficient and appropriate lists of data to collect and analyse?

4. Scoping

4.1 Evaluate your understanding of Scoping: Good Medium Low

4.2 If low or medium, what didn't you understand?

4.3 Do you think the workshop participants provided sufficient and appropriate lists of data to collect and analyse?

5. Situational Assessment

5.1 Evaluate your understanding of Situational Assessment - also called Pre-Project Assessment: Good Medium Low

5.2 If low or medium, what didn't you understand?

5.3 Do you think the workshop participants provided sufficient and appropriate lists of data to collect and analyse?

5.4 Do you agree with the responsibilities assigned to each stakeholder?

5.5 Do you have any comments?

6. Prediction of Impacts

6.1 Evaluate your understanding of Prediction of Impacts: Good Medium Low

6.2 If low or medium, what didn't you understand?

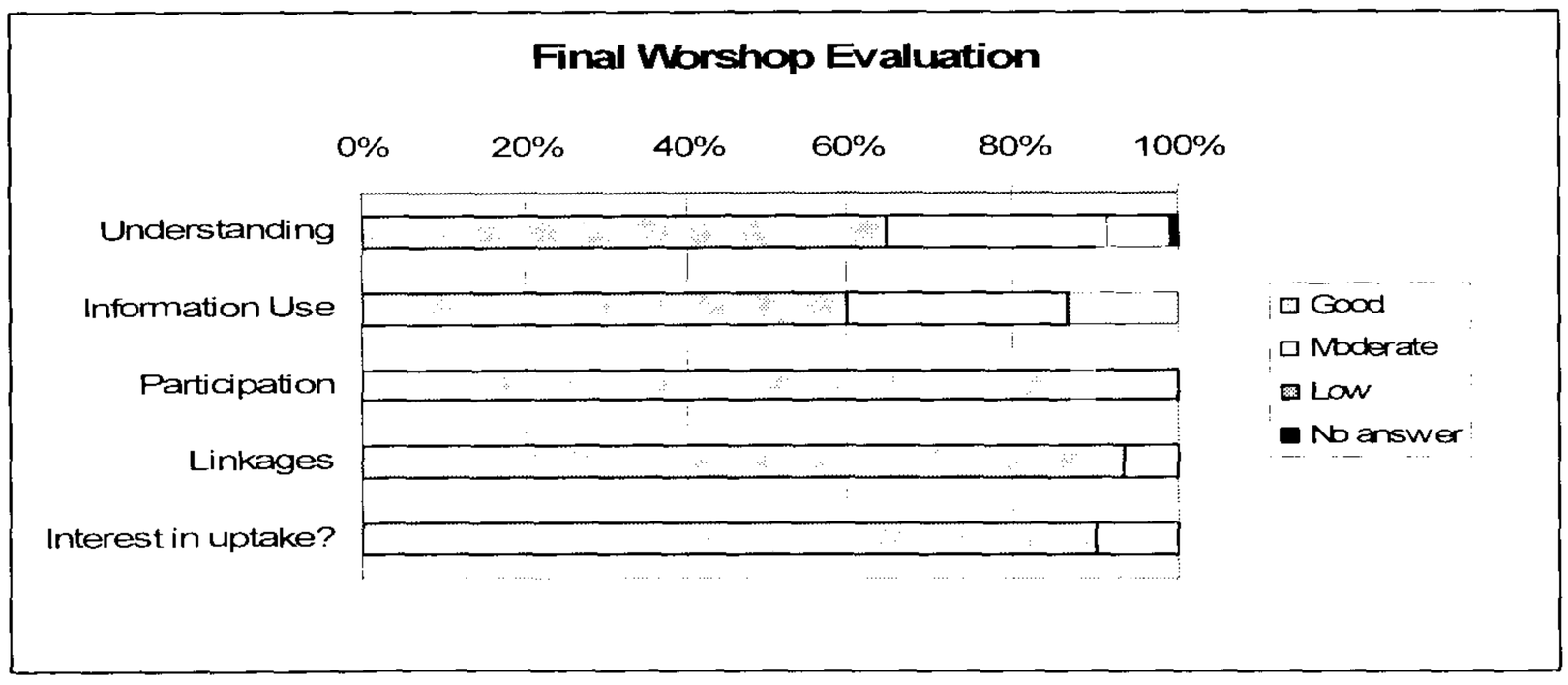
6.3 Do you think the workshop participants provided sufficient and appropriate lists of data to collect and analyse?

6.4 Do you agree with the responsibilities assigned to each stakeholder?

6.5 Do you have any comments?

7. Participation

Do you think your participation has been fully and equally integrated?



n=22

Chapter 6 - Testing and Evaluation of APIA in Sri Lanka: Ex-post impact assessment

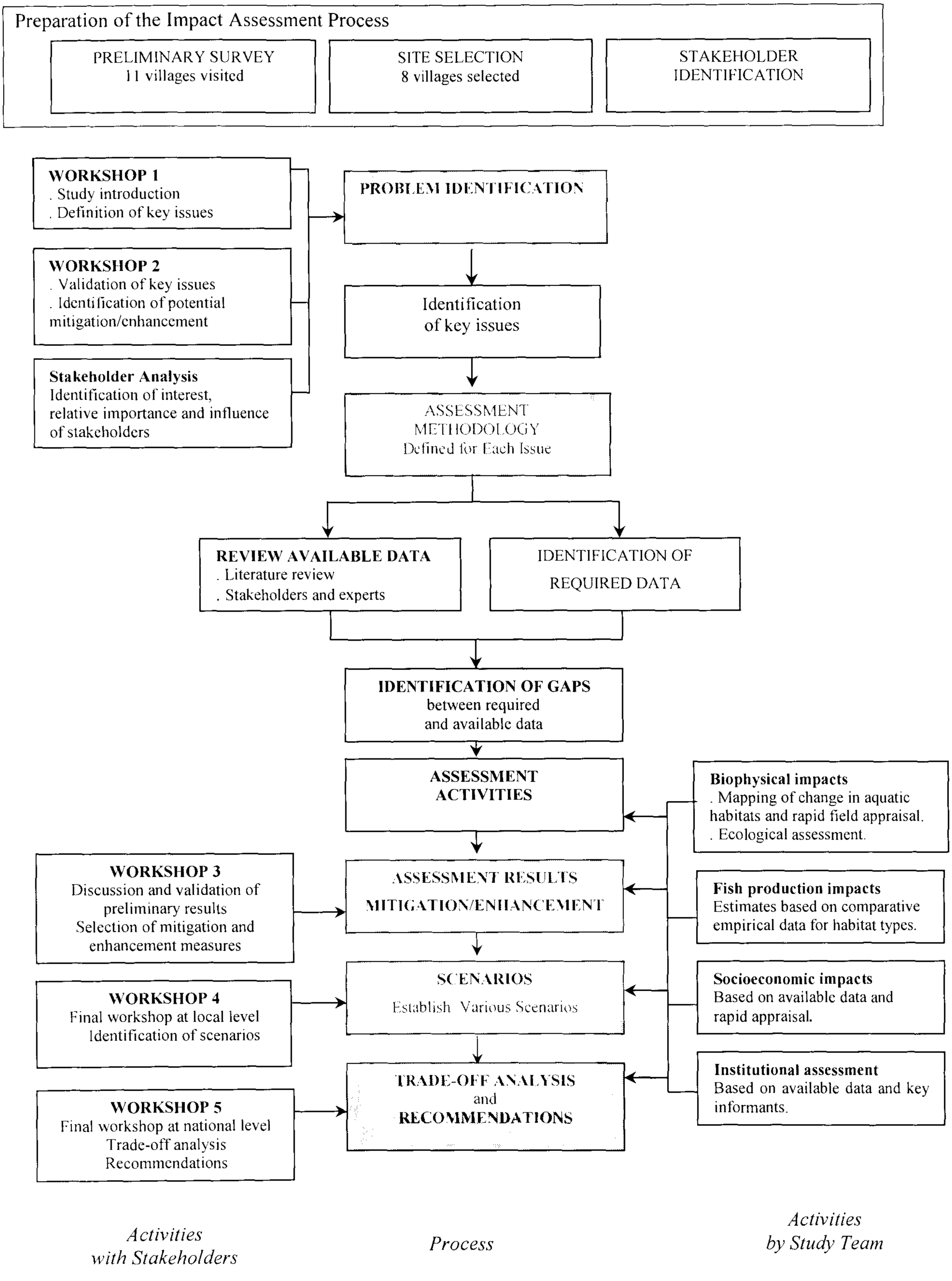
The approach for impact assessment (APIA) proposed and developed in Chapter 4 was secondly tested and evaluated in Sri Lanka, for an existing large-scale irrigation system. The aim was an integrated and participatory ex-post assessment of the impacts of the irrigation system on fisheries. Methods and activities are described for assessment of the baseline situation and evaluation of impacts. Drawing from the impact results, management options based on mitigation and enhancement measures are identified and discussed. Throughout implementation, the approach has been evaluated for its operation, performance and impact. Conclusions draw from the impact assessment results and discussion of the evaluation of the APIA approach.

6.1 Methods and activities

The assessment was carried out over nine weeks from February to April 2002, 16 years after completion of the irrigation and settlement scheme. Two partner institutions contributed to the implementation: the International Water Management Institute (IWMI) and the University of Kelaniya. The assessment was carried out in a sequential process built around a series of stakeholder workshops (Figure 6.1), and following the sequence defined and justified in Chapter 4. Methods and activities are described below.

A local study team was built with the local partners and consisted of two permanent field officers and one supervisor part time from IWMI, two researchers and two students part time from University of Kelaniya, and one independent field officer part-time. The international study team was composed of an interdisciplinary team of UK based researchers covering the fields of fish ecology, irrigation, agriculture, socio-economics and institutions.

Figure 6.1 Implementation of the impact assessment approach



6.1.1 Project selection

A preliminary visit in August 2001 gained an overview of irrigation schemes in Sri Lanka to support the selection of an appropriate irrigation project. As for the Laos case study (Chapter 5) the selection of the project was based on the requirements envisaged for testing the approach (rather than the decision of policy-makers and stakeholders), and resulted from a preliminary consultation with local partners. Selection criteria were identified as follows: the relevance and potential interest of local partners and stakeholders in applying the approach for the study area related to the number and importance of issues raised by the impacts of irrigation on fisheries; an existing irrigation scheme to conduct an ex-post assessment (as opposed to the ex-ante assessment previously conducted in Laos, Chapter 5); sites that were not affected by local political troubles or at least with low risk; appropriate scale of the irrigation scheme (large or medium); existing fishing activities; adequate logistics: accessibility, distance, extent of the area covered and feasibility within the planned time schedule; and existing information and data on the study area.

The Kirindi Oya Irrigation and Settlement Project (KOISP) in the southeast of the island was judged to fill the criteria and was selected. Its key characteristics were that it was a medium-scale dam irrigation scheme implemented in 1989, in an accessible area, with important fisheries existing within the catchment, and where significant impacts from the project had been identified, with unresolved conflicts over water for farming and fishing occurring, and some available and relevant data.

6.1.2 Data sources

Secondary information was collected with the aim of providing the background context and a historical perspective, and to as far as possible substantiate the discussions with stakeholders during the workshops and impact assessment. The collection of secondary information comprised the following activities.

i) Library searches (IWMI, University of Kelaniya, and National Aquatic Resources Research Development Agency (NARA)) and review of existing project evaluation reports, other relevant studies and available statistics (see respective bibliography). Information on hydrology and irrigated agriculture was provided by project assessment studies carried out since implementation of KOISP (e.g. IIMI 1995a, 1995b).

ii) Use of experience and lessons gained from prior studies (quantitative impact assessment, Chapter 3) and particularly from the first testing in Laos (Chapter 5);

iii) Meetings with local government agencies and other organisations to review their knowledge and perceptions of the situation;

iv) Interviews with field officers and researchers from relevant organizations: IWMI, University of Kelaniya, NARA and the National Aquaculture Development Authority (NAQDA).

Collection of secondary information continued throughout the study, with particular emphasis on the assessment of key issues that emerged during the investigation (see Section 6.1.6).

6.1.3 Overview of activities

A series of five workshops was organized to match the main impact assessment phases (see Figure 4.2) and cover the whole process. These meetings were based on the active contribution of stakeholder participants, and involved both plenary and group discussions. Each activity was presented with its respective outputs. Stakeholder contribution both oriented and diverted the impact assessment, and reviewed and validated (as far as possible) the results and outcomes at each stage. The planning and content of workshops and parallel surveys are summarized in Table 6.1.

Table 6.1 Planning and content of workshops and parallel surveys

No Date	Objectives	Activities	Outputs	Surveys
WS 1 15/02	▪ Understanding of study ▪ Understanding of impacts ▪ Screening introduction	▪ Introduce study and series of workshops with preliminary planning ▪ Present results of preliminary investigation (literature, meeting and rapid appraisals)	▪ Results on perceived significance of impacts ▪ Assignment of participants responsibilities	Preliminary investigation Reconnaissance survey in 11 villages
WS 2 21/02	▪ Screening finalization ▪ Scoping	▪ Introduction of workshop (plan & objectives) ▪ Screening continued ▪ Scoping: introduction ▪ Present assessment method and activities	• List of key issues • Identification of activities for assessments	
WS 3 14/03	▪ Impact assessment results ▪ Management of impacts	▪ Study team presents assessment results per issue ▪ Group discussion on assessment results and possible mitigation and enhancement measures ▪ Workshop evaluation	▪ Conclusions on assessment results ▪ List of adequate mitigation & enhancement measures	Assessment: Rapid appraisal in 8 villages
WS 4 26/03	▪ Trade-off analysis ▪ Support decision-making	▪ Scenario building per group ▪ Selection of evaluation criteria ▪ Selection of scenarios per group ▪ All participants suggest and agree on recommendations ▪ Conclusion on study implemented at local level ▪ Workshop evaluation	▪ List of selected management options ▪ List of preliminary recommendations for the management of impacts	
WS 5 Part I 04/03	▪ Introduction of study and purpose ▪ Exchange and discuss with national officers, results obtained at local level	▪ Official opening ceremony ▪ Introduction of study and workshop plan ▪ Presentation of assessment results (per issue) ▪ Management scenarios proposed from local level ▪ Discussion on local level results	▪ List of new issues (if relevant)	
Part II 05/03	▪ Trade-off analysis ▪ Support decision-making	▪ Identification of evaluation criteria ▪ Selection of scenarios per group ▪ All participants suggest and agree on recommendations ▪ Workshop evaluation ▪ Conclusions for the whole study	▪ List of feasible scenarios ▪ Preliminary list of recommendations	

The international study team visited Sri Lanka for one to two weeks each to carry out assessment activities in their respective discipline, including a contribution to the reconnaissance survey and to the rapid appraisal (see Section 6.1.6). These visits were distributed over a five week period (from 15 February to 30 March). The author designed the case study and was present to organize, coordinate, and observe and evaluate all activities throughout.

6.1.4 Stakeholder identification and capacity building

The study population was first identified from the project area covering the irrigation system and its command area. Key stakeholders were selected for the study. These were the community leaders who represented each selected village, and representatives of provincial and district agencies covering the two districts and six divisions relevant to the study area. Selection of stakeholders from these government agencies was based on the following criteria: the relevance of the agency to the management of irrigation impacts on fisheries (irrigation, water resources, agriculture, environment, and inland and coastal fisheries); the coverage of provincial and district levels; and stakeholder seniority in each selected institution (head, deputy head or in their absence the officer with responsibility for the study area). The results of stakeholder identification (Table 6.2) were validated through consultation with workshop participants. This led to the further introduction of two representatives of farmer societies.

The representation of local stakeholders only by their community leaders could be questioned in terms of whether they can be expected to truly represent the views and interests of all members of a community. It was decided to rely on the participation of local leaders alone for three reasons. First the practical reason of limiting the number of workshop participants. Second the fact that participants needed at least a minimum level of education, experience and self-confidence to be able to engage in both technical and non-technical debates with the other stakeholders (with appropriate facilitation as required; see the evaluation of participation in Section 6.4.2.1). Third it was judged that community leaders would represent the interests of fishing as an activity and source of livelihoods in their respective villages.

Secondary sources of information and informal interviews with local researchers confirmed that community leaders can and generally do represent the main concerns of their respective villages (Jinapala 1994, Jinapala et al. 1996), though possibly with varying emphasis depending on the significance of the activity in village livelihoods

(in particular in comparison to farming). That the community leaders may explicitly or implicitly express a bias against the interests of groups within their communities was thus a secondary concern. The main results derived from these representatives were also cross-checked through direct consultations with villagers during rapid appraisals and this reduced the risk of this otherwise inevitable bias in participation (see Section 6.4.2.1).

Table 6.2 List of workshop participants and respective affiliations

	Organisation	**Positions of Participants**
Villagers	Villages: Ranawaranewewa, Kudagama 1, Debara Ara, Bandagiriya, Boralessa, Pallemalala, Uda Malala, Sippikulama	Community leaders (8)
District level	Divisional Secretariats: ▪ Hambantota ▪ Lunugamvehera ▪ Tissa	Divisional Secretaries (3)
	Irrigation Management Division	Project Manager (KOISP)
	Fisheries	Asst. Director (Tangalle) Fisheries Inspector (Kirinda)
	Department of Agriculture	Assistant Director (Hambanthota)
	Central Environment Authority	Environmental Officer (Lunugamvehera) Environmental Officer (Hambanthota)
	Coastal Conservation Department	Director of Coastal Resources Development Division
	Southern Development Authority	District Director
	Farmer societies (2)*	Chairmen
Provincial level	Department of Irrigation	Chief Irrigation Engineer (Southern)
	Department of Wildlife Conservation	Assistant Director (Southern)
National level**	NARA NAQDA University of Kelaniya	Researchers (2-4) Extension Officers (1-2) Researchers (1-2)

* Farmer societies were not represented at the first workshop
** Stakeholders from the national level doubled their representation at the final workshop

Capacity building started with the identification of the nature of impacts and in particular their potential interactions. For this purpose, an exercise visualizing the

interactions between impacts was organised. Participants wrote each relevant impact identified in the project area on a card. All cards were displayed on a board and classified per order[5] of impact, from first to third order. For example, drainage inflows to coastal lagoons reduced water salinity, contributing to a sharp decrease in shrimp production. The resulting loss of income forced fishers to look for other livelihood opportunities, such as shell mining and lime making which required encroachment of a protected conservation area (Bundala National Park). This exacerbated conflicts with the conservation agencies. From the linkages established on the board, participants could observe various forms and degrees of interaction with regard to the impacts of irrigation development on the fisheries within the catchment.

Capacity building continued throughout the process, during all workshops and along with the assessment developed below (see also the evaluation of participation, Section 6.4.2.1).

6.1.5 Screening and scoping

The local study team and workshop participants identified on available maps from IWMI, the KOISP command area and the Kirindi Oya catchment area. Given that impacts may spread over into neighbouring catchments, the mapping exercise continued throughout the assessment in order to include any additional information and emerging issue.

The mapping results were first used to select villages for the preliminary investigation. The representativeness of villages for different zones of aquatic resource use within the Kirindi Oya watershed was the main selection criterion. At least one village was selected in each of the following areas: above the Lunugamwehera reservoir; close to the reservoir; downstream of the reservoir and upstream of the lagoons; close to the

[5] An impact of first order is a direct impact and following orders are indirect – respectively second, third, etc. through the chain of reaction.

lagoons; along the coast; and near the river mouth. Eleven villages were selected and judged to be spatially representative of all important zones within the river basin. In each village, reconnaissance walks and informal interviews were carried out with community leaders, a group of villagers, and with one or two fishing households. The results provided information on the perceptions of project impacts held by villagers.

Participants listed all problems they perceived as a cause of irrigation impacts on fisheries in the project area during the screening workshop (see Box 6.1). The list of impacts was filtered through elimination of irrelevant ones (i.e. those lacking irrigation as a root cause) during the scoping workshop. Identification of the most important impacts arose from the key issues perceived by stakeholders and scientists, substantiated by secondary data and preliminary field visits. A clear focus for the impact assessment emerged but the approach also left sufficient breadth and flexibility to allow for identification of later emerging issues if required.

The scoping determined that for the impact assessment a rapid appraisal of livelihood impacts completed mainly through informal village surveys would be an appropriate means of investigation given the objectives, and time and resource constraints. The site sample was also reduced to a sub-set of eight villages judged to adequately represent the main issues of concern. These provided stakeholder representatives (Table 6.2) and locations for more detailed investigation of impacts. This second village selection was based on the location of the villages in the watershed, the importance of fishing as a livelihood activity, and the adequacy of coverage of the key issues identified by the screening and scoping activities (see results in Section 6.3.3).

6.1.6 Impact assessment

The impact assessment of the KOISP was an ex-post assessment given that the project was first implemented 16 years previously. In such a case, the current, i.e.

post-project, situation constitutes the baseline. Evaluation of project impacts required comparison of this baseline with a pre-project situation reconstructed on the basis of planning and other surveys conducted in the early 1980s, and participatory assessment by stakeholders who could compare pre- and post-project conditions.

For this purpose the search for secondary data sources concentrated on the most critical gaps, supplementing stakeholder knowledge gained during workshops. For example, empirical data for reservoir drawdown modeling were sought at international level. Key sources included: quantitative estimates of reservoir and lagoon fisheries production (De Silva 1988, Amarasinghe 1998, Joyeux & Ward 1998); and socio-economic data and some characterization of fishers' livelihoods before the project (Chandrasiri 1986, Senanayake & Wijetunga 1987), and after its implementation (Jayakody 1993, Kularatne 1999, Renwick 2001).

Assessment activities were proposed for each of the key issues. Preliminary assessment results and follow-up activities were discussed for further integration of local knowledge and other sources of information. During the following workshop, assessment results were presented for each key issue and discussed within working groups (one issue per group). A group representative presented the outcomes for plenary discussion with all participants. Different techniques were used for assessment of the biophysical environment, fisheries production and rural livelihoods.

Biophysical environment

Changes in aquatic habitat availability and quality were assessed using a comparison of pre- and post-project water resources maps, information from previous surveys, comparative data from other locations, and stakeholder consultation. First the project area covering the irrigation system and command area (old and new), and the wider catchment were identified. Relevant features of the potentially impacted area were indicated: water resources (streams, rivers by category order, lakes, ponds, etc.), and land use types (forests, agricultural, urban) and known modifications to the natural

river course, such as reservoirs, embankments, and weirs, etc. were indicated on the map.

In a second step, changes related to the project such as new reservoirs, canals, and irrigated fields that facilitated comparison of the current and pre-project situation were added or highlighted. This allowed identification of aquatic habitats lost or gained, as well as possible effects on the ecological connectivity of habitats i.e. changes that would impede or facilitate migrations of aquatic organisms. The changes were further discussed with stakeholders during the assessment workshops.

Fisheries production

Estimates of fisheries production and respective value for each of the major habitat types in the catchment were analysed through a comparative table called a 'fisheries balance'. The balance was established for estimates before and after implementation of KOISP. Comparative empirical data on fisheries production are available for most habitat types and geographical areas, and were used in this impact assessment as time and resources to collect location specific primary data were lacking.

Thus empirical data relevant to this case study were drawn from the estimates of fisheries productivity for different aquatic habitats given in Chapter 2, Table 2.2. In order to adapt the estimate to local conditions, assumptions were made for an appropriate adjusted figure (see Section 6.2.4.2). All production estimates were cross-checked with consumption and market estimates and discussed with stakeholders, as a further means of validation.

Impacts on rural livelihoods

Village and household profiles were broadly established from secondary sources. The economic and social importance of inland fisheries in the area indicated that some primary and location specific data collection should be conducted for key variables. The quality of stakeholder prior knowledge about the situation and the availability of

relevant secondary information supported the choice of rapid and informal survey methods for this. The socio-economist from the international team contributed to the rapid appraisal. Emphasis was placed on triangulation of information from the following varied sources for the purposes of data verification.

Key informant interviews were conducted in the eight selected villages (see also Table 6.2). The respondent was a community leader and in most cases the president or other office bearer in the village Fishing Society. Information was collected about the village economy, including: natural, social and physical capital; financial capital (in terms of access to credit and main income/employment sources); the local labour market and relative labour surplus or scarcity. Attention focused on the proportion of households engaged in fishing and its relative importance compared to other livelihoods. In addition ad hoc interviews of fish traders and fishers were conducted during early morning visits to sites when fish catches were commonly being returned to shore.

For further detailed investigations, five from the eight surveyed villages were later identified as representative of the areas that had the most important fisheries and/or the most significant project impacts. These areas were the scheme head reservoir, ancient reservoirs within its command (2 villages) and coastal lagoons impacted by scheme drainage inflows (2 villages). In each of these five villages household interviews were conducted to inform a more disaggregated assessment of the role of fishing in livelihoods and to provide detailed household case studies. The household interviews focused on household composition, productive assets, income sources and diversity, the livelihood role played by fishing and the impact of both the irrigation scheme and a recent drought on fishing.

In each of the five villages, two poor, two middle-income and two rich households were interviewed. Households were selected by asking the key informant to nominate two households for whom fishing was a significant full-time or part-time activity in each of the three wealth categories. Clearly this was based on a subjective assessment,

and the wealth categories were considered only indicative. However, observation of assets, economic opportunities and housing conditions during the interviews suggests that the selections were generally appropriate. Progression from relatively poor to relatively rich was consistent for the six households in each village, although cross comparisons by wealth category across villages would not necessarily be consistent.

Survey visits involving just observations, key informant interviews and two household interviews revealed that project impacts on fisheries in two of the remaining villages (and thus zones within the basin) were not significant. These were the upper catchment and river floodplain, upstream and downstream of the head reservoir respectively. Given time constraints only two fisher household interviews were conducted in each of these villages. These provided household level perspectives and confirmed the relative lack of importance of fishing in these zones. The final village was located near the coastal lagoons and was not surveyed further because of time constraints and because the coverage provided by the two 'lagoon villages' referred to above was deemed adequate. The Sustainable Livelihoods Approach (DFID 1999) and a categorization of fisheries functions in rural livelihoods provided a conceptual framework for the assessment (see Smith et al. 2005).

6.2 Results

6.2.1 Background

Biophysical and socio-economic environment

Since liberalisation of the economy from 1977, economic growth in Sri Lanka has been relatively strong (on average 5 percent per annum from 1990 to 2000, Central Bank of Sri Lanka 2001) apart from frequent slow-downs resulting from the internal conflict or international economic shocks. In 2001 the GDP reached US$898 billion,

equivalent to US$536 per capita, but unemployment remained a persistent problem. The agricultural sector, including forestry and fisheries, was the mainstay of the national economy, contributing 20 percent of GNP in 2001, providing direct employment to 35 percent of the workforce, and remaining an important source of income for about 70 percent of the population (Central Bank of Sri Lanka 2001).

Irrigation has been the most important strategic factor in the development of the agricultural sector (Kikuchi et al. 2002). Coupled with the diffusion of seed-fertiliser technology, irrigation development has contributed to increasing the national rice production. The objective was to enhance the productivity of the irrigated land base by diversifying agriculture with high-value, non-rice crops and increasing the productivity of paddy cultivation (Barker & Samad 1998). The total investment in the irrigation sector declined sharply from the early 1980s until the mid-1990s, due to a decline in public irrigation investment. Since then investment has slightly increased, mainly through rehabilitation and increasing contribution of the private sector (e.g. agro-wells and pumps). Rather than the expansion of irrigated areas as in the past, the objective focused on improved water management of existing irrigation schemes including operation and maintenance of the irrigation system, and on better design and implementation of rehabilitation projects.

Despite strong growth in some sectors, a growing middle-income class in urban areas and good progress on social indicators at national level, much poverty remains in rural areas, particularly in the northwest and southeast dry zone of the country. In this context, both marine and inland fisheries have played an important role in supporting the livelihoods of a significant number of rural households, and as a source of animal protein, despite their modest share in GNP (2.7 percent, Central Bank of Sri Lanka 2002). Coastal, off-shore (or deep sea), and inland fisheries contributed 57, 30 and 13 percent respectively of total fisheries production (Central Bank of Sri Lanka 2002).

In 2000 fisheries were believed to directly support the livelihoods of over 10 percent of the population in many coastal areas, but no precise figures existed for the inland

sector (Murray et al. 2000). An estimated 96 percent of the population regularly consumed some form of fish, while in 1996 fish products constituted an estimated 59 percent of the nation's total non-vegetable protein consumption (NARA 1997). Inland fisheries are mostly concentrated in perennial reservoirs where the activity has been promoted since 1952 through the introduction of exotic tilapia species (*Oreochromis mossambicus and O. niloticus*) and government programmes subsidizing fishing craft and gear (Amarasinghe 1998). While reservoir fisheries are managed mostly for tilapia, the species accounts for only about ten percent of the reservoir fish biomass, and native fish remain important in both production and biodiversity terms (Pet et al. 1996).

Freshwater fish have thus been important as a source of protein for low income households, being relatively abundant and affordable within irrigation districts where there are productive reservoir fisheries (Weligamage 2001, Amarasinghe 2002). Murray et al. (2000) reported that in rural inland areas of the dry zone demand was predominantly for cheaper, locally available inland fish, rather than for fresh or dried marine fish that had to be transported further.

The irrigation project

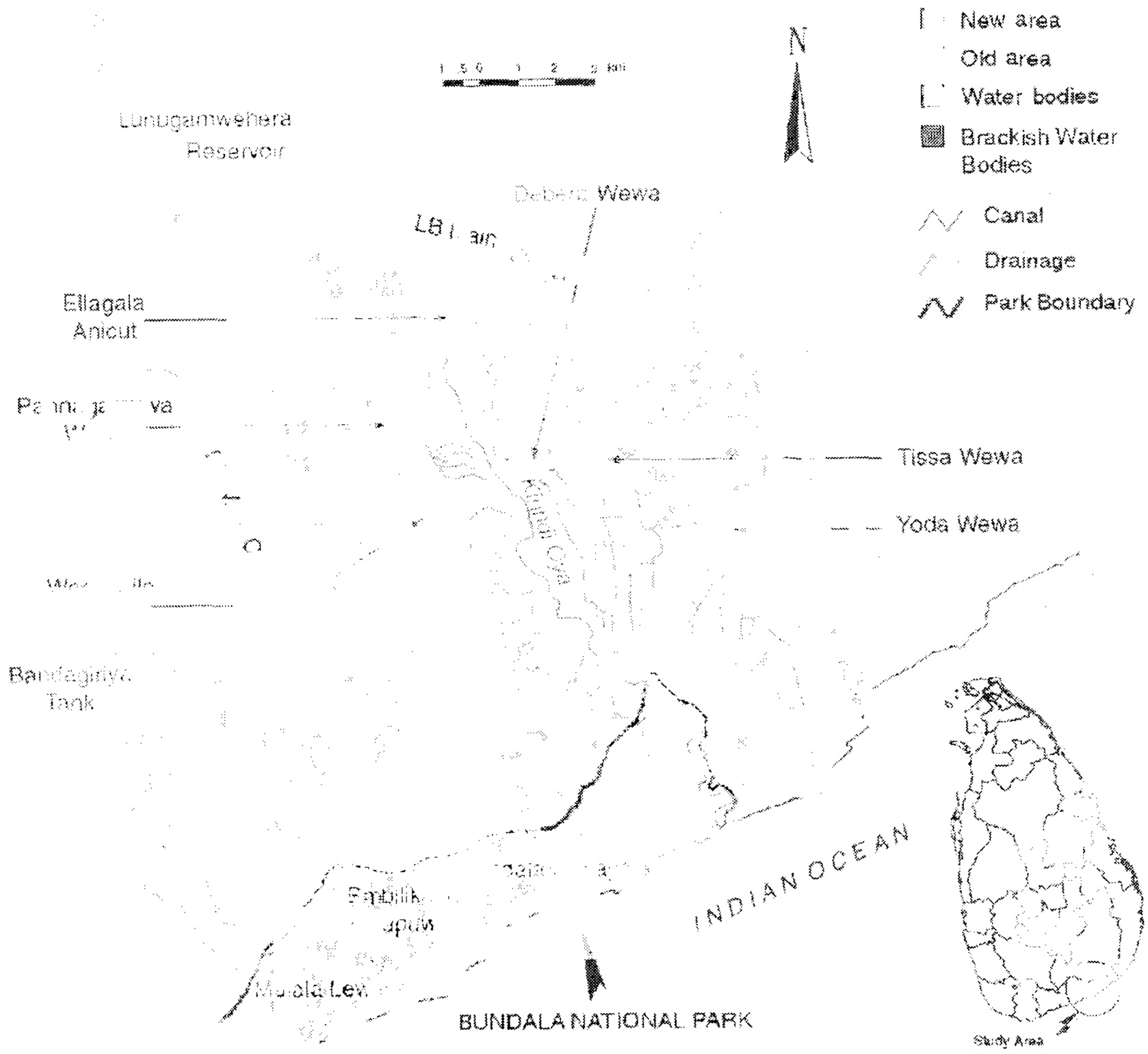
The Kirindi Oya Irrigation and Settlement Project (KOISP) is a major agricultural development project implemented in 1986 in the eastern part of the southern province and dry zone (Figure 6.2). The project rehabilitated and incorporated an ancient reservoir-based irrigation system (also called "tank[6] system"), which was replaced by an open cascade irrigation system draining into the Indian Ocean through a network consisting of a headwater reservoir of 200 million cubic metres, five ancient reservoirs and command areas.

The ancient reservoir system that supplied a command area of 4,200 ha was thus supplemented by a new command area of 5,400 ha. The new right bank command

[6] In Sri Lanka, "tanks" refer to irrigation schemes with small scale (below 200 acres or 81 ha) and medium scale (between 200-1000 acres or 81-405 ha) command areas.

area extends and drains into a neighbouring watershed from which drainage flows into two coastal lagoons. The project has created a large additional area of irrigated land, and re-settled a substantial population in the new irrigated area. It was designed for a diversified cropping pattern but since operation commenced, it has mainly grown rice (IIMI 1995a, 1995b). As a result the demand for irrigation water has been higher than expected, and overall economic performance lower than planned. Nonetheless, the project is considered to make an important contribution to the economy of the Southern Province (IIMI 1995a, 1995b).

Figure 6.2 Map of the Kirindi Oya watershed and the KOISP irrigation system



Source: Matsuno et al. 1998.

The KOISP command areas and the fisheries of concern to the assessment lie mainly within Hambantota administrative district and partly in Moneralaga district. The study area covers 6 Divisions: two above the reservoir (Tanamalwila, Wellawaya); and four below the reservoir (Lunugamwehera, Tissa, Hambantota, Ambalantota) with a population of 201,710 inhabitants and 44,178 houses (Hambantota District Secretariat Office 1998, cited in Zhongping et al. 2001).

6.2.2 Screening

The reconnaissance survey (see Table A.6.1 in Appendix) and review of secondary information revealed that there was a significant inland fishery in the Kirindi Oya basin, with fishing predominantly practiced in the reservoirs and in coastal lagoons. This is illustrated, for example, by Sippikulama and Malala villages near the Malala lagoon where as many as respectively 31% and 26% of households have actively fished as a significant part of their livelihood. Fishing also contributes to livelihoods in Kugama 1 village near the head reservoir though for a smaller proportion of households (6%). This is in part explained by the relatively greater importance of farming in this newly created area under the re-settlement scheme. Bandagiriya village is near an ancient reservoir and again shows the duality of farming and fishing as livelihood activities for some households (13% in this case).

The full list of impacts initially perceived by the workshop participants are summarised in Box 6.1. These results showed a large number of impacts associated with various sectors and domains (irrigated agriculture, fisheries, wildlife conservation, institutions, livelihood strategies, etc.), which can be classified as either direct (e.g. decrease of water availability) or indirect (e.g. environment protection), and variable in space (upstream and downstream of the reservoir). This list of key issues gave a first indication that fisheries production and fishers' livelihoods might mainly be affected by the management of water resources (particularly for irrigated agriculture), restrictions on access to water bodies (lagoons), and conflicts with

farmers, rather than the direct impacts of the physical infrastructure. The variety of impacts among sectors and stakeholders, and their spatial distribution showed that effects extended up to the coast, including the lagoon and estuarine fisheries.

Box 6.1 Identification of KOISP impacts on fisheries (Screening stage)

1) Irrigation and water resources management

- Release and distribution of irrigation water not considering fisheries needs (e.g. regular drying up of tanks)
- Siltation and sedimentation of small reservoirs. Most small tanks have been neglected and have suffered from siltation and sedimentation. They were used as fisheries (e.g. in Ranawaranewewa)
- In the upstream catchment, stakeholders report cases of obstruction of inflows to the large reservoir (see also IIMI, 1995).

2) Development of irrigated agriculture

- Water requirements
- Agro-chemical pollution of aquatic habitats, particularly tanks and lagoon fisheries
- Drainage water inflow into the lagoons and the restrictions on access to the national park where the lagoons are located; a decrease (particularly shrimps) or the extinction of some river species (notably 'Wallapota', *Ompok bimaculatus*), in or near to the estuary.
- Conflicts between farmers and fishers on water management issues (e.g. drawdown in reservoirs, drainage inflow in lagoons)

3) Environment and biodiversity

- Wildlife conservation: restricted access to water bodies (lagoons), changes in ecosystem balance.
- Biodiversity changes in irrigated ecosystems: through irrigation and/or reservoir fisheries management.
- Increased risk when lagoon and river fishing due to wild animals, particularly crocodiles
- Conflicts between wildlife conservation and fishing in protected areas: depletion of fish biodiversity and fish stocks that are important for migratory birds, restricted access to water bodies in protected park areas.

4) Rural livelihood strategies

- Lack of alternatives when income from fishing decreases, difficult transfer from inland fishing to marine fishing, general lack of livelihood opportunities.

5) Institutions

- Institutional and social issues: lack of linkages between Fisheries Cooperative Societies (FCS, see section 3.4.1) and other institutions, the social status of fishers in the community seems low.

While all issues identified were related to irrigation and fisheries interactions, most had also been influenced by drought conditions prevailing for three years at the time of study and which had led to general water scarcity, increased rural underemployment, and recession in the regional economy. Although differentiation

between current (drought-influenced) and average post-project conditions was required, a complete separation of irrigation and drought impacts was not always possible, neither analytically nor through the stakeholders' perception of change over time. For example while an overall decline of fisheries production in the catchment was noted, the relative contribution of negative irrigation impacts and drought could not be quantified.

Despite this the high probability that impacts on fish production and rural livelihoods had occured, along with probably negative impacts on fish species diversity, warranted implementation of an impact assessment.

6.2.3 Scoping

From the list of impacts identified during screening (Box 6.1), participants identified a few issues that they perceived to be most critical:

1) Reduction in river flow and flooding
2) Declining dry season water retention in small and medium-scale reservoirs
3) Inflow of drainage water into the lagoons
4) Conflicts between fishers and farmers
5) Weak linkages between fisheries institutions and irrigation institutions

Concerned by the potential loss of fish diversity and the decrease of floodplain production, the research team tended to emphasise the reduction of river floodplain and river flow downstream of the dam. Interestingly most stakeholders were concerned by other issues, primarily the loss of livelihoods from reservoir and lagoon fisheries and the resulting conflicts in these locations. All participants agreed that local and national institutions were not adequately addressing the impacts of irrigation on fisheries, essentially because of a lack of coordination between Irrigation and Fisheries agencies. It was notable that water quality was not perceived as a major

issue, as industries in the watershed were not much developed and agricultural input use was still relatively low.

6.2.4 Assessment of KOISP impacts

As noted above the assessment of project impacts aimed to compare the current (post-project) baseline with a pre-project situation reconstructed on the basis of surveys conducted in the early 1980s and participatory assessment involving older stakeholders who could compare pre- and post-project conditions. The assessment involved characterization of the current situation, identification of current fisheries problems related to irrigation development, and evaluation of project impacts on the natural resource system and rural livelihoods of the project area.

6.2.4.1 Baseline Situation

The baseline situation presents the natural resource and livelihood conditions at the time of the assessment.

Natural resource system

Land use in the Kirindi Oya catchment is predominantly agricultural, although the upper catchment is partially forested and an area of the lower catchment is set aside as a National Park. Water resources include the Kirindi Oya river itself, the large Lunugamwehera reservoir constructed by KOISP, a number of large ancient reservoirs, and coastal lagoons. All rice fields in both the "old" and the "new" area are irrigated, as the catchment is too dry to support rainfed rice culture. Consequently water levels in the rice fields are low on average and typically fluctuate between 0 and 10 cm over short time scales (in terms of days).

Fisheries production is almost entirely concentrated in the reservoirs and lagoons of the Kirindi Oya catchment area. The Kirindi Oya river has an innately low production

potential due to steep gradients and rapid and seasonal river flows, with flooding limited in duration and extent (De Silva 1988, Arthington et al. 2004). Likewise, the irrigated rice fields support little fisheries production. Of the total inland (including lagoon) fisheries production in the watershed (see Table 6.5 for details), the river, floodplain and rice fields were estimated to contribute less than 160 t/year (10-20%). Lagoon fisheries have been most drastically affected by the recent drought, and had virtually ceased at the time of impact assessment. At the time of the assessment these fisheries were dominated by tilapia (which can tolerate brackish water), but had previously included a large harvest of shrimp.

Livelihoods

Agriculture, forestry and fisheries dominated the local economy. Apart from a minority specialized in fishing, most communities depended on agriculture as the main source of income. Other than farming, the main skills and experience in the area were in fishing, in other natural resource based activities (e.g. shell mining, lime making, and firewood collection), government servants (school teachers, clerks, etc.) and other activities such as drivers, carpenters, and masons. Statistics by district showed that unemployment, and the proportion of employment in agriculture and fisheries for both men and women, were significantly higher in the region than national averages (Department of Census and Statistics 1999).

Given scarcity of land and water for farming, new jobs were needed for the second generation of those households who migrated and settled in the dry zone. At the time of the assessment the regional economy was very depressed by a prolonged drought that directly affected employment in agriculture and inland fisheries, and slackened the demand from farming and fishing households for local goods and services. Simultaneously Sri Lanka was suffering from a recession in tourism resulting from domestic and international security concerns.

In this context, the reservoir and lagoon fisheries were important as a source of livelihood for a significant number of rural households. Approximately 1230 households were engaged in fishing (7 percent of the total), and the gross income from fishing was estimated at 1.4 million US$/year, which represented 13 percent of total income in the area. Fish catches from lagoons and ancient reservoirs were used for own consumption and for sale in the main markets of inland urban centers for reservoir fish. Smaller seasonal reservoirs in the catchment were also used for fish, but this activity was usually confined to occasional or subsistence fishing. Little et al. (2001) note that the poorest, most marginal members of communities gained benefits from consumption of fish caught in these seasonal reservoirs.

The village rapid appraisal found that 5 to 15 percent of households in villages near to the reservoirs regularly fished for own use and to generate cash income (Table 6.3). Although a minority, over half of these were landless or marginal farming households for whom fishing was the primary source of livelihood (as also observed by Chandrasiri 1986 and Renwick 2001). The others were farmers and fishers, for whom farming was the main livelihood, with fishing an important supplementary source of food and income. It was notable that a significant number of reservoir fishers were young men and the second generation of the settlers under the KOISP scheme. Without direct access to irrigated land for farming and with limited alternative employment opportunities, they relied on fishing and other activities such as casual labouring, and the renting or sharecropping of small plots when available.

Overall in the KOISP catchment, most inland fishing is carried out either as a full-time specialisation, or as an opportunist activity by the poor and landless who also engage in other irregular activities such as firewood collection, labouring and sharecropping when able. Part-time supplementary fishing by farming households also occurs as described above, but is much less common than in the Lao case where it was almost universal.

Table 6.3 Proportion of households in surveyed villages engaged in fishing in 2002

Village	Location in catchment	Fishery	Number of households	No. of fisher households (full and part-time)	% of household s engaged in fishing
Ranawaranewewa	upper catchment	small reservoir	196	15	8%
Kudagama 1	new command area	new reservoir	240	15	6%
Bandagiriya	old command area	ancient reservoir	1500 approx.	200 approx.	15%
Malakapupathana Nadiganwila	old command area banks of Kirindi Oya	ancient reservoirs and river downstream of reservoir	282 265	17 30 approx.*	6% 11%
Pallemalala	near coast	lagoon	350-388	102**	25%
Udamalala	near coast	lagoon	435	30	7%
Sippikulama	near coast	lagoon	450	140**	30%

*mainly opportunistic and "leisure" fishing in the river.
**few fishing during prevailing drought.

Source: Village survey, February 2002

At the time of the impact assessment reported incomes from fishing compared poorly to other non-skilled employment and most fishing households, particularly those fishing full-time, were amongst the lowest income group in the region (Table 6.4). However, fisher households reported that prior to the recent drought reservoir fisheries had provided higher incomes than other available non-skilled employment. Renwick (2001) similarly reports average incomes for reservoir fishing pre-drought of approximately Rs.300 per day and estimated that annual income from full-time fishing would exceed that from irrigated agriculture. Incomes from fishing are, however, inevitably variable and dependent on experience and access to boats and gear.

In the villages near to the lagoons approximately 25-30% of households in villages had been regularly engaged in fishing (Table 6.3). As the lagoon fisheries had virtually ceased under the prevailing drought the assessment of their contributions to livelihoods under more normal conditions drew on information from surveys conducted pre-drought, in the early to mid-1990s, and from key informants. Between 250 and 400 households appear to have relied primarily on shrimp fishing in the

lagoon in the early 1990s, reducing to 100-200 by 1996 (IIMI 1995a, 1995b; Kularatne 1999). Fishing was the main source of income for 88 percent of all fishing households in the relevant administrative district (Pallemalala Division), with agriculture and fish retailing as the main alternatives. In addition some households engaged in fishing on a part-time basis, and many 'non-fishing' households fished in the lagoon for their own consumption only. The average monthly income in 1996/97 for full-time lagoon fishing households was reported to be three times that of non-fishing households in the same area (Kularatne 1999).

Interviews with lagoon fisher households indicated that during the prevailing drought the most common alternatives to fishing engaged in by men were retailing (usually by bicycle) of marine and reservoir fish caught by others, collection of firewood and casual labouring in saltpans also located in some of the coastal lagoons (see also Table A.6.1). Although relatively remunerative on a piece rate basis for those physically fit (Table 6.4), the arduous nature of work in the saltpans meant that most alternative activities were preferred whenever available. Changes in the shrimp fishery and their relation to irrigation are discussed in more detail in the following section.

Table 6.4 Income from fishing and alternative male employment, Rs per day (estimates from household interviews, village survey, February 2002).

Employment	**Income per day, Rs**	
	Before drought (late 1990s)	During drought (2002)
Reservoir fishing	200-800	50-150
Lagoon fishing (fish)	200-800	Nil
Lagoon fishing (shrimp)	700-5000*	Nil
Fish retailing (freshwater only)	300-1000	100-200
Farm labour	*145-180***	200-250
Construction sector:		
Colombo	*185***	255
Locally	*110-145***	150-200
Saltpan	*160***	220

* Reported income range prior to decline of shrimp fishery.
** Inflation adjusted estimates for *1997* from 2002 figures (Colombo Consumers' Food Price Index, Department of Census and Statistics).

Conflicts between fishers and farmers about water management issues were found to be common. In the ancient reservoirs these conflicts centred on levels of maximum drawdown, with fishers claiming that low water retention in the dry season reduced annual catches. Although maximum irrigation releases were set at the beginning of each season, the needs of fisheries were not given weight in the planning process, and in practice farmers tended to demand and use more water than initially allocated. This conflict was especially severe under the prevailing drought conditions.

In the lagoons, the conflicts between fishers and farmers centred on the opening of the coastal sand bar. Prior to the drought farmers opened the sand bar frequently to reduce water levels and avoid flooding of agricultural land, while fishers considered that this allowed shrimp to emigrate and thus reduce catch quantity and value. Institutional arrangements to deal with fisheries and water management issues and related conflicts were weak, and this was seen as a major problem by fishers.

6.2.4.2 Assessment of KOISP impacts

It is important to note that the comparison of biophysical and socio-economic conditions before and after the project spanned a period of 16 years. During this period many social and economic changes are likely to have occurred that were not directly related to irrigation. Moreover, the KOISP itself has had impacts through its settlement programme that exceeds by far those expected from its irrigation component alone. For example, population density in the Kirindi Oya watershed has increased by a factor of five from 42,304 in 1980 (Senanayake & Wijetunga 1987) to 201,710 in 1998 (IWMI 2001). This dramatic increase reflects settlement of households in the new command area as well as natural population growth.

Impacts on aquatic habitats and their connectivity

The main physical changes were identified as:

i) A reduction in river flow and the frequency and extent of floodplain inundation below the dam. Flooding has, however, always been a short-term phenomenon.

ii) A large (3200 ha) and shallow headwater reservoir (Lunugamwehera) has been constructed, creating a substantial and very biologically productive aquatic habitat. The reservoir has inundated about 2000 ha of natural floodplain (which would have been inundated only for short periods and thus relatively unproductive) and some 100 ha of small ancient reservoirs.

iii) The project has reduced natural inflow into the ancient reservoirs in the Kirindi Oya basin, but offers the potential to re-charge these water bodies from the headwater reservoir and reduce seasonal variation in water levels. The impact on ancient reservoirs is thus complex and dependent on water management decisions. This issue is discussed further below.

iv) The right bank command extends and partially drains into the neighbouring Malala Oya catchment. Irrigation drainage flows enter the Malala and Embilikala lagoons, raising water levels and reducing salinity (from 10-41 ppt.[7] in the mid-1980s to less than 7 ppt. a decade later, Jayakody 1993). Rising water levels posed a flood risk to agricultural land and dwellings around the lagoon, forcing a need to breach the coastal sandbar more frequently than before to discharge excess water to the sea.

v) Drainage flows can benefit the wildlife and livestock in the National Park (Bakker et al. 1999) as long as the quality of drainage water is maintained at safe levels for living organisms.

Fisheries production

A fisheries balance was established to compare the production and value of fisheries in the Kirindi Oya catchment before and after implementation of the dam. Recent

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[7] ppt: parts per thousand

estimates of fisheries productivity in Lunugamwehera and two of the ancient reservoirs (420-860 kg/ha/year) obtained by Renwick (2001) were substantially higher than the average (220 kg/ha/year) reported for Sri Lankan reservoirs by De Silva (1988). Two different balance tables were therefore drawn up to assess the sensitivity of net fisheries production changes to uncertainty in reservoir productivity. Fishers operating on ancient reservoirs consistently reported a decline in catches in recent years, and linked these to water management issues (see screening/scoping and mitigation sections). It is not entirely clear to what extent these problems are linked to KOISP construction, or to the recent drought.

However, total catches estimated in 1999 by Renwick (2001) compare favourably with values estimated in the mid-1980s by De Silva (1988), both on average and within specific ancient reservoirs covered in both studies. This suggests that recent productivity declines in the wake of low water retention are primarily linked to the drought rather than KOISP per se. Therefore, the fisheries productivity of ancient reservoirs was assumed to be the same before and after KOISP. Sensitivity analysis shows that even if ancient reservoir fisheries had been lost completely, the impact of KOISP would remain positive over the catchment area (109 or 167 tons respectively for hypotheses (a) and (b), see Table 6.5).

The lagoons had been the location of a specialized shrimp fishery that had been very profitable in the past (Table 6.4). Early juveniles recruited to the lagoon from the sea when the sand bar was naturally breached by seasonal tides and wave action, and remained trapped in the lagoon until a breach recurred about a year later. The shrimp fishery has declined drastically since completion of the KOISP as a result of a combination of environmental change and overexploitation. Increased freshwater inflow has reduced salinity and made the lagoons less suitable as habitat for marine Penaeid shrimp, while more frequent breaching of the sandbar for water level regulation allows shrimp to emigrate from the lagoon earlier than before. At the same time, increased exploitation by much higher numbers of fishers operating with increasingly small-mesh nets was widely seen by fishers as leading to overfishing and

consequent decline in catches per fisher and overall. It appears that by the mid-1990s the shrimp fishery had been largely replaced by a finfish (mostly tilapia) fishery of similar productivity but much lower value.

A comparative international study of yields from lagoon fisheries by Joyeux and Ward (1998) concluded that a lagoon's connectivity with the sea is the major determinant of its productivity, whilst salinity levels have little impact on total productivity. However, low salinity may reduce the proportion of marine shrimp (the most valuable species in this location) in total production. For lagoons of this type they estimated an average total fisheries yield of 100 kg/ha/year, including 25 kg/ha/year of shrimp. This average is comparable to an independent estimate of 120 kg/ha/year for these specific lagoons (Jayakody 1993). It was thus decided to assume constant overall productivity, but higher per unit value of lagoon catches in the pre-KOISP period (Table 6.5).

There are no quantitative fisheries production estimates for the irrigated rice fields prior to KOISP, but it is clear that production will have been far lower than the 60 kg/ha/year average for rainfed rice fields (Chapter 2, Table 2.2). A figure of 20 kg/ha/year was assumed, but this is likely to be an overestimate given that virtually no fishing in or around rice fields was reported by stakeholders or in village surveys either before or after KOISP implementation.

Overall results (Table 6.5) suggest that catchment scale fisheries production has increased by about 75% after implementation of the KOISP. The value of fisheries production however has increased by only about 10-25%, due to the replacement of the particularly valuable shrimp fishery by a similarly productive but much less valuable tilapia fishery in the lagoons. Possible effects on coastal fisheries outside the lagoons have not been assessed. These may well be equivocal, given that freshwater outflows are lower overall but likely to be richer in nutrients as a result of agricultural intensification.

A limitation that must be taken into account is that the catchment scale balance neglects distributional and livelihood impacts likely to have arisen within the catchment. It is clear that the greatest benefits have been generated in the upper catchment around Lunugamwehera, while the greatest loss in economic value has occurred in lagoons outside the catchment as a result of increased drainage water inflow.

Table 6.5. KOISP Fisheries balance in terms of production and value

Table 6.5(a) Reservoir productivity based on a recent survey by Renwick (2001)

Before KOISP						
Waterbody	Catchment ha	Area ha	Productivity kg/ha	Production Tons	Value/kg 1000 Rs/kg	Total Value 1000 Rs
Floodplain		6200	20	124	0.4	50
Lagoons		1500	100	150	1.5	225
Head reservoir		0	0	0	0.4	0
Ancient reservoirs		1608	630	1013	0.4	405
Small reservoirs		300	630	189	0.4	76
River	117800		0.3	35	0.4	14
Total		9608	1380.3	1511		769
After KOISP						
Floodplain		0	20	0	0.4	0
Lagoons		1500	100	150	0.4	60
Head reservoir		3200	420	1344	0.4	538
Ancient reservoirs		1608	630	1013	0.4	405
Small reservoirs		200	630	126	0.4	50
River	117800			0	0.4	0
Total		6508		2633		1053
Change		**-3100**		**1122**		**284**

Table 6.5 (b) Reservoir productivity based on average for Sri Lankan reservoirs by De Silva (1988)

Before KOISP						
Waterbody	Catchment ha	Area ha	Productivity kg/ha	Production tons	Value/kg 1000 Rs/kg	Total Value 1000 Rs
Floodplain		6200	20	124	0.4	50
Lagoons		1500	100	150	1.5	225
Head reservoir		0	220	0	0.4	0
Ancient reservoirs		1608	220	353	0.4	141
Small reservoirs		300	250	75	0.4	30
River	117800		0.3	35	0.4	14
Total		9608		737		460
After KOISP						
Floodplain		0	20	0	0.4	0
Lagoons		1500	100	150	0.4	60
Head reservoir		3200	220	704	0.4	282
Ancient reservoirs		1608	220	353	0.4	142
Small reservoirs		200	250	50	0.4	20
River	117800			0	0.4	0
Total		6508		1257		503
Change		**-3100**		**520**		**43**

Livelihood impacts

Prior to implementation of the KOISP the area constituted a depressed region in the country, economically, socially and agro-ecologically (Senanayake & Wijetunga 1987), and about two-fifths of households were below the poverty line (Wanasinghe et al. 1983, Tudawe 1986). Senanayake and Wijetunga (1987) pointed to limited productive livelihood and employment opportunities, predominantly based on the local natural resources. They estimated unemployment at about 20% of the labour force (amongst the highest in the country) and from the prevailing cropping patterns and intensities they deduced that the level of underemployment was also high.

The KOISP has increased overall agricultural and fisheries production in the catchment, but creation of new employment opportunities has not kept pace with population growth. The industrial and service sectors have not expanded sufficiently to absorb surplus labour, whilst increase in agricultural employment has been constrained by availability of land and irrigation water. As a result, indicators of the overall socio-economic status of households in the catchment continue to compare poorly with national averages.

Participation in fishing appears to have increased roughly in proportion to overall population growth. Numbers of boats estimated on Lunugamwehera and two ancient reservoirs in 1999 (Renwick 2001) are approximately four times higher than those estimated in the mid-1980s (De Silva 1988). Chandrasiri (1986) estimated that in 1986, 263 fishermen from five ancient reservoirs (Ridiyagama, Bandagiriya, Wirawila, Tissa Wewa, Yoda Wewa) were FCS members, and that a substantial but non quantified population of non-organised fishermen existed.

Despite a substantial increase in the number of fishers, total catches and catches per boat in the ancient reservoirs appear to have increased after KOISP completion. This conclusion is supported independently by the KOISP evaluation study (IIMI 1995a, 1995b) and Renwick (2001). This suggests increasing contributions of reservoir

fisheries to livelihoods in terms of both the number of beneficiaries and the average magnitude of benefits gained. By contrast, fishers operating in lagoons have suffered substantial reduction in income between 1987 and 1997, with the proportion of fishers earning more than 26 US$/month having declined from 52% to 35% (Kularatne 1999).

Virtually all fishers in the project area suffered from declining fisheries productivity during the period of drought. Other natural resource based activities such as shell mining, lime making, firewood collection, retailing of marine fish and labouring in the saltpans increasingly replaced fishing as a means of support for significant numbers of the landless and unemployed who had previously engaged in fishing. The impact of the drought was most severe in the lagoons, where fishing became virtually unsustainable as a source of livelihood.

Of the conflicts between fishers and farmers at the time of impact assessment, only those relating to water management and sand bar opening in the lagoons were directly attributable to implementation of the KOISP. Conflicts over reservoir water management arose from general water scarcity due to low rainfall and increasing irrigation demand. The project has some potential to alleviate the problem through its ability to re-charge the ancient reservoirs, but expansion of the command areas, little diversification away from rice cultivation and water allocation regimes dominated by farmer interests have tended to exacerbate it. While linkages between fisheries and irrigation institutions have never been strong in the project area, increasing control over water resources has made this lack of linkages a more pressing problem.

6.2.5 Opportunities for mitigation and enhancement

Despite the fact that catchment scale impacts of the KOISP on fisheries production and related livelihoods opportunities are likely to be positive in aggregate, there are clearly issues that should be addressed by way of mitigation and enhancement.

Identification and performance of mitigation and enhancement measures for the reservoir and lagoon issues were discussed during plenary sessions. Trade-offs of measures were evaluated during group discussions, and recommendations were made to support the management of the impacts of irrigation in the downstream reservoirs and lagoons. Both issues may be helped by more efficient use of irrigation water, and this was identified as an overall long-term priority.

Improving reservoir water management

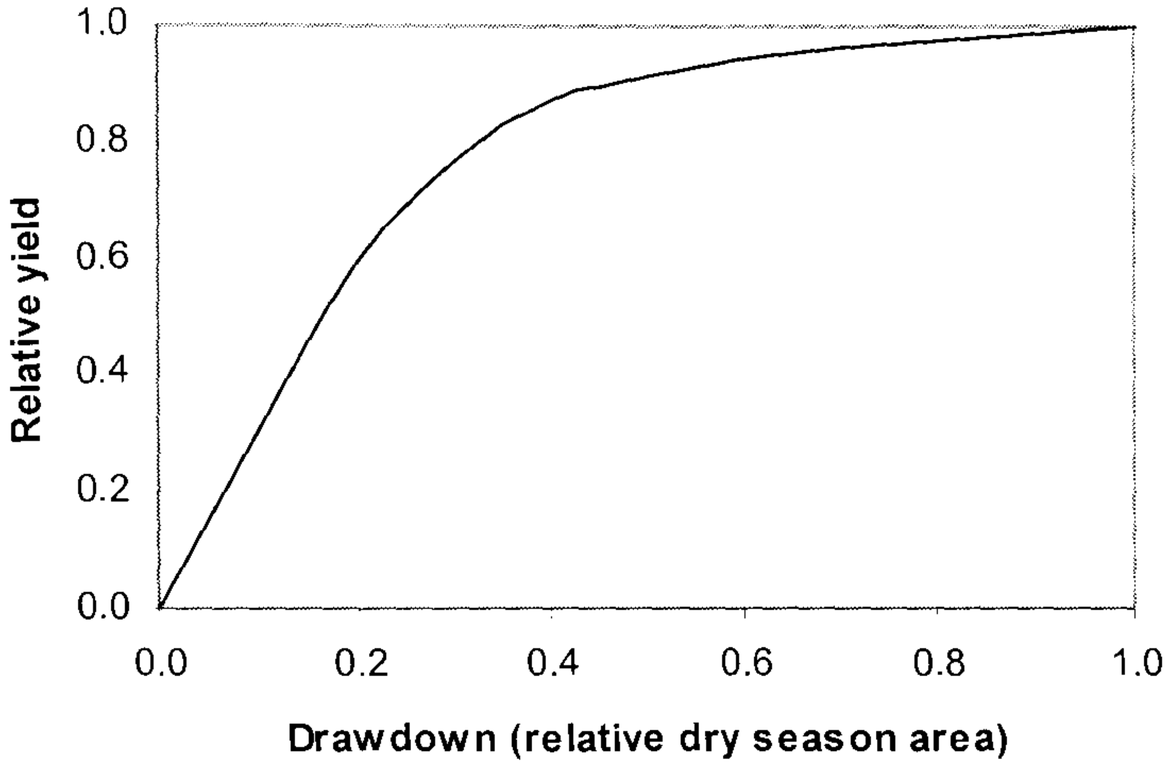
Improving reservoir water management with respect to fisheries is best described as an enhancement measure because it may further improve fisheries that owe their existence to irrigation development in the first place. Stakeholders identified in the screening and scoping phase that recurrent, sometimes extreme drawdown of water level was causing overall decline in productivity and profitability of reservoir fisheries. Such episodes have become increasingly common during the peak dry season months when water levels were not sufficient to satisfy the needs of fishers and sustain the fishery.

The relationship between drawdown and fisheries production is complex and subject to considerable controversy. Drawdown concentrates fish stocks and thus increases the efficiency of fishing gear and effort. In addition, periodic drying of the reservoir bottom may increase biological productivity. These positive effects of drawdown on fisheries production are counteracted by reductions in stock abundance under conditions of high density resulting from natural factors as well as fishing.

Population dynamics models of fish populations in water bodies subject to large fluctuations in water level and area (Halls et al. 2001, Lorenzen et al. 2004) indicate a strongly non-linear relationship between long-term fisheries yield and drawdown of the form illustrated in Figure 6.3. This suggests that yield is fairly insensitive to drawdown until the dry season area is reduced to a low proportion of full storage area. Location-specific empirical data (time series of fisheries and hydrological data) are

required to quantify the relationship, which will depend on characteristics of the reservoir and its fish populations. It is not possible at present to give general "safe levels" of drawdown, but the general shape of the relationship is useful in that it focuses attention on the likelihood of rapid change at higher levels of drawdown.

Figure 6.3 General relationship between relative dry season water area and fisheries yield



Source: Lorenzen et al. 2004

Long-term recording of fishing effort and catch over several years may be required to establish the precise relationship between drawdown and fisheries production. However, historical information may well allow definition of approximate minimum water retention targets.

It can be seen that the issue is primarily a conflict of interests between competing water users – here mainly the farmers and fishers – and though this may have occurred prior to construction of the KOISP, neither implementation of the scheme nor its subsequent operation have adequately resolved it. Workshop stakeholders agreed that fisheries interests should be considered in irrigation water management and they suggested fishers to be represented in the seasonal planning meetings. Further awareness creation and accompanying institutional measures would be required to support this integration and to improve the planning, control and

management of irrigation. Establishment of improved water management for fisheries in the reservoirs will also create opportunities and incentives for other fishery enhancement measures such as stocking and nursery habitat creation.

Drainage management in the lagoon area

As opposed to the enhancement of reservoir fisheries, addressing the problems created by drainage water inflow into the lagoons on the other hand was clearly a mitigation measure. Three possible mitigation measures for drainage inflows to the lagoons were considered by stakeholders: 1) diversion of drainage water around the lagoons with a channel; 2) reduction of drainage flows through rehabilitation of irrigation infrastructure and re-use of drainage water; and 3) better management of sand bar opening through coordination of farmer and fisher interests. Limited data on environmental and socio-economic costs and benefits of these measures did not allow a comparative analysis and selection of the best measure to be completed.

Increasing irrigation efficiency

It was proposed that increased efficiency of irrigation water use would help to alleviate fisheries problems related to water management. The objective would be to increase the ratio between crop evapotranspiration and reservoir releases. An increase in crop evapotranspiration would reduce the drainage flows to the lagoons. A decrease in reservoir releases would help keep more water stored in the reservoirs to maintain fisheries. In this case the potential loss of agriculture production would need to be traded-offs with the benefits brought by fisheries (an example of multiple uses of water is given in Bakker et al. 1999).

6.3 Summary and conclusions

The KOISP had a modest positive impact on pre-existing fisheries in terms of aggregate productivity and actual production. As neither subsistence nor commercial

fisheries developed in the river-floodplain system of the project area, the reduction of flow and flooding was not important in terms of fisheries and its livelihood functions. The large new reservoir created by the project substantially increased aggregate fish production from the catchment, compensating for losses downstream and in the lagoons.

However, while the impact of construction has been to increase the aggregate potential productivity of fisheries in the catchment, scheme operation and water management has had a negative impact on the actual production of the pre-existing reservoirs and lagoons. In combination with failure to effectively enforce access restrictions, resulting overfishing and the effects of recent drought, this has degraded fish stocks and driven fishing towards being little more than an opportunistic and residual source of livelihood for households with few alternatives. Given local population growth and unemployment rates, particularly among landless second generation settler households, this has provided an important social safety net, albeit at low income levels. Alternative livelihoods for the economically marginalised, such as firewood collection, shell mining and lime-making tend to be more environmentally damaging.

Improvements in water management across the KOISP catchment thus have the potential to deliver a range of environmental, social and economic benefits. Productive fisheries can be restored in reservoirs if savings can be made in the water needs of farming and management regimes can take account of minimum levels needed to conserve sustainable fish stocks. The benefits of this will include contributions to national fish output, employment and improved nutrition for poor households. More research is needed on the ecology of the coastal lagoons, but similarly (though subject to wildlife conservation priorities given recent designation of the area as a National Park) a productive and valuable fishery can potentially be restored. Here conservation objectives can potentially be realized, as well as social and economic benefits.

6.4 Evaluation of the APIA Approach

Evaluation of the operation, performance and impact of the approach drew from the generic framework presented in Chapter 4 (Table 4.5). The indicators suggested in the generic framework were refined in consultation with stakeholders in the workshops. The sources of information and means of verification of these indicators included informal and formal techniques such as direct observation by the study team, assessments by interviewed stakeholders, and anonymous workshop participant questionnaires. The questionnaires were distributed at the end of the workshops corresponding to the completion of the main impact assessment phases (see Figure 6.1). Informal evaluation was carried out in parallel through direct observations during the workshops and through informal discussions with workshop participants and key informants.

6.4.1 Operation

Implementation of the approach was evaluated in terms of the adequacy of required inputs and activities completed.

Inputs

The venue for workshops held in the KOISP catchment was accessible for community and local agency representatives apart from a few who faced difficulties in transportation arrangements and funding. Workshop evaluation results show that the facilities of the workshop venue were judged adequate overall. Short-term inputs were provided by international experts in the fields of aquatic resource ecology, agriculture, irrigation management, socio-economics and institutional analysis. The impact assessment was thus well resourced in terms of disciplinary coverage and expertise.

On average 25 participants attended each workshop including four facilitators and organizers. This number was manageable given the need for careful briefing and some training to facilitate participation by representatives from communities and local level agencies with little experience of such activity and lower educational standards. Representation of the selected communities of each sector (agriculture, irrigation, forestry, wildlife conservation and fisheries) and each governance level (community and local government) was achieved for the local workshops. Attendance of community representatives could be secured along the pre-determined sequence and schedule, as opposed to attendance of stakeholder representatives from government agencies. For these, the presence of at least one representative of each relevant institution and administrative level (below the national level) was ensured at each stage in the process.

Although the final workshop was held near to Colombo specifically to include national level representatives, it lacked adequate attendance by Irrigation Department officials. This highlighted that adequate participation by senior representatives from higher levels of governance can be difficult to secure even if limited to the final synthesis and management focused workshop. This also probably means that more effort should be put into the promotion of the approach at national level in order to gain their commitment.

Activities

The impact assessment was able to draw on relatively extensive secondary sources of data concerning the agricultural, water management and economic performance of the KOISP itself, in the form of project feasibility studies and evaluation reports. Much less information was available on fisheries, apart from a small-scale study of the economic value of the KOISP tank fisheries (Renwick 2001), and some empirical data on the productivity of reservoirs in Sri Lanka (De Silva 1988, Amarasinghe 1998). Statistical data on the local regional economy such as sources and levels of

employment were available, but disaggregation of information at district level or below was rare.

The composite approach to assessment made selective use of a relatively simple range of tools and analytical methods as described above (Sections 6.1 and 6.2). Given the limited time and resources for primary data collection, much of the assessment of biophysical, fish production and livelihood impacts relied on use of local knowledge and comparative data from secondary sources. These methods selected were judged adequate in terms of their coverage and predictive ability, and further evaluation of their performance is made below.

Four workshops were held in the project area and a final one near the capital (see Table 6.1). The workshops were observed to be an appropriate means for application of the approach's features (integration, participation and adaptation, see the evaluation of the performance in Section 6.4.2). In particular, providing a forum for exchange of information and priorities, debate, and mutual learning created an enabling environment for perspectives and attitudes to change. The workshops paralleled the impact assessment process and this improved the effectiveness and efficiency for dissemination and validation of information and assessment results.

6.4.2 Performance

The performance of the approach was evaluated in terms of its effective demonstration of the key features and objectives of its design, and the relevance and utility of its outputs.

6.4.2.1 Features

1) Holistic and integrated

The assessment encompassed all relevant sectors (irrigation, agriculture, fisheries, water resource planning, other land use including forestry and wildlife conservation) and disciplines (fisheries ecology, hydrology, irrigation engineering, socio-economics, and institutional analysis) although it was production and livelihood focused. Also selective use of adequate spatial and temporal scale of the assessments was sought. The following examples illustrate some of the benefits of the integrated assessment achieved.

The integration of sectors and disciplines identified factors that could have been neglected by a narrow focus on fisheries based on ecological assessments, or socio-economic assessments directly drawing from biophysical impact results. In the KOISP area, levels of unemployment and landlessness meant that the economic contribution of fisheries could not be considered in terms of the value of fish output alone. Fisheries were revealed important as a livelihood of 'last resort' or a source of income supplement for a significant number of landless and marginal farming households. This also meant that their degradation could increase pressure on other natural resources including forests and wildlife conservation areas.

In terms of spatial distribution the wide variety of issues initially identified led the investigation to range throughout the catchment and in different types of water bodies: river-floodplain, small and medium reservoirs, and lagoons. It was notable that the most adverse economic, social and ecological project impacts on fisheries were occurring in the coastal lagoons and outside the project catchment itself.

The holistic assessment diagnosed that degradation of the lagoon fishery was not solely the result of project impacts but this was caused by a combination of factors including overexploitation, the effects of a prolonged drought and the impacts of

project drainage inflows. This was important in a context where most local stakeholders, experts and managers perceived drainage from the irrigation scheme to be the major causal factor, and facilitated consideration of a wider range of possible mitigation measures than had been the case in the past. In particular, workshop participants began to look beyond engineering solutions in the form of expensive drainage diversion canals to catchment-wide improvements in the management of water resources, and water-use efficiency of irrigation and fisheries.

The reservoir issue showed the importance of irrigation management through regulation of water level drawdowns, plus the longer-term effects of extreme drawdowns on reservoir fish populations. Mitigation measures emphasised the management of water levels in the reservoir, while conventional management of reservoir fisheries generally focuses only on fish stock enhancement and aquaculture.

2) Participation of stakeholders and decision-makers

Degree of participation achieved. As introduced, the testing attempted to reach a genuine level of participation (as described in Chapter 4, Section II.4.1.2) of stakeholders and decision-makers. This level of participation was monitored and evaluated throughout the process with the participants themselves. The objective was to detect any decline in commitment, to control the cost of participation (time and resources) and to identify any need for stronger inputs from a particular group following identification of a specific issue.

Workshop evaluation results (see Appendix, Box A.6.1) showed that the inclusive and participatory nature of the approach was strongly appreciated by the participants since they were all able to make active contributions to identification of issues, analysis of results and debate. Their commitment to the process was firstly reflected in the high level of attendance (80-90%), and in the event of unavoidable absences by individuals, through their replacement by colleagues. The degree of interaction and information exchange between sectoral interests, and between local interests and

district and national agencies was high, and was remarked upon by agency staff as both innovative for the region and effective. Overall it is concluded that there was a satisfactory level of genuine participation in the process of impact assessment and identification of management options by all stakeholders.

Integrated use of local knowledge. The interaction between local and scientific knowledge improved understanding of inter-sectoral issues, the nature and causes of project impacts and the resolution of problems. This was particularly important in the identification of the focus of the study and the objectives for improved management. For example, in prioritisation of the key issues identified for the assessment, five were selected from an initial list of nine. This selection was contingent on the values and priorities of stakeholders, but it was also based on scientific knowledge. That is why the floodplain issue was addressed although not perceived key by most stakeholders. On the other hand, technical specialists may have underestimated the importance of reservoir issue, and they may have omitted the lagoon issue, certainly in studies where the definition of 'inland fisheries' does not include the coastal area or brackish water.

Another example of the use of local knowledge was the determination of the low productivity of the unmodified river channel and floodplain. This was anticipated by fisheries ecologists and confirmed by community interviews. Similarly, a combination of knowledge of fish population dynamics in shallow water bodies and local fishing, access regulation and irrigation practices will be essential in the development of improved management of reservoir drawdown levels and fish stocks. Overall the knowledge and perception of impacts differed between groups, and such differences were valued in achieving the holistic perspective. The study scope was then narrowed ensuring that critical issues were not overlooked or left unresolved.

Representation of interest groups. As noted above representation of the selected communities and each sector and governance level was achieved in terms of number of participants from each organization. While workshop attendance achieved

representation of different interest groups, during the workshops specific attention was paid to ensure adequate representation by all interest groups in terms of their opportunity to express interests and concerns. On major issues, each group was sequentially given the chance to state their position. Approximately the same time was allowed for each, with additional time for those less able and experienced in presenting their case, for example, representatives of fishing communities with low educational levels.

Attempts were thus made to balance stakeholder power and influence throughout the process. This specifically addressed an imbalance in favour of farmers since fishers were initially much more diffident and reticent in expressing their views. During the process concerns of fishers progressively gained weight as awareness, understanding and integration of fisheries needs increased in the debates on water management. Notably, irrigation managers (particularly the Project Management Committee representative) suggested that fishers should be invited to seasonal water planning meetings[8]. This suggestion was considered inconceivable or at least not negotiable prior to the process.

Communication and conflict reduction. The assessment revealed the conflicts of interest that existed between farmers and fishers, and the sectoral agencies responsible for irrigation, fisheries and wildlife conservation. These were reinforced by variation in the perceptions and knowledge of these groups with regard to causal factors and the severity of project impacts. For example, farmer and fisher groups were in conflict over reservoir levels during periods of water scarcity and over lagoon water levels and management of a drainage connection to the sea (a breachable sand bar). These conflicts initially appeared irreconcilable but the assessment approach reduced tensions by establishing the main causal factors underlying the conflicts and a shared knowledge of the severity of the issues for each group.

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8 For KOISP project, seasonal water planning meeting include 'project committee meetings' occurring about once a month and 'kanne' meetings coordinated by the Division Secretariat.

Collation, dissemination and discussion of the impact assessment results in ways that were accessible to all tended to decrease uncertainty and the levels of misunderstanding and controversy between the two stakeholder groups. This led to a more positive and creative dynamic in which both sides collaborated and identified possible solutions and principles for agreement deemed equitable and acceptable by all. Creation of a shared responsibility for problem solving and time bound generation of management oriented solutions also contributed to this. However final resolutions and detailed design of implementable proposals were not achievable within the time frame available.

Overall it was demonstrated that the approach provides an effective means to promote communication and a common understanding of problems across sectors and interest groups that have different concerns and priorities. Options gathering broad based support could be identified and used as the basis for preliminary recommendations accepted as legitimate by all participants, even when this required change in attitudes and behaviour. This was also achieved despite differences in education level, skills as a representative and language. However, it is recognized that such participatory processes can also raise or exacerbate conflicts that have lain 'dormant' because of a lack of means for their expression. This is most likely when a "voice" is given to groups that have previously been the most marginalised and neglected, the fishers in this case.

3) Adaptive approach

The adaptive approach required outcomes to be continually monitored and evaluated by the study team and workshop participants. The timing of responses to outcomes and lessons was sometimes critical. For example, the first workshops revealed the need for time to be spent in building the capacity of members of fisher groups to act as representatives and active workshop participants. This involved additional briefings and confidence building exercises. This approach was essentially required to

adapt the impact assessment to available resources, emergent outcomes (and surprises), and for learning.

The first objective of the adaptive approach was to target an optimum match between the scope and detail of the impact assessment, and the resources available. The constraints on time and resources imposed to optimize available knowledge, focus primary data collection on filling the gaps and to combine different types of knowledge as performed by the composite assessment (see below). The assessment thus evolved towards concentration on main issues, feasible and relevant impact assessment methods. However further requirements have been detected in terms of research (see Section 6.4.2.2) and institutional promotion (see Section 6.4.3) that were not possible to satisfy although not critical for this pilot testing. In regular assessments, sufficient flexibility should be provided to extend the time frame or provide more resources when strongly needed.

Adaptation and flexibility were also required to cope with unanticipated or unplanned outcomes. In particular, the nature of the conflicts between farming and fishing interests identified early in the assessment shifted emphasis away from the impacts of construction to operational issues, and specific aspects of water management within the scheme. Identification of the conflict between farmers and fishers over reservoir drawdown prompted additional investigation of available data and methods to structure the problem and develop management recommendations.

The adaptive approach also established the ability to respond to outcomes and lessons learnt and the capability to recognise windows of opportunity for change or improvement. Lessons focused on the implementation, outcomes and process design: some were used simultaneously or within a short time frame (days) and some were used retrospectively. For example, the moment when attitudes of farmers with regard to the needs of fishers 'softened' was detected to progress from discussion of problems to identification of solutions. Similarly the timing of awareness creation at

the national level and dissemination of recommendations was highlighted to coincide with the formulation of a national Integrated Water Resource Management Policy.

4) Composite assessment

The composite character of the assessment was evaluated mainly in terms of the variety of formal and informal tools and methods, secondary and primary data and information and combination of scientific and local knowledge.

i) Variety of tools and methods: for example, a dynamic biomass model was built using data from comparable fisheries in Sri Lanka and Bangladesh (see Section 6.2.5, Figure 6.3) for the prediction of fish stock dynamics in relation to reservoir drawdown levels.

ii) Increased use of secondary information: for example, the 'fisheries balance' (see Section 6.2.4.2 and Table 6.5) was lacking data on fisheries production in the floodplain influenced by the KOISP. To overcome this, quantitative and comparable data from Laos (Chapter 3 and Lorenzen et al. 2000) were used with assumptions for an appropriate adjusted estimate.

iii) Scientific and local knowledge: the combination of different types of knowledge, mainly scientific and local, can increase overall understanding of impacts and knowledge of the perception of priority issues. However this combination may not be straightforward and bring constraints as developed in the evaluation of participation (Section 6.4.2.1).

6.4.2.2 Outputs

The impact assessment approach has delivered outputs in terms of evaluation of KOISP impacts on fisheries, management recommendations and identification of key research areas.

Impact assessment results

Impact assessment results were evaluated in terms of evaluation capability and accuracy, scientific quality and contribution to general knowledge of irrigation impacts on fisheries.

i) Evaluation capability and accuracy: through the degree of sectoral and inter-disciplinary integration achieved and coverage of issues, the impact assessment revealed relevant and feasible opportunities for improvement without radical changes in the system, as it particularly emphasised the linkages between fisheries production and management of the irrigation system, as developed below.

ii) Scientific quality: peer reviewed outputs and longer-term evidence of uptake and adoption of both the approach and its outputs will become more important over time. To date, peer-reviewed reports (Nguyen Khoa et al. 2005a, 2005b) have been published.

iii) Contribution to general knowledge: the results (see Section 6.2.4) have provided insights in the understanding of the impacts showing that fisheries can be productive even in irrigated systems, and that the management of irrigation can be at least as important as the irrigation infrastructure. However even if positive in aggregate, impacts can be negative at a disaggregated level (per location or per socio-economic category) and their distribution can be equally important. These outputs could not have been provided by conventional narrow and non-participatory assessments.

iv) Utility to the management and decision-making: assessment results brought new perspectives to the management of impacts, in particular in showing the interacting effects that might otherwise impede effectiveness, and improvement of coordination between institutions central in water, land and fisheries management. The resulting management measures (see below) are likely to be more efficient and cost effective than conventional engineering or single-issue measures such as canal building.

Management recommendations

Management recommendations were evaluated in terms of their adequacy to the project and feasibility of recommended measures, and potential for local uptake.

i) Adequacy to KOISP: at first the remedial measures proposed by stakeholders tended to lack creativity, with a tendency to repeat obvious options and past attempts that had already proved unsuccessful or costly, for example, an ineffective (and now silted) canal constructed to discharge water from the lagoons to the sea or proposed drainage diversion canals around the lagoons. As understanding and consensus grew some innovation arose from recognition of the potential benefits of integrated combinations of measures rather than a sectoral or engineering measure. These aimed at improving the management of water within the Kirindi Oya catchment to optimise allocation of the resource while satisfying the needs of the poorest sections of communities and preserving their livelihood opportunities. These measures were judged adequate by the stakeholders and the research team.

ii) Feasibility of recommended measures: due to both the coverage of issues and the degree of integration achieved (particularly across sectors), their potential for reducing conflicts and broad based acceptance (across sectors and institutional levels), these management recommendations were likely to be more effective and more sustainable compared to those originating from a conventional reductionist and single sector analysis alone. All of these issues that are amenable to mitigation by relatively low cost measures were well understood by stakeholders. These results demonstrated a sensible focus on existing resources, capabilities and opportunities.

iii) Potential for local uptake: linkages between fisheries and irrigation institutions have never been strong in the project area, but both increasing control over water resources and increasing demands have made this lack of linkages a more pressing problem. Opportunities to address this within current institutional arrangements by inclusion of fisheries in the national Integrated Water Resource Management Policy were identified.

Key research priorities

The approach identified knowledge gaps and research priorities, the relative importance of these, and helped in screening out other issues. Given the importance of livelihood functions in fisheries in a depressed region, more effective management regimes for rehabilitated reservoir and lagoon fisheries need to be studied.

The reservoir issue calls for the assessment of minimum water levels required to sustain the fish population in reservoirs of different physical and limnologic characteristics, and of different water management regimes. The valuation of fisheries value per unit of water is also required to carry out detailed trade-off analyses and compare the costs and benefits of the various users of reservoir water, in particular agriculture. The lagoon issue calls for further investigation of the ecological and socio-economic impacts of different water exchange scenarios including drainage water inflows, and the natural and man-induced sea and lagoon exchanges. Ultimately, this research should support the management and sustainability of irrigated agriculture, fisheries and biodiversity conservation altogether.

In contrast the KOISP case suggests that in-stream flow studies or the design of facilities for fish passage across dams and other structures are a low priority from fisheries production and livelihoods perspectives, even if desirable from a biodiversity conservation perspective. Finally a strategic assessment of the impacts of water resource developments on inland fisheries is required at national and river basin level. This assessment would take account of cumulative impacts on a river or a group of rivers, in a context of growing water scarcity.

6.4.3 Impact

As this was a pilot testing of the APIA approach the evaluation of its impact can only be tentative and preliminary. Therefore no subsequent changes in water or fishery

management were expected to take place immediately as a result of the assessment. Assuming the recommendations made were refined in detail and taken up by scheme managers, a more rigorous evaluation would then require monitoring of implementation of the recommendations, plus a continued process of consultation among the relevant stakeholders.

Despite this, use of the approach for the KOISP demonstrated significant positive outcomes for each of the following:

i) A process of increasing the representation and influence of fisher communities in scheme level processes of water management was initiated, and improved communication and cooperation between farming and fishing interests.

ii) Modern and innovative methods were used to address complex and longstanding conflicts of interest between competing uses for water.

iii) The fishers-farmers conflicts tackled during the process were significantly reduced through improved understanding of respective interests and essentially through the identification of management measures that could take into consideration both farmers and fishers' needs in the reservoirs and lagoons.

iv) The assessment produced information of relevance and practical use to scheme management, identified possible mitigation and enhancement measures and established a broad based local consensus on feasible management improvements. The management orientation of the approach meant that identification of potential impacts of its use and possible 'institutional uptake pathways' were part of the process, and this helped to ensure outcomes that were relevant and significant. Strong interest in continued use of the approach was demonstrated by the reactions of workshop participants and responses to workshop evaluation questionnaires.

The experience also showed that recommendations will have most impact after detailed costing and feasibility studies are completed. Lastly the capability of local

agencies and communities to implement recommended measures and adapt to the technical changes inherent in them may also need to be enhanced.

In terms of uptake and adoption potential at national level, the approach raised awareness of the socio-economic importance of fisheries and irrigation impacts among policy makers, stakeholders and relevant experts, and should increase the weight given to fisheries in the policy agenda for water resource management. For example, a member of the Water Resource Secretariat showed a strong interest in provision of better understanding and guidance on how to address and give weight to fisheries and environmental issues, as required by Integrated Water Management Policy.

Interest at national level was also evidenced by strong representation in the process from the fisheries scientific community and most relevant government departments. The opportunity to influence national policy making needs to be developed through further awareness creation, dissemination of the results and completion of additional project and strategic assessment studies that clarify how best to integrate fisheries into water policy. A disadvantage that needs to be overcome is that the approach falls between sectors and agencies, and thus may lack both a natural institutional home and "champion" to carry it forward.

At international level there is potential for uptake of the approach, particularly in countries with significant inland fisheries that contribute to the livelihoods of large numbers of poor households. For international uptake a Guidance Manual (Lorenzen et al. 2004) has been built along this research and it includes both a knowledge base and guidelines for the approach described in this thesis.

6.5 Conclusions

The approach proposed and developed in this thesis (APIA, Chapter 4. Part II) for the assessment of the impacts of irrigation development on inland fisheries was pilot tested through an ex-post assessment of the impacts of the Kirindi Oya Irrigation and Settlement Project (KOISP) in Sri Lanka. The approach combined an integrated assessment of impacts with participation by stakeholders, and an adaptive response to the outputs generated at each stage of a structured and sequential process.

6.5.1 The impacts of KOISP irrigation project on fisheries

The KOISP irrigation system had a modest positive impact on pre-existing fisheries in terms of aggregate productivity and actual production. However, the disaggregation of results spatially, between different types of water bodies and between different socio-economic groups showed a different picture of the impacts. While the created headwater reservoir has increased the total production in the catchment, scheme operation and water management has had a negative impact on the production of the downstream ancient reservoirs and lagoons. This has affected fisheries in their important role of livelihood safety net, albeit at low income levels.

Assessment results showed that improvements in water management across the KOISP catchment have the potential to deliver a range of environmental, social and economic benefits. Productive fisheries can be restored in reservoirs if savings can be made to maintain minimum water levels in the water body. Similarly, a productive and valuable fishery could be potentially restored in the lagoons if the management of drainage water takes account of fisheries and conservation requirements.

6.5.2 The APIA approach

The adaptive, participatory and integrated impact assessment was advantageous in respect of all of these issues, and thus its benefits compared to a conventional narrow technical assessment have been shown to include the following:

i) The ability to study inland fisheries in a larger context of multiple competing uses for water and alternative livelihood opportunities, with explicit identification of conflicts within the sequential, structured and management oriented process it requires;
ii) The ability to identify and focus on the most important issues and for solutions to be sought;
iii) The emphasis on existing opportunities and the need for workable and cost effective mitigation and enhancement measures, with avoidance where possible of costly modifications to the irrigation infrastructure or other engineering solutions;
iv) The commitment of stakeholders to seek out irrigation management options that exploit complementarities between irrigation and fisheries, with the potential to determine "win-win" solutions from resolution of conflicts between farmers and fishers.

In terms of future research needs, improvements can still be made in the knowledge and approach for the assessment of impacts of irrigation on fisheries, in particular for analysis of interactions and determination of causal relationships. Possible cumulative and synergistic impacts on fisheries of multiple irrigation schemes and other water resource developments within a river basin also need to be studied. Overall, implementation of further case studies in contrasting natural and social environments will help to broaden and deepen the knowledge base and contribute to improvements in the methodology.

Appendix

Table A.6.1 Main village characteristics, natural resources and livelihood activities: Results of reconnaissance surveys: informal interviews of key informants (households and villagers groups) in 8 villages in the project area.

Village name	**Ranawaranewewa**
Visit	• 10/02/02 • Interviewed: M.B.Siriyawathie; B. Andris; R.M. Buddedase; P.B. Amaradase
Village characteristics	• 196 households (only 50 with legal land titles, others encroaching) • Old village (settled about 100 years ago) • Mostly rainfed upland agriculture (groundnuts, cowpea)
Water resources	• Kirindi Oya River (seasonal-dry in August-Sept) • Two small tanks (20 ha, 8 ha), dams currently broken but being rehabilitated
Fishing activities	• 15 households involved in fishing as occupation (7% of total) • Fishing almost exclusively in tanks (not much fish in river?) • Tanks need regular stocking, fingerlings supplied free by fisheries ministry to fishing cooperative (but have to pay transport) • Catch sold locally by bicycle (3-5 km radius) • Fishing income up to 900 R/day under good conditions
Changes in fishery	• Declined in 1997 when dams broke
Problems identified	• Small tanks need to be rehabilitated (small one is being rehabilitated now)
Village name	**Debara Ara**
Visit	• 10/02/02 • Interviewed: (fisherman)
Village characteristics	• 74 households (only 13 with legal fishing permit, 38 members of Fisheries Society) • 60 farmers under irrigation command area
Water resources	• Small tank built in 1973 (180 acres)
Fishing activities	• Mostly fishers/farmers; passive fishing with gill nets left in tank during nights • Occasional fishing by rod and line by other households
Changes in fishery	• Declined in 1999 because of decrease of water level and overexploitation in tank
Problems identified	• Low water level – drought
Village name	**Kudagama 1**
Visit	• 10/02/02 • Interviewed: W.A.K. Weerasinghe; Mr Premalal
Village characteristics	• 238 households, mostly with legal land • New settlement under KOISP right bank scheme • Were given 1 ha irrigated paddy plus several ha upland
Water resources	• Lunumgamwehera reservoir
Fishing activities	• 15 households (6%) fishing as occupation (all also farming) • Catch before draught about 40 kg/boat/day
Changes in fishery	• Declining fish populations last few years • Reduction in local fishing households used to be 40 in early 1990s • Increased use of small mesh nets • Lack of water
Problems identified	• Lack of water (drought) • Increased use of small mesh nets

Village name	**Malakapupathana**
Visit	• 11/02/02 • Interviewed: W.B. Chandrapala
Village characteristics	• 282 households • Old village
Water resources	• Weerawila tank • Also use Lunumgamwehera occasionally
Fishing activities	• 17 Families (35 people) fish as occupation (6% of total) • Catch tilapias, snakehead, eel, and stocked carps • Regular stocking with seed from • Tried hapa nursing of fry but did not find it profitable
Changes in fishery	• Increase in number of fishers (from 10 in 1980s to 35 now) • No changes in species composition
Problems identified	• Too much water taken out of tank for irrigation – fishers can not influence irrigation decisions ("tanks are for irrigation, not for fish") • Drainage water from KOISP – salinity, sediment, pesticides (only when new areas irrigated for paddy)
Village name	**Nadiganwila**
Visit	• 11/02/02 • Interviewed: H.G.M. Munidasa
Village characteristics	• 148 households • Old village
Water resources	• Kirindi Oya river (in particular around small irrigation weir)
Fishing activities	• Some 50 people fish with rod & line for their own consumption • Catch some 2-2.5 kg/day • Catching with nets when the gates of the irrigation weir are opened (March/April)
Changes in fishery	• Used to fish in paddies after flooding, but flooding is rare since Lunumgamwehera (2 times since construction) • More people fishing now (10 in 1980, 50 now) • Now people like freshwater fish better than before • Species affected by Lunumgamwehera: negative: walaputa, kawaya, madara, marandu, petya, prawns; positive: tilapia, catla, rohu.
Problems identified	• Reduction of water in river due to Lunumgamwehera
Village name	**Pallemalala**
Visit	• 11/02/02 • Interviewed: Mrs Chandra Malania; her husband
Village characteristics	• 388 households • Old village
Water resources	• Malala and Embellikala lagoons
Fishing activities	• 102 fishing households (26% of total) • Fishing in the lagoons (March-June), and in the sea (July-February) • Catch value up to 6000 R/day (shrimp/lagoon), less than 1000 R/day all other fishing • Cut open the sandbar to allow shrimp recruitment into lagoon (usually once a year, but several times/year since KOISP drainage enters lagoon) • Currently survive on sea fishing and salt collection
Changes in fishery	• Drought in recent years • Increased freshwater inflow from drainage of KOISP • Shrimp farm development was attempted 1994 but prevented by protests from local people
Problems identified	• Drought – water level in lagoon very low

	• Drainage of freshwater into lagoon • Access restrictions to Bundala national park • Shrimp stocking not requested – seen as first step towards aquaculture
Village name	**Bandagiriya**
Visit	• 12/02/02 • Inteviewed: Mr Charlis; E.M Athur; Mrs K.L. Rangeni
Village characteristics	• 1500 households • Settlement began 1956, last settlement 1970s. Expansion as 2nd generation sets up households
Water resources	• Bandagiria tank • Several smaller tanks
Fishing activities	• 200 households fish as occupation (13%) • Sell to traders in Pallemalala
Changes in fishery	• Water levels: always enough water before 1985, the expansion of command area (from 900 to 2000 ha) led to increased drawdown. Now too little water is left after a few months. • Water problem now dominated by draught. • Fish diseases: occasional • Traders no longer come because catch volume too low
Problems identified	• Water allocation: no water allocated for fish, fishermen powerless to influence irrigation decisions (they obtained promises at cultivation meeting, but farmers pressed politicians and got permission to use all water in tank) • Fishers request to retain at least 5 ft of water in tank. • Fishers not allowed to fish in other reservoirs
Village name	**Uda Malala**
Visit	• 12/02/02 • Interviewed: Mr Kichchil
Village characteristics	• 435 households
Water resources	• Embellikala and Malala lagoons
Fishing activities	• 30 households fishing (7%) • Fishing in the lagoons (December – May), and in the sea (June-November)
Changes in fishery	• Reduction due to irrigation drainage since late 1980s, now aggravated by draught
Problems identified	• Irrigation drainage • National park access
Village name	**Boralessa**
Visit	• 12/02/02 • Interviewed: T.M.Piyasena
Village characteristics	• 102 households
Water resources	• Embellikala and Malala lagoons
Fishing activities	• 60 fishing households (60%) • Lagoon fishing all year round
Changes in fishery	• Before 1965: very good catches (but prices low) (25 fishers) • 1965-74: lower catches due to low water levels (draught) and outsiders coming to lagoon to fish (300 fishers) • 1974-85: good catches again • 1985-98: rapid decline of shrimp catches due to drainage water inflow (150 fishers- cooperative started an outsiders excluded, then grown to 240 local fishers) • 98- : draught, very little fish altogether
Problems identified	• Freshwater drainage to lagoon • Access and other restrictions from national park

Village name	**Sippikulama**
Visit	• 13/02/02 • Interviewed: Mr. Shahiama
Village characteristics	• 450 households • Village about 75 years old
Water resources	• Malala lagoon
Fishing activities	• 140 villagers fish in the lagoon (31% of total) • 16 young villagers fish in the sea with fishermen from Hambantota (don't own the boat and learn marine fishing)
Changes in fishery	• Used to fish in the lagoon and get good shrimps catches (700 Rp/day) • In 90's when drainage water came into the lagoon, shrimps catches decreased • but not only 15 were allowed to fish in the lagoon 1.5 year ago • Some young fishermen learn sea fishing • Decrease of income: about 5000 Rp/month 5 years ago to 2000 Rp/month now • Most lagoon fishermen didn't go fishing for 2 years
Problems identified	• Problems with crocodiles (increasing number) in the lagoon: damage fishing nets and bite fishermen • Fishing restrictions from Pallemalala Fishing Society (nets size and numbers of fishing permits) • Sippikulama fishers are considered as outsiders for lagoon fishing
Village name	**Mahagama**
Visit	• 13/02/02 • Interviewed: Mr. Senadase and Mr. Sapremana
Village characteristics	• 261 households
Water resources	• Kirindi Oya at junction with the sea
Fishing activities	• only 2 full time fishermen fishing in the river and in the sea • river fishing for bait; marine fishing aiming large fish (hooks and line) • some households fishing occasionally in the river for self-consumption
Changes in fishery	• more marine fishing than river fishing • better income from marine fishing
Problems identified	• some river fish species disappeared (wallapota, prawns; no lula for a long time)

Box A.6.1 Workshop 1 evaluation questionnaire and results (percentage of participant responses)

Workshop 1 Questionnaire

1. Understanding

1.1 Before continuing the impact assessment process, have you reached a sufficient understanding on the nature of impacts and impact assessment studies?

1.2 Do you have any comments?

2. Perception of impacts

2.1 Do you think we have considered all irrigation impacts on fisheries that participants could perceive?

2.2 Do you have any comments?

3. Linkages between sectors

3.1 Has the common work with most stakeholder representatives (from different sectors, at different levels, with villagers) been more beneficial in providing the first outputs than a sectoral approach?

3.2 Does it stimulate the creation of linkages between sectors?

3.3 Do you have any comments?

4. Participation

4.1 Do you feel that your participation has been fully and equally integrated in the identification of problems and key issues?

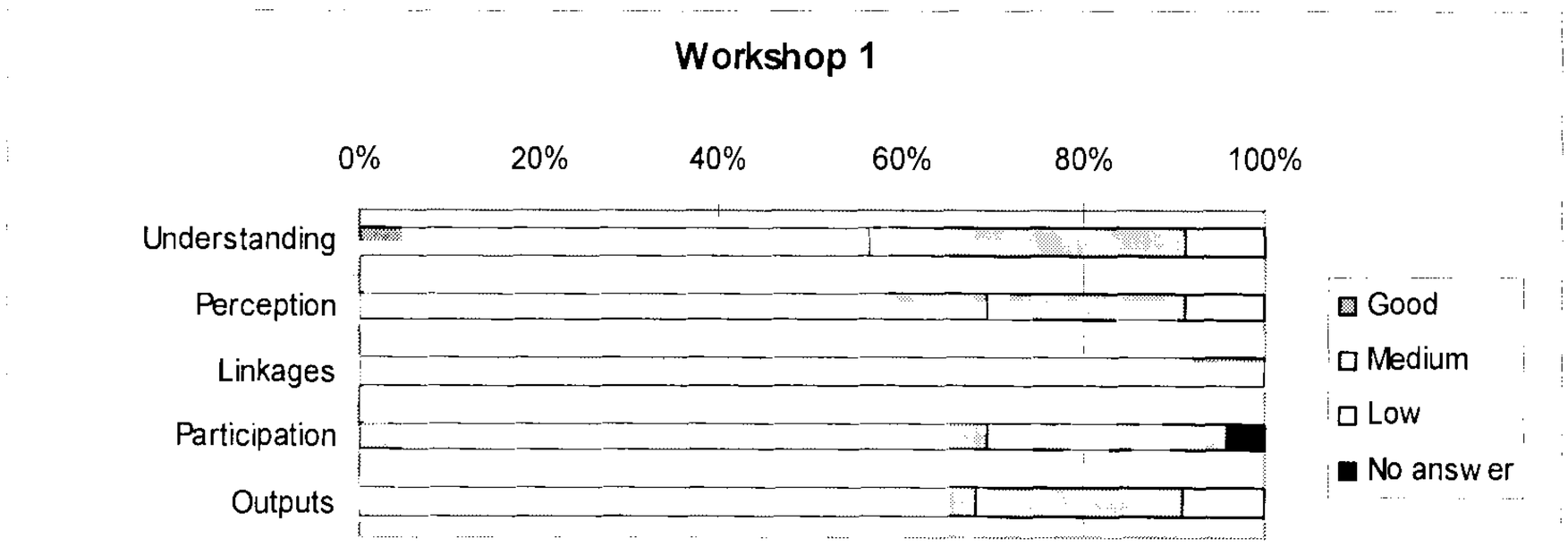
4.2 Do you have any comments?

5. Workshop outputs

5.1 Do you think this workshop has been useful for your work (better awareness of impacts, better understanding, etc)?

5.2 Do you have any comments for the next workshops?

Results



n=23

Box A.6.2 Workshop 2 evaluation questionnaire and results (percentage of participant responses)

Workshop 2

Questionnaire

1. Key Issues

1.1 Do you think the workshop has raised the issues you consider the most important?
1.2 Do you have any comments?

2. Interactions between Impacts

2.1 Has the workshop provided a better understanding on the interactions between the main impacts - identified as key issues?
2.2 If not, what would you like to be clarified?

3. Potential Mitigation and Enhancement measures

3.1 Do you think the workshop has provided a sufficient list of measures to mitigate or enhance the identified impacts?
3.2 Do you have any comments?

4. Available information

4.1 Do you think we have considered all available information for the impact assessment?
4.2 If not, what other source of information should be considered?

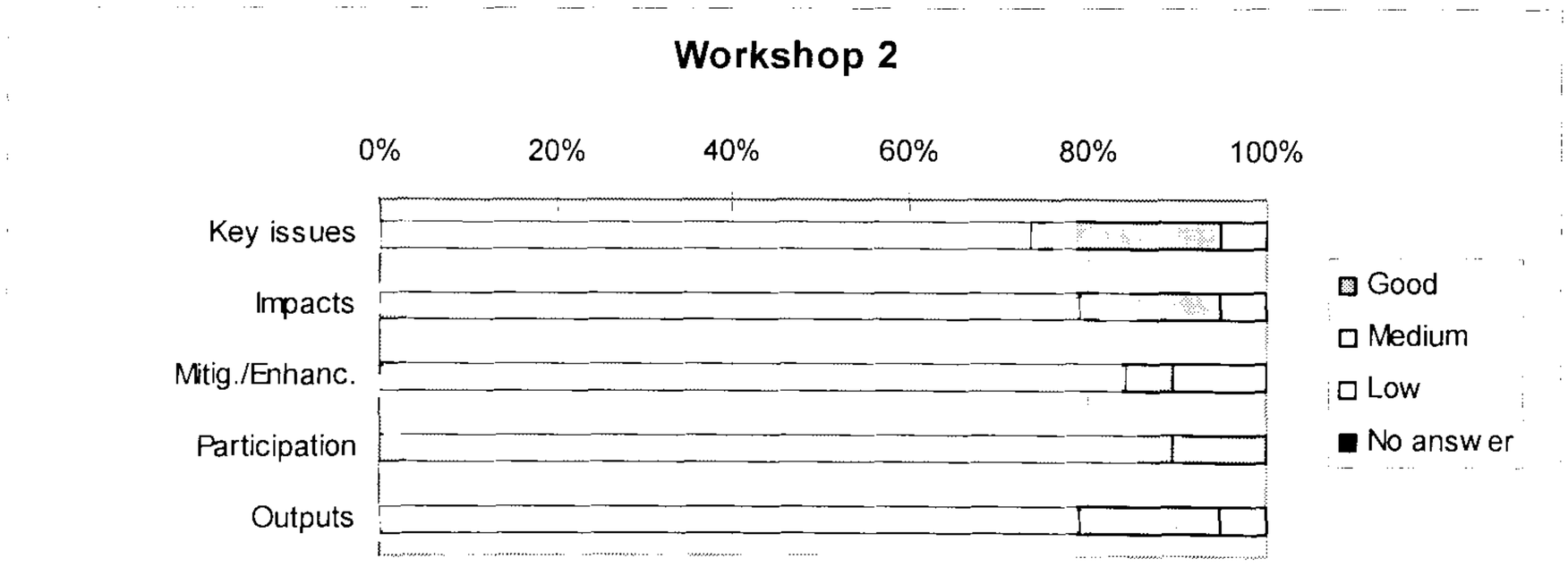
5. Participation

5.1 Do you feel that your participation has been fully and equally integrated in the identification of problems and key issues? . Fully integrated: _ ; Equally integrated: _
5.2 Do you have any comments?

6. Workshop outputs

6.1 Do you think the activities planned for the assessment are appropriate and feasible?
6.2 If not, why?
6.3 Do you have any other comments?

Results



n= 19

Box A.6.3 Workshop 3 evaluation questionnaire and results (percentage of participant responses)

Workshop 3 Questionnaire

1. Impact Assessment methodologies

1.1 Do you think the methodologies adopted for the impact assessment are adequate (time constrained)?

1.2 If not, which improvements or changes would you recommend?

2. Impact Assessment results

2.1 Do you think the quality, reliability and coverage of data used in the assessment are sufficient?

2.2 If not, which other data would you recommend?

2.3 And what key knowledge gaps remain?

3. Mitigation/Enhancement measures: rationale and implementation

3.1 Do you think the workshop has provided adequate measures for the identified issues?

3.2 Do you think the measures can be implemented as suggested?

4. Representativeness of sectors interests

4.1 Do you think the discussions and conclusions reflect the interests of all relevant sectors?

4.2 Did it stimulate linkages between sectors and institutions?

5. Participation

5.1 Do you feel your participation has been fully and equally integrated in the discussions (within the group, with all participants)? . Fully integrated: _ ; . Equally integrated: _

5.2 Do you have any comments?

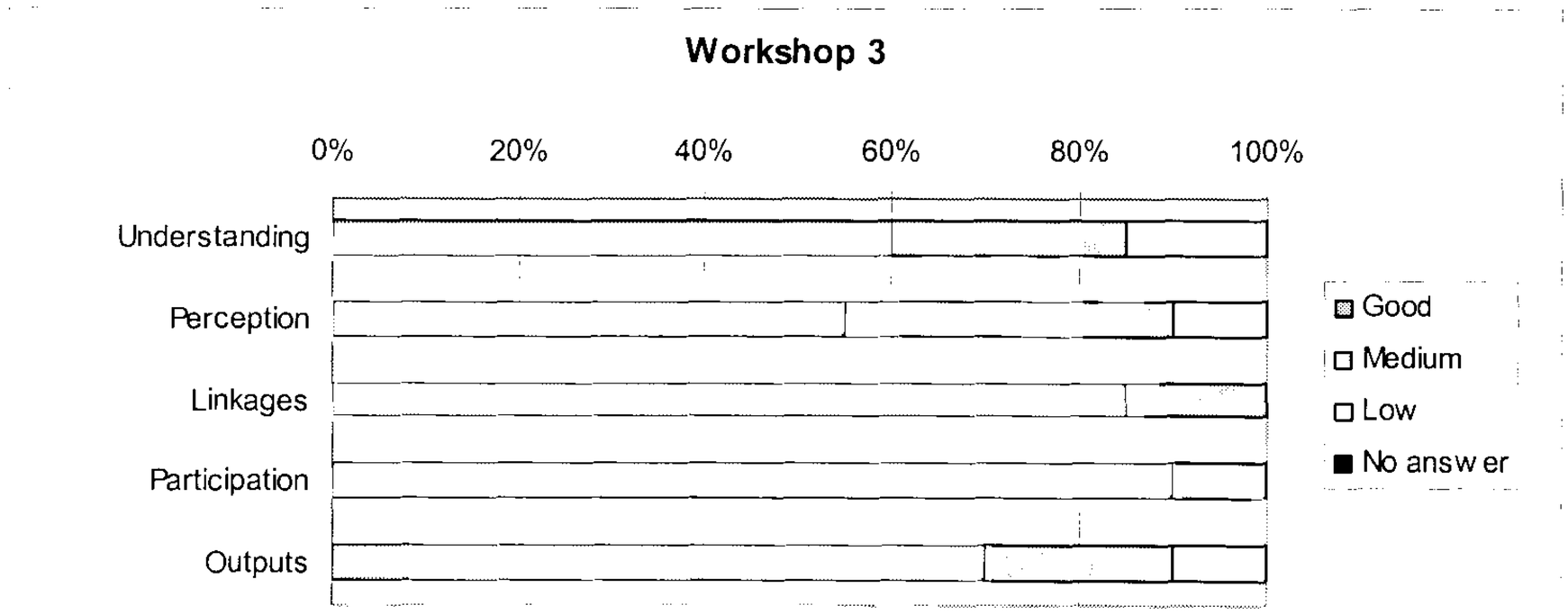
6. Workshop outputs

6.1 Do you think the workshop has provided enough outputs to continue the process?

6.2 Did we reach a consensus in providing the outputs?

6.3 Do you have any other comments?

Results



n = 20

Box A.6.4 Workshop 4 evaluation questionnaire and results (percentage of participant responses)

Workshop 4 Questionnaire

1. Management scenarios

1.1 Do you think the methodologies adopted for the impact assessment are adequate (time constrained)?

1.2 If not, which improvements or changes would you recommend?

2. Selection of most adequate scenarios

2.1 Do you think the criteria selected are appropriate, complete, etc?

2.2 If not, which other data would you recommend?

2.3 And what key knowledge gaps remain?

3. Preliminary recommendations

3.1 Do you think the workshop has provided adequate measures for the identified issues?

3.2 Do you think the measures can be implemented as suggested?

4. Representativity of sectors interests

4.1 Do you think the discussions and conclusions reflect the interests of all relevant sectors?

4.2 Did it stimulate linkages between sectors and institutions?

5. Participation

5.1 Do you feel your participation has been fully and equally integrated in the discussions (within the group, with all participants)

5.2 Do you have any comments?

6. Testing of impact assessment

6.1 Do you think the workshop has provided enough outputs to continue the process?

6.2 Did we reach a consensus in providing the outputs?

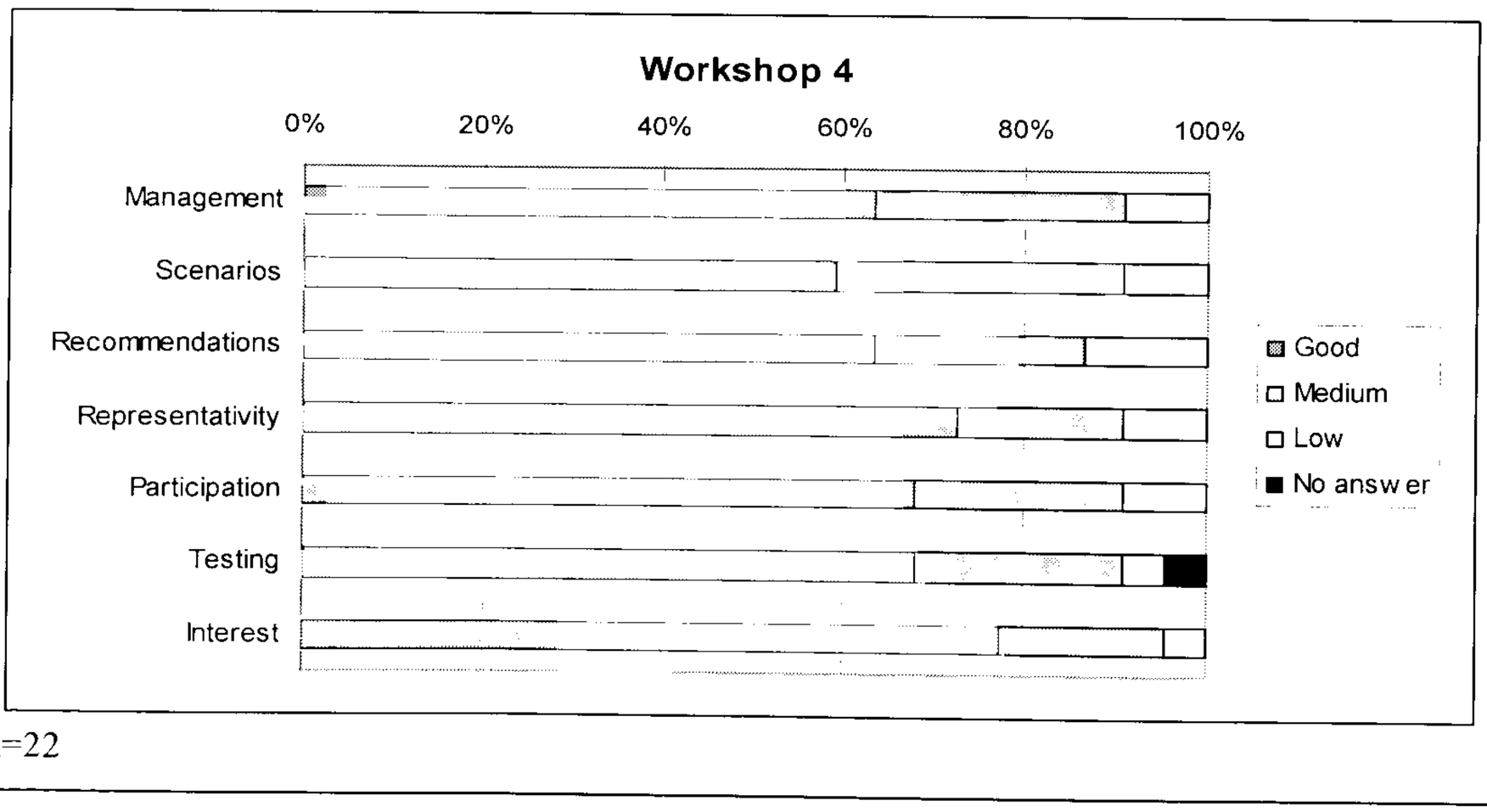
6.3 Do you have any other comments?

7. Interest in the study

7.1 What is your overall interest in the project?

7.2 What do you expect from the project: . For your work?
. For your institution (if applicable)?

Results



n=22

Box A.6.5 Final workshop evaluation questionnaire and results (percentage of participant responses)

Final Workshop (No.5) Questionnaire

Part I

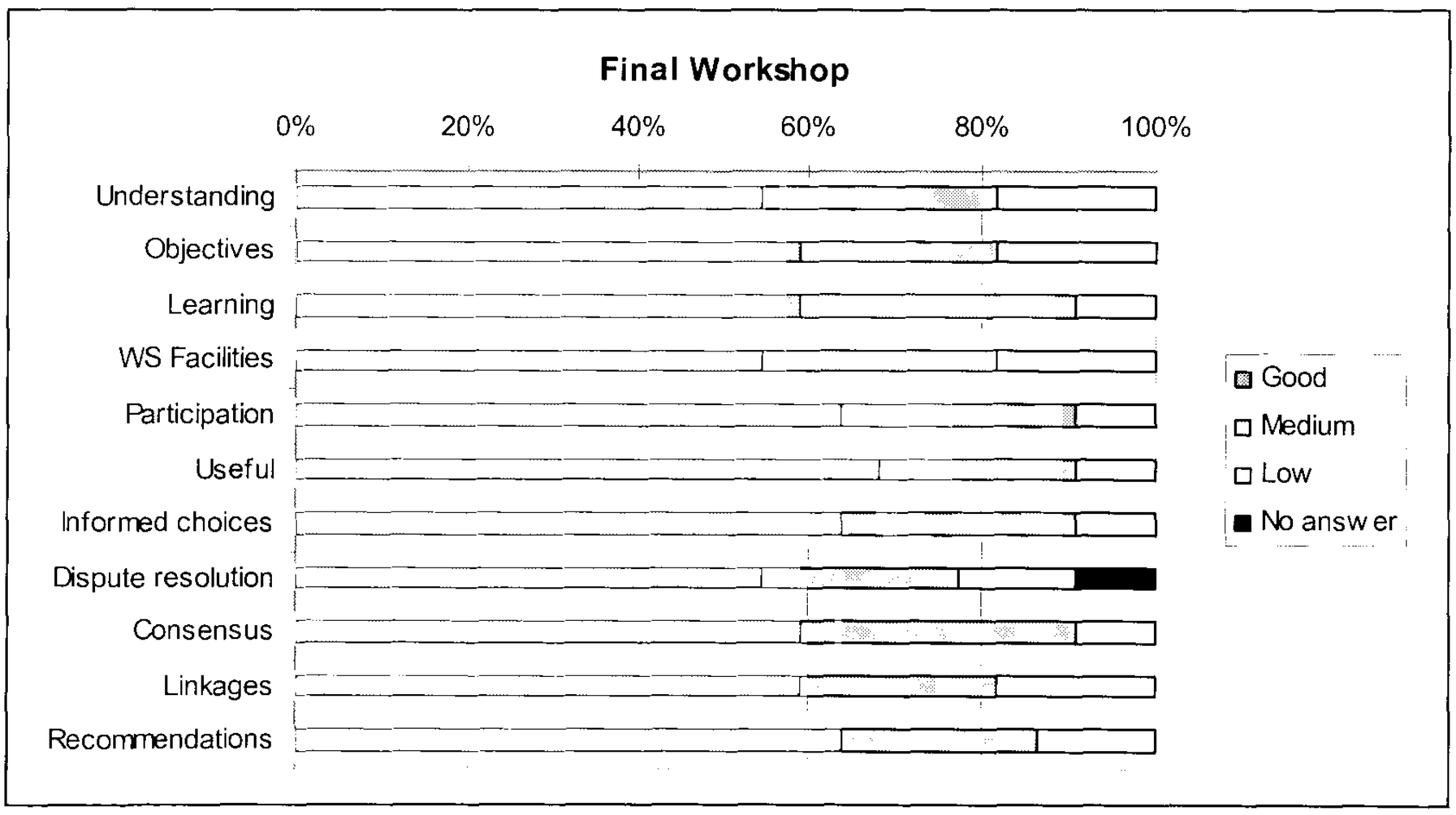
Please score the following questions from 1 (lowest level) to 5 (highest level)

1. Did you understand the objectives of the workshop?
2. Do you think the objectives of the workshop were met?
3. Do you think you have learnt from the workshop?
4. Were the facilities adequate?
5. Do you think you have reach adequate participation?
6. Do you think the workshops have been useful for you?

Part II

1. Has the workshop provided enough information and results to allow stakeholders making informed choices?
2. Did trade-off methodologies provide workable mechanisms for resolving disputes and for arriving at decisions?
3. Do you think we have reached a consensus in providing the recommendations?
4. Did the workshop promote the creation of linkages between sectors?
5. Do you think the recommendations are adequate for implementation?
6. Do you have any other comments?

Results



n=22

Chapter 7 - New Perspectives on the Impacts of Irrigation Development on Fisheries - Challenges for their Assessment

The assessments conducted in Laos and Sri Lanka shed new light on the nature and magnitude of impacts of irrigation on fisheries and on improved approaches for impact assessment. The discussion of results first focuses on the impacts of irrigation on the biophysical environment, fisheries production and livelihoods of rural households, and on their implications for the management of irrigation and decision-making. The benefits and limitations of the APIA approach are secondly discussed in order to highlight the remaining challenges and priority research areas for further improvements in the approach and its implementation.

7.1 Impacts of irrigation on inland fisheries production and the rural livelihoods: lessons and new perspectives

The three impact assessments in Laos and Sri Lanka revealed that the net impact (aggregated result) of irrigation development on fisheries production in an affected catchment is not necessarily negative and can range from negative to positive. This highlighted generic and specific key lessons, some of which run counter to conventional expectations that irrigation development will degrade the environment and thus fisheries. Such assumptions were the basis, for example, of the review of impacts on fisheries conducted by the World Commission of Dams (WCD 2000) within the context of the international debate on the impacts of large dams.

Impacts will depend on one or several of the following key factors: the initial biophysical context; the productivity of the newly created habitats especially reservoir and rice field, the role of fisheries in livelihoods, and the management and

accessibility of these aquatic habitats. The main lessons developed below offer new perspectives on the impacts of irrigation on fisheries.

7.1.1 Aquatic ecosystems modified by irrigation can support productive fisheries

Whilst irrigation development is usually regarded as negative to the development and sustainability of inland fisheries (see Chapter 2, Section 2.2), both case studies showed that catchments with predominantly agricultural land use supported high levels of fisheries production from man-made habitats prior to the assessed intervention. In the Laos and Sri Lanka cases irrigation development created new aquatic habitats without substantially affecting the extent or production capacity of the existing habitats supporting fisheries production: rain-fed rice fields in Laos and ancient reservoirs in Sri Lanka.

Impacts of irrigation on fisheries will thus depend on the baseline biophysical conditions in the project area, the changes in aquatic habitats (in terms of area, nature and function), and the net effect on the availability of aquatic habitats and their respective productivity. Prior to irrigation the key habitats supporting fisheries production in situations may be significantly different. In contrast to Sri Lanka where reservoir fisheries dominate, rice field and river-floodplain fisheries dominate the overall aquatic habitat and aquatic resource production in Laos. After irrigation some aquatic habitats will be lost (e.g. reduction of the downstream floodplain) but others will be created: mainly reservoirs in the case of dam storage irrigation, but also irrigation and drainage canals, some natural aquatic habitats that have become perennial, and eventually irrigated fields (in particular in the case of flooded rice fields).

Impacts do not only depend on the biophysical characteristics of aquatic habitats but also on the management of water and agriculture in the irrigated systems. Rice-farming systems constitute man-made wetlands and as such, they can also play an

important role in the production of fisheries. More broadly rice field landscapes have been recently recognized at the international level, as potentially rich and biodiverse ecosystems (e.g. Sutawan 2004) (see also Section 7.1.4). Appropriate farming practices and management of water in rice fields that preserve the production and biodiversity potential of rice fields can thus enhance the overall benefits of irrigation development.

The case of reservoirs is particular in that they can have the potential to support major fisheries production in the irrigation system area. Typically, reservoirs are characterized by a low residence time of water (less than one year in seasonal reservoirs, and 1 to 2 years in most others), and very pronounced fluctuations in water level and surface area in shallow reservoirs. That is why in some cases (especially for shallow reservoirs) this potential can be realized only if the needs of fisheries are considered in the management of water for irrigation (intensity and frequency of drawdown, released flow downstream and storage regime) (see below Section 7.1.3).

The aquatic habitats newly created by irrigation can entirely or partially compensate for the loss of aquatic habitat, particularly the reduction of the river-floodplain downstream, and the net effect on the extent of aquatic habitats can be positive. This suggests the importance of establishing a balance of changes in the distribution of the different aquatic habitats and fisheries potential in the catchment, in terms of area and productivity, within the year (at least between dry and wet seasons) and throughout the years. Average productivity for a range of aquatic habitats has been established (e.g. Lorenzen et al. 2004, and Chapter 2, Table 2.2) to support comparative analysis and cross-checks for the case study. In addition, tools such as GIS and remote sensing are useful for the mapping of the various environments and possible comparative analysis of biophysical characteristics with and without irrigation systems, or before and after irrigation.

In contrast, and although not discussed in detail here, impacts on the biodiversity of inland aquatic resources are likely to be negative on at least some components of

local aquatic biodiversity (see Chapter 2, Section 2.2.1.4), since the characteristics and connectivity of natural habitats are modified by the development of irrigated agriculture and its infrastructure (see Chapter 2, Section 2.2.1.3). However impact of irrigation appeared to be less negative than expected in both Laos and Sri Lanka because they applied to ecosystems already impacted by human activity and by the economic development of the area. In this situation, the resilience of the ecosystem to impacts of development should be further addressed, as well as the particular linkages between the objectives of ecosystem conservation and the objectives of fisheries production for improved rural livelihoods (see Section 7.1.3).

In conclusion, although irrigation systems may have negative effects on biodiversity, the production and exploitation of fisheries will not necessarily decrease, in particular in rice farming systems with dam storage irrigation. This result strongly supports the need to manage fisheries in aquatic ecosystems even though they have been modified by human development (e.g. Dudgeon 2000 and Section 7.1.3). Rather than focusing only on compensation measures such as aquaculture development, the effective management of irrigation impacts on fisheries has the potential to maintain or enhance fisheries production.

7.1.2 Inland fisheries can be significant for rural livelihoods even in irrigated systems

All three impact assessments showed that the biophysical characteristics (as shown in Section 7.1.1) are not the only determinants of impacts on fisheries. The exploitation of aquatic resources (changes in efficiency of fishing and/or accessibility to the fishing grounds), the role played by fisheries in the local economy, and trends in livelihood strategies adopted in the project area can be as important as determinants of impacts, if not more so in some cases.

A dominant assumption in prior perspectives on fisheries livelihoods in irrigated systems is that fishing is essentially an activity of last resort which can readily be 'replaced' by irrigated agriculture. However assessment results in Laos and Sri Lanka showed that fishing was not restricted to an activity of last resort and it can remain an important activity even in irrigated systems. In Laos the majority of rural households fished as part of a traditional and diversified livelihood strategy that also involved farming, collection of a range of non-timber forest products and occasional wage labour. River-floodplain systems and rice fields provided important fishing space, and these were very accessible for women.

In Sri Lanka, fishing had been either a specialized occupation or a means of diversification for farming households, but with increasing population pressure, unemployment and the degradation of the fisheries, it had become largely a residual activity for some of the poorest and most vulnerable households in the project area. In most small to medium-scale reservoirs and lagoons, specialized fishers had been impoverished by the decline in productivity. Under the prevailing conditions (a drought, a stagnant regional economy and high unemployment) productive fisheries could have been extremely valuable in contributing to the revitalization of the region. In the longer term their role as a residual activity could also remain valuable for any households unable or slow to benefit from anticipated improvements in irrigated agriculture and growth in the wider local economy.

These results confirm the diversity of livelihood roles played by fisheries as indicated by Allison and Ellis (2001), Jul Larsen and Van Zwieten (2002), and Béné (2003). More specifically in relation to irrigated systems, Smith et al. (2005) found that the range of livelihood functions performed by fisheries can vary from an activity of last resort, through being one element in a diversified livelihood strategy to a specialized and remunerative occupation. Where impacts of irrigation systems on fisheries production are positive (e.g. around the reservoir), fishing can become a lucrative activity and enhance the livelihoods of different socio-economic groups through both part-time and full-time fisheries (commercialized activity). That is why the usual

expectation that the development of irrigation will degrade the productive potential of fisheries (see also Section 7.1.1 for biophysical arguments) and further marginalise fishing as an economic activity inadequately represents the potential complexity of interactions between irrigation development, fisheries and rural livelihood opportunities (Smith et al. 2005).

In the longer-term results also showed that fishing tends to decline in relative social and economic importance both at the household level (generally less fishing in better-off households) and at the larger scale where the rural subsistence economy undergoes an increasingly rapid transition to a more commercialized and market-oriented production system. Compared to rainfed farming the demand for labour in irrigated cultivation will usually be higher, less variable and for a longer period of time in the year. More intensive use of inputs, higher levels of output and higher farm incomes can also stimulate growth and employment in the rural non-farm economy. Irrigation may thus lead to a progressive shift to more reliance on agriculture and new economic opportunities outside the agricultural sector.

On one hand these effects can draw labour away from fishing, or compensate for reduced productivity of, or access to, a fishery. In comparison to rain-fed farming, the demand for labour in irrigated agriculture will usually be higher, less variable, and for a greater proportion of the year. On the other hand the relatively non-seasonal nature of the newly created reservoir fishery and the opportunities they provide for economies of scale (fishing with many nets and motorized fishing crafts) may lead to the emergence of full-time professional fishers. In addition poor households without access to the benefits of irrigation, and perhaps economically and socially marginalized by its development, may be driven to rely more heavily on fishing (and/or other open access natural resources) as one element of a usually diversified survival strategy.

In terms of trajectories of change in rural livelihoods, fisheries will thus continue for the foreseeable future to provide an important means of support for land deficit and

labour surplus rural households, while having the potential for more commercialised development. Outcomes will also depend on a wide range of regional and local social and economic factors. The dynamic pattern of the socio-economic environment, especially when implementing an irrigation project, should be included in the prediction or evaluation of impacts and for example, poor households may progressively improve their livelihood status and become less dependent on fisheries.

In conclusion, consideration of fisheries and their productive and employment potential is important because they can perform a range of significant roles in irrigated systems. They may be particularly well suited to meeting the needs of some of the poorest and most vulnerable groups either neglected by, or adversely impacted by irrigation, because of their relatively low barriers to entry as a livelihood activity. However it is also important to go beyond stereotypes of fisheries as the last resort of the poorest and most marginalized. This implies looking at the range of contributions fisheries can make in the diverse livelihood strategies commonly found in rural areas of developing countries. In general the question whether a shift to more irrigated agriculture leads to less vulnerability and improved livelihood resilience should also be addressed.

It is notable that the review of EIA and irrigation planning guidelines (Chapter 4, Section 4.1.1) revealed a lack of coverage of such issues. The findings of this research can thus directly contribute to the improvement of such guidelines through further integration of a more holistic and comprehensive perspective on the nature and importance of fisheries, and the complexity of impact mechanisms.

7.1.3 The management of irrigation may impact fisheries more severely than the irrigation infrastructure *per se*

All three assessments demonstrated that because productive fisheries can continue to co-exist in a variety of habitats in irrigated systems, impacts on fisheries arising from

operational aspects of the system may be at least as important, if not more so, than impacts arising from the infrastructure itself (see Section 7.1.2). That is why in both Laos and Sri Lanka, key mitigation measures referred to an improved management of water; irrigation and irrigated agriculture (see Section 7.2).

In Laos, most of the fisheries production comes from the river-floodplain and the rice fields. Even in irrigated systems, paddy rice is cultivated in the traditional rainfed way through storing water in the fields for extended periods. This practice maintains a sufficient ecological connectivity with perennial habitats to allow colonization by fish. In that case the management of rice field water levels and other agricultural practices do not adversely affect the aquatic resources. However development of irrigation and improved availability of water may lead to the future intensification of rice production with a concomitant reduction in water storage in the fields and a drastic reduction of temporary wetland area suitable as fish habitat. This modification in the wet season farming practices is likely to have a far more dramatic impact on fisheries production than the irrigation infrastructure *per se* and the development of dry season irrigation as assessed in this thesis (Chapters 3 and 5). This key point has tended to be neglected in studies of fisheries in rice-based irrigated systems as recently acknowledged internationally, for example, by the International Network for Water and Ecosystem in Paddy Fields (INWEPF).

In Sri Lanka, reservoir fisheries and lagoon fisheries dominate (prior to irrigation in the case of the KOISP) but they have been affected by the management of irrigation water. Extreme drawdown in small and medium-scale reservoirs have dramatically reduced their fisheries production. Since these reservoirs can be very productive under conditions of moderate drawdown (De Silva 1988, Amarasinghe 2002, and see Section 7.1.3), management regimes taking account the needs of fisheries have the potential to drastically increase the productivity of these reservoirs. In the lagoons the management of both drainage flows and the sandbar are required for the reestablishment of the shrimp fishery. Therefore conventional mitigation measures for

river storage and diversion structures will have little or no effect on the main fisheries occurring in the project area, i.e. reservoir and lagoon fisheries.

In conclusion, in both Laos and Sri Lanka most of the fisheries production comes from habitats that are not uniquely depending on the river flow and on the longitudinal migration of fish. While the focus of irrigation impact mitigation used to be the engineering aspects of the scheme and the restoration of river flow (e.g. environmental flows; see Chapter 2, Section 2.3.1), reservoir and agriculture management may impact fisheries more strongly. In rainfed rice farming landscapes the greatest threat to the fisheries productivity is a reduction in rice field water storage during the wet season. At the international level the increased awareness of the role of rice fields as potentially rich and biodiverse ecosystems (see also Section 7.1.1) supports the preservation of farming practices that are acceptable for the environment and natural fisheries.

7.1.4 Fisheries production and livelihood objectives do not always match biodiversity conservation objectives

Although holistic, the production and livelihood orientation of the process adopted in this research also helped screening out other issues and ensuring the relevance of the assessment and its outcomes to resource users and managers. For example, in neither of the case studies reported here does the impacted river contribute significantly to overall fisheries production. Hence in these cases, instream flow studies (such as IFIM, e.g. Bovee 1998, and environmental flows, e.g. Tharme 2003) or the design of facilities for fish passage across the dam (e.g. Bernaceck 2000, Larinier 2000) are of low priority from a fisheries production or livelihood perspective, even though they may be desirable from a biodiversity conservation point of view. Despite this, all assessments ensured that biodiversity was not critically affected (as would be the case for example in a situation of high endemism, extinction of species, or risk of

resilience loss), first in the scoping phase of the test cases and later through cross-checking throughout the impact assessment (Chapters 5 and 6).

Fisheries production and livelihoods impacts are often seen as co-terminous and are even sometimes treated as synonymous with biodiversity impacts. Indeed the two can be closely linked, but as the Laos and Sri Lanka assessments show this is not necessarily the case. In both cases, irrigation development was deemed to increase overall fisheries production and related livelihood opportunities for the local population. In terms of ecological integrity, the systems were heavily modified at the outset and were subjected to further modifications by the irrigation projects. In both cases the river that represented the dominant aquatic habitat prior to human interference, accounted for only a small proportion of aquatic habitat and fisheries production in the catchment. That is why conserving or restoring the river was not a priority of local stakeholders, and this was unlikely to yield significant developmental benefits.

From a biodiversity conservation point of view however, the river represents the original aquatic habitat in the catchment. In some cases, the restoration of near natural flow patterns and lateral connectivity may be the most important measure to conserve the remnants of the system's original aquatic biodiversity (Arthington et al. 2004, Tharme 2003, King et al. 1999). This shows that fisheries impacts should be approached from different perspectives (fisheries production, rural livelihoods, ecosystem conservation), and that these may call for very different measures that could be funded from different sources. For example, river restoration may be a good investment for the livelihoods of poor groups in some cases (supplementing food and income security), and entirely irrelevant in others (when river resources are not used for livelihood support and survival). Thus outcomes and management responses may differ depending on the balance of national and local values and priorities, and the objectives assigned to both projects and impact assessments.

7.1.5 The importance of a disaggregated assessment of impacts

With respect to the methodological approach, the discussions in Sections 7.1.1 to 7.1.3 suggest that assessments should identify and evaluate (or predict) impacts at project level, as well as the distribution of impacts by location in the project area (e.g. upstream and downstream of the reservoir) and by socio-economic group or category. For example where specific aquatic habitats (e.g. the river-floodplain) play an important role in rural livelihoods and are degraded by irrigation development, attention should be paid to the impacts on livelihoods, particularly for poor and vulnerable households, even when compensation is provided in aggregate by creation of a reservoir fishery.

As demonstrated above, aggregate impacts are not always as negative as expected, and all three impact assessments resulted in net impacts that were positive or only slightly negative in the worst case scenarios. However these aggregated results can also hide undesirable local ecological or socio-economic impacts and in all assessments, the disaggregation of results per location within the catchment, and per socio-economic group of households revealed a variety of impacts in terms of their nature, magnitude and distribution. The main reasons have been identified below.

The compensation by the reservoir for any degradation of overall fisheries production downstream may only be partial, and access to it may be limited to households concentrated in the immediate area. Contrasting the two test cases, spatial differentiation was not significantly important in Laos, but crucial in the distribution of production and livelihood impacts in Sri Lanka. Hence the distribution of impacts may not be equitable and any assessment, particularly in large-scale systems, must look beyond production changes in aggregate and encompass physical, temporal and institutional determinants of the productivity and accessibility of fisheries for all affected groups.

The disaggregation of impacts spatially (e.g. above and downstream of a dam), and between different types of aquatic habitat (e.g. river-floodplain, rice fields, reservoirs, lagoons) will almost always reveal impacts that are differentiated over the catchment in terms of severity and importance (Jackson & Marmulla 2001, WCD 2000, Petr 2003). Similarly, the differentiation of impacts across socio-economic household categories or social groups is likely to reveal diversity and complexity in the range of economic and social changes resulting from irrigation development. These can be of importance to the livelihood activities and opportunities of rural people, as developed above (Section 7.1.2).

In conclusion, positive aggregate results at catchment level should not prevent the disaggregation of impacts to inform at least on the spatial and socio-economic distribution and differentiation of impacts. A critical issue in the impacts of irrigation on fisheries lies in the balance between positive and negative effects and at the same time, in the distribution of its costs and benefits. Implications for the management of impacts of irrigation development are developed below (Section 7.2.1).

7.2 Implications in the management and decision-making of irrigation development

The importance of fisheries in irrigated systems (Sections 7.1.1 and 7.1.2), and the likely impacts of irrigation management on fisheries (Section 7.1.3) suggest that the management of both irrigation and fisheries is critical to improving the overall benefits achievable from development of irrigation (social, economic, and environmental). However preserving or enhancing the benefits of fisheries may impose significant constraints on the management of irrigated agriculture. The respective tradeoffs between irrigation and fisheries thus need to be assessed and management options should be selected in the light of policy priorities for the development of the area.

7.2.1 Management measures

The impact assessment results and especially their disaggregation showed that management options cannot be similarly applied everywhere (throughout the project area) and to everyone (across the different socio-economic categories). In cases such as Laos, where fishing remains an important part of the livelihood strategy of most rural people, avoiding or mitigating any negative impacts on fisheries should be the primary objective. That fishing is likely to remain a significant livelihood activity in the irrigated system and that it may not be fully compensated by the newly created reservoir fishery reinforce the need to consider fisheries in the future management of the Huay Thouat irrigation scheme. More generally, changes in farming practices and increased water resource extraction are the main threat to the preservation of fisheries.

In cases such as Sri Lanka, where fishing performs a range of livelihood functions from a 'safety net' to a diversified income generating activity, the management of irrigation schemes and other water resource developments with regard to fisheries has the potential to generate socio-economic benefits. This requires protecting and sustaining existing fisheries in ancient reservoirs and lagoons, or developing new fisheries in created or modified habitats. In the lagoons, the management of drainage inflows and sandbar breaching needs to reestablish the initial ecological balance. This should be accompanied by the management of fisheries, in particular the control of fishing effort, to ensure their sustainability. Although knowledge of adequate management measures is lacking (see priority research needs, Section 7.4.4), the assessment results highlighted the potential of such measures for restoration of the lagoon fishery and reestablishment of a specialized and relatively high income generating activity.

The assessment results also showed that high levels of reservoir drawdown are likely to provoke a rapid decrease of reservoir fish populations, mainly due to the increasing efficiency of fishing attracting a greater fishing effort on the resource. As a result, unrestricted fishing during periods of low water level can lead to the complete

depletion of fish stocks. Again, this shows that both management of irrigation and management of fisheries are required. Irrigation management should limit the intensity of drawdown and maintain a minimum level of water in the reservoir, while management measures for fishery access and allowable catches during periods of low water level should be enforced.

These conditions will also create opportunities and incentives for other fishery enhancement measures such as stocking and creation of nursery habitats, which could further increase reservoir fish production. Here the aim can be to develop commercial fisheries that provide employment and incomes to landless or marginal farming households, either as a full-time or as a part-time activity. The emergence of full-time professional fishers can be facilitated through development projects to improve capture and post-harvest technologies, marketing, and the development of fishers organizations.

Although not critical for the KOISP the management of reservoir levels also has important implications for fisheries production downstream and trade-offs between reservoir fisheries and river floodplain fisheries may occur and require evaluation of social, economic and environmental costs and benefits (see below, Section 7.2.2).

7.2.2 Trade-offs between fisheries and irrigated agriculture

The identification of the main interactions between the biophysical and social systems in Laos and Sri Lanka has provided a new and broader perspective to the management of both irrigation and fisheries. In particular, integration of land and water management within irrigated systems can be crucial to sustaining or enhancing fisheries. This interdependence is clearly reflected in the likely effects of potential changes in rice cultivation practices in Laos, and the problems arising from failures to take account of the needs of fisheries in irrigation planning, water allocation from reservoirs and management of the coastal lagoons in Sri Lanka.

The case in Sri Lanka highlighted that effective future management of created, restored or protected natural fisheries is equally as important as mitigating irrigation scheme impacts. In addition the measures had to be well integrated on a spatial and temporal basis with the management of irrigation water allocation regimes e.g. the timing and seasonality of water needs in the reservoir, and the timing of the sandbar breaching in relation to drainage inflows in the lagoons.

All situations confirmed that the management of irrigation impacts on fisheries needs to be multi-sectoral, taking account of multiple and competing water uses within a river basin and involving processes that can recognize and resolve trade-offs between competing interest groups in the management of irrigation. Sustaining or enhancing fisheries production in irrigated agricultural landscapes requires both conducive irrigation water management and farming practices, and not only the mitigation of irrigation scheme impacts. Where fisheries interests are taken into account in the design, operation and management of irrigation projects, overall irrigation performance in terms of rural livelihood improvements can be substantially increased.

Where reservoir fisheries are significant, tradeoffs between releases for irrigation and downstream environmental and fisheries purposes, and the maintenance of reservoir fisheries production should be evaluated carefully. Where floodplain fisheries have declined substantially and reservoir fisheries are the primary aquatic resource use, fisheries production considerations may favor retention of water in the reservoir over flow releases. Biodiversity considerations on the other hand are likely to attach greater importance to flow releases. This reveals another case of possible divergence between conservation and livelihood objectives (see also Section 7.1.4).

The evaluation and management of such trade-offs calls for the development of existing analytical tools. They would aim at optimising the aggregate economic value of crops and fish production from the system, or the livelihood and social benefits (e.g. employment creation), while preserving the environment in terms of ecosystem goods and services. Ultimately the management of irrigation should seek optimum

allocation of water for multiple users, including domestic and industrial use, and livestock (e.g. Bakker et al. 1999). This insight is very topical, for example, becoming an important part of the agenda of international conferences of debates on the integrated assessment of use of water for food and the environment (e.g. the conference on "Integrated Management of Water and Fish in Developing Countries", Manila, Philippines, Sept. 2004; and conference on the "Water for Food and the Environment: Make it Happen!", The Hague, The Netherlands, Feb. 2005).

In terms of assessment frameworks, the concept of Integrated Water Resource Management (IWRM) promotes evaluation of multiple and competing water uses within a river basin. By showing that irrigation projects can offer opportunities to increase the production of fisheries, and by proposing management measures that may improve the overall benefits of irrigation, this research has supported the need for assessment of water and aquatic resources in a context of multiple users. Results here refer to the catchment level but could also inform assessments conducted at river basin level (see Section 7.4.4.2).

7.2.3 Policy priorities

As discussed above, fisheries can add value to the use of water in agriculture under favourable conditions, be it in reservoirs (Sri Lanka) or in other aquatic habitats such as the river-floodplain (Laos). This should be given due weight in decision and policy-making on water allocation, particularly in situations of water scarcity. However such trade-offs and decision-making will also depend on the priorities given to the development of the area in which the irrigation scheme is located. Since irrigated agriculture is often assigned a key role in driving the economic and social development of areas suited for it, management of irrigation projects must at least ensure that negatively affected groups are not made significantly worse off without adequate mechanisms for compensation and the mitigation of impoverishment. In this case planners and policy makers should also ensure that a too strong disparity in the

distribution of benefits and costs does not create or exacerbate conflicts (see Section 7.3.4 and Nguyen-Khoa & Smith 2003).

If the aim is to increase the benefits of fisheries in view to improving the overall performance of the irrigation project, an initial and central question emerges: i.e. what role should fisheries play in the social and economic development of an area? The answer must take account of: i) the state of the rural economy and potential of alternative sectors (for example, tourism and garments in Sri Lanka) to provide alternative livelihoods, and ii) increasing water scarcity and competition between alternative water uses, including fisheries and environmental conservation. In this case, planners and policy-makers would need to recognize both the potential productivity of aquatic habitats in irrigated systems (Section 7.1.1) and the diversity of roles possibly played by fisheries in rural livelihoods (Section 7.1.2).

7.3 Strengths of the APIA approach

Evaluation of the approach used in Laos and Sri Lanka has demonstrated particular strengths in broadening the scope of an impact assessment, exploiting local knowledge and reducing potential conflicts through an open and flexible approach. Assessment results also proved relevant and useful to the management of impacts and to decision making. These issues are considered further below.

7.3.1 Broader scope and coverage of assessment

Not surprisingly in both Laos and Sri Lanka, the concerns of community stakeholders were directly related to their livelihoods and the management of natural resources. Fisher groups emphasised the production changes they have (or had) perceived, their appreciation of the causes of these changes and the associated or potential conflicts with other water users. Government officers had a broader sense of national and

regional priorities for economic and social development and environmental conservation, but their perceptions of the range of important issues were sometimes restricted to their relatively narrow disciplinary training and sectorally based experience.

The research team raised concerns about the integrity of the overall ecosystem, the links between fish ecology and fisheries production, and the wider trends in livelihood opportunities and the rural economy. Initially scientists were not fully aware of the importance of the lagoons and reservoir issues, and resulting conflicts. The case in Sri Lanka was a significant example where divergence of perceptions of key issues between stakeholders and scientists was revealed. As a result, the issue of floodplain reduction would not have been raised without the intervention of scientists, and probably less weight would have been given to the ancient reservoir and lagoon issues without the intervention of stakeholders. In both case studies, priorities from participants were clearly expressed and all important issues (in a reasonable number for the scope of the study: 3 in Laos and 5 in Sri Lanka) related to the impacts of irrigation on fisheries were considered.

Inclusion of stakeholders, scientific perceptions and preliminary results thus tends to broaden the scope of the assessment. As a result impact assessments covered a wider range of issues than would often be the case for an environmental impact assessment primarily centered on ecological change in the river (Welcomme & Petr 2004, and Chapter 4, Section 4.2.1). Simultaneously the screening and scoping stages achieved the rapid identification of key issues, working estimates of the magnitude of observable (or likely) impacts, and definition of priorities for mitigation or enhancement, in order to keep the focus on feasible assessment and management outputs. However in some cases, this may be difficult to achieve for example where too many important (or perceived so) issues are raised and consensus on key ones cannot be reached.

7.3.2 Increased use of available knowledge

While the scope of the assessment was broadened, this initiated a search for research evidence and empirical data for the range of issues raised. However secondary data and information on fisheries production and livelihoods were strongly lacking in both countries. Given the seasonality of fisheries and their dispersed and inconspicuous nature, and the general lack of data for inland fisheries (Coates 2001), it is often impractical to estimate production levels during short project impact assessments. This constraint is often reported in EIAs and SIAs (e.g. Sadler et al. 2000, Hirsch 2001).

The composite nature of the assessment places emphasis on the use of diverse sources of knowledge through the combination of technical expertise and local knowledge, including indigenous knowledge. Throughout the impact assessment, the approach sought access to comprehensive and up to date knowledge of existing methods in each relevant discipline, plus the ability to select appropriate tools in relation to the issues raised and given available resources. Where location specific data were lacking, comparative empirical data on fisheries production estimated for the different habitat types and geographical areas were used. Simple and transparent tools such as mapping of habitats and budgeting of fisheries production on the basis of comparative yield information provided quantified estimates of the value of fisheries and these were made transparent and accessible to stakeholders.

Comprehensiveness in the search of data and information, accurate selection of relevant sources of knowledge and combination of these in the assessment exercise can thus help provide the impact assessment outputs in a context of lack of data and information.

7.3.3 Open-ended and flexible process (no 'blueprint' approach)

In Laos and Sri Lanka, the flexible nature of the approach was demonstrated at different stages of the impact assessment process, for example: in defining the issues and scope of the study (Chapters 5 and 6, Sections 5.3.1 and 6.3.1), in providing entry points for introducing a variety of methods and tools (Chapters 5 and 6, Sections 5.3.2 and 6.3.2), in managing unexpected outcomes (emergence of tension or conflict, Chapter 6, Section 6.3.6; or lack of understanding of results by participants, Chapters 5 and 6, Sections 5.4.3 and 6.4.3).

This flexibility also helped deal with the uncertainty inherent in the prediction or evaluation of complex and variable phenomena, particularly for practical applications where an experimental model of investigation cannot be readily applied. In the case studies, appropriate use of techniques such as sensitivity analysis (as applied to the fisheries balance, Chapters 5 and 6) was useful in making explicit the outcomes of different assumptions where uncertainty did not allow identification of appropriate values. Adopting the precautionary principle (FAO 1996) and aiming to remain within identified thresholds for ecosystem integrity or social change may also be applicable, in particular where definitive evidence of an impact and its causality is lacking.

However the case studies showed that overall, it was important to acknowledge where uncertainty existed and to respond with an iterative and adaptive approach well informed by continuous monitoring and evaluation. Iteration could then allow a phase to be prolonged and analysis repeated or refined as necessary to overcome a constraint, fill a knowledge gap and achieve improved and widely supported outcomes. The additional benefit was the possibility to come back to the specific step where there is a need for improvement. For these reasons, the approach has been an exploratory and transparent process subject to constructive criticism and learning.

In conclusion the approach provides a structured framework rather than a prescriptive process, leaving scope for incorporation of appropriate tools and methods as necessary, and for responding to uncertainty and unexpected outcomes. In turn the constraints and limitations of the flexible and open-ended nature of the approach are described in Section 7.4.2.

7.3.4 Potential for conflict reduction or resolution

While seeking to benefit from the interaction of a wide range of stakeholders with different views, perspectives and interests, the approach acknowledges the potential for creating or exacerbating conflicts. Perceptions of the relative importance and value of impacts varied largely among different stakeholder groups and sectors. There can also be socio-cultural barriers to participation by, or negotiation between, stakeholder groups.

In Sri Lanka tensions emerged when bringing to the fore issues that had lain dormant or hidden because of a lack of means for their expression. Typically this occurred when the approach gave a "voice" to the fishers groups, noting that they were both more vulnerable and less influential than the farmers. A notable example was a farmer representative expressing firmly and loudly farmers concerns for the reservoir issue, in these terms: "we, farmers, do not have enough water to irrigate our own fields then why should we leave some to fishers?" This initially strong and resistant expression of farming interests became progressively more amenable to the potential benefits demonstrated by the study by showing: i) the benefits of improved management of water leading to reduced loss of farming area (less than perceived), ii) the importance of the timing of water needs rather than only the water volume, and iii) the benefits of reducing conflicts between fishers and farmers. At the end of the workshop the farmers' group recognized the benefits of improving their understanding of the reservoir issue through interaction of the various interest groups.

The approach thus initiated a negotiation process that had the potential to resolve or at least reduce conflicts between farmers and fishers interests. It successfully brought stakeholder groups together and established a common understanding of the key impacts and their causes in the project area. While recognizing the difficulty of managing these tensions, the approach valued these in ensuring comprehensive coverage of all relevant issues and concerns. The focus on areas of overlapping interests and of broad support among stakeholders also helped reaching convergence on the study scope and outputs such as management recommendations. In both Laos and Sri Lanka, the approach established a consensus at least at local level, on the need to include fisheries considerations in water use planning, and on a range of possible mitigation and enhancement measures. This facilitated the definition of management options and enhanced local "ownership" of, or commitment to, measures ultimately agreed for implementation.

However evaluation of the quality and sustainability of the consensus established by the approach may reveal that further conflict resolution approaches are required, in particular when implementing the selected management measures. In case of a persistent or recurrent disagreement, or where consensus cannot be readily reached through a predominantly technical analysis, additional approaches for conflict resolution should be introduced (e.g. Bruckmeier 2005). These can be used within the flexible framework of the approach and indeed are more likely to be most successful as complementary rather than independent measures.

In conclusion participatory impact assessments are likely to be biased if the representation and influence of competing groups is unbalanced, and there is risk that conflicts that are difficult to resolve can receive undue emphasis. Expression of conflicts was seen as an opportunity for creative thinking and common understanding of the different views and interests in place. By increasing information, maintenance of a regular flow of analysis and information to and between stakeholders, creating awareness and building a common ground of understanding, the approach attempts to reach a consensus. Information, skilled workshop facilitation and appropriate

communication strategies will thus be key in turning these tensions into positive outcomes. This should promote further work to strengthen this consensus and establish it at all institutional levels.

7.3.5 Relevance and utility to the management and decision-making

The results of the assessments made provided a base for improved management of irrigation and decision-making by providing the following insights on the impacts of irrigation on fisheries: i) that irrigated systems can support fisheries that are productive and important to rural livelihoods; ii) that the management of irrigation and agriculture is crucial to the preservation of fisheries in rice-based farming systems. In addition the approach directly led the impact assessment towards identification of options for improved management. This was through a transparent and participatory process involving fishers and farmers, oriented towards solving problems raised by stakeholders and scientists. This was outcome oriented and ultimately should increase ownership of the management recommendations produced.

The assessments results also supported the identification of adequate mitigation and enhancement measures and evaluation of their feasibility. The potential for improved management of irrigation and fisheries was highlighted and this drove the focus on the management of farming practices (Laos) and the management of irrigation water in reservoirs and drainage flows in the lagoons (Sri Lanka). The assessment also prevented counter examples of poor practice, through objective and transparent comparison with data available internationally. A typical example has been given in Laos where the potential of reservoir fisheries production was highly overestimated in the planning of the project, probably to reinforce the estimated economic viability of the Huay Thouat scheme (see Chapter 5, Section 5.2.5).

Lastly key trade-offs (see Section 7.2.2) were identified, and these guided prioritization and the selection of adequate management measures and policy options.

Assessment results revealed the need for an intersectoral and intrasectoral policy mix, and highlighted the opportunity for an integrated management of fisheries and irrigated agriculture. This showed the potential of the approach to encompass such complexity and generate policy relevant outcomes.

7.4 Limitations of the APIA approach and identification of future challenges

Along with the benefits developed above, the approach presented several limitations that raised challenges for further improvements of the approach (design and implementation) and its outcomes. The following limitations will thus have to be regularly evaluated and balanced with the benefits gained from the approach.

7.4.1 Increased complexity and uncertainty in the impact assessment

Compared to a narrow technical assessment, the holistic and participatory nature of the approach substantially complicates the technical analysis and thus increases the overall difficulty of the process of assessment and its management. Although the adaptive approach has been designed in response to this increased complexity and uncertainty, the task may be too ambitious to effectively respond to all of these. The main issues have been identified as follows.

Introduction of local knowledge and value judgment in the impact assessment

The impact assessment process carries some degree of contingency in so far as the outcomes of the assessments may directly depend on how the problems were framed and on the assumptions agreed by all parties. Although implementation is structured throughout the process, outcomes may also vary depending on how interactions between stakeholders evolve and on the way in which implementation of the approach is facilitated. As a result the outcomes of the process may not be precisely

reproducible, and inevitably retain an element of subjectivity to the extent that they are contingent on the values and rationality of the stakeholder participants.

In Laos and Sri Lanka, the evaluation process gave a significant role to the participants of the workshops in validating the results at each stage of the assessment process, and for a wide range of activities, from the identification of stakeholders to the assessment results and management recommendations. This inevitably raised questions on their ability to legitimate the process while being part of it. This question also applied to the features of the participatory approach itself, such as the selection of stakeholders and their representativeness during the workshops. The evaluation of participation showed that the presence or absence of participants was difficult to predict, particularly for representatives of national level agencies for whom last minute changes in priorities could occur. This increased uncertainty of the impact assessment process left room to underlying power influences and political issues (Mayoux 2001; Hirsch 2001, 2004).

Maintaining the required level of scientific rigor

The introduction of local knowledge, stakeholder perceptions and value judgments in the impact assessment process inevitably raises the question of the likely decrease of scientific rigor. While aiming for the highest possible degree of scientific rationality, the approach is implemented from within an existing social and political setting, and it is thus subject to the risks and constraints arising from sensitivities between groups, new or existing conflicts (see Section 7.3.4), and irrational reactions or interpretations.

In both studies, reductionist analyses have provided the background knowledge for the impact assessment and the approach has produced results (e.g. the empirical relationship for reservoir water level and the livelihood analysis in Laos and Sri Lanka) that are technically valid and of value to the scientific community. In some cases technical methods can resolve situations where perceptions or information differs, as shown in the discussion on the shrimp value assumptions for the fisheries

balance. A range of values was thus considered and reflected in the building of scenarios and interpretation of results.

The argument for an integrated and participatory approach can also be demonstrated by default, as shown by the cases in Sri Lanka. These revealed that a failure to integrate local concerns can be misleading and may give a false impression of scientific rigor and accuracy, e.g. seeking technical and sometimes expensive options for fisheries (such as fish farming or stock enhancement) not taking into account the possibility for the medium-scale reservoirs to face excessive drawdown by irrigated farming and possibly to dry up. Ultimately, unresolved conflicts may reduce the relevance and feasibility of reductionist and technical outcomes leading to a decreased applicability or adequacy of the respective measures.

The approach provides structured means such as the evaluation process in order to check whether the participatory and integrated analysis is performing better than a specialist analysis alone. Even where further specialist analysis is required as was the case for the lagoons of Sri Lanka, the holistic view has shown the range of possible causes of impacts (Chapter 6, Section 6.3.4.2) and this highlighted the misperception in the regular focus given to the irrigation cause only. The new research perspectives provided more breadth and value to the assessments. The results have informed on the nature and scope of further needs for reductionist analyses, for example, the need to study lagoon ecology along with fisheries patterns of exploitation, in a context of future climate events (especially drought or flood). Lastly transparent and regular monitoring of the conditions in which the approach was implemented should enable discrimination of the scientific results from the socially driven decisions expressed in participatory approaches.

To conclude participation and local knowledge can be of great value, but should not be a substitute for rigorous reductionist or single-issue assessment where needed. The subsequent difficulties have been clearly recognised by the approach and in response

the APIA approach has provided means for managing these, especially through its adaptive and iterative process.

7.4.2 The delicate management of the research process

The implementation of the approach in Laos and Sri Lanka required both technical and practical issues to be addressed, for example the integration of disciplinary and sectoral specialisms, and the capacity building of primary stakeholders alongside empirical relationships on fish stocks dynamics. This required simultaneous management of knowledge, people and the impact assessment process. The research process thus requires adequate skills in communication, organization and management, and not only scientific skills.

The participatory and integrated approach tends to increase the diversity and number of sources of knowledge and participants in the process. Subsequently this is likely to increase the diversity of objectives and priorities, and complicate the specification of study objectives and processes for selection of preferred outcomes (see Section 7.4.1). Furthermore interdisciplinary research is more difficult to manage due to the required coordination between researchers, the different approaches to harmonisation and different paradigms in use.

Despite these benefits, the open-ended and flexible nature of the approach (for which benefits have been described in Section 7.3.3) may not suit technicians or decision-makers expecting deterministic and 'blueprint' solutions. Outcomes have to be kept under continual review, based on updated knowledge or changing objectives of stakeholders and decision-makers, and ensuring adaptation to system dynamics and evolving conditions. Improvement is also a continuous requirement of the management process. Lastly results and management recommendations should be provided in a proportion that justifies at least the implementation of the impact assessment and the resources spent.

7.4.3 Critical Requirements

As mentioned in Section 7.3 and above, the integrated and participatory nature of the approach may increase resource requirements in terms of time, budget and expertise, as long as this is justified (see above). In addition a genuine and continuous support from local and national institutions is critical to the performance of the process and its outcomes.

7.4.3.1 Adequate time and human resources

Whilst achieving representation for all groups has been made possible in Laos and Sri Lanka, it took time, patience and specific efforts to ensure achievement of these for the least educated, confident and influential. Use of the approach has been demanding of communication skills, expertise for its implementation and support, especially for workshop facilitation and capacity building.

As a direct consequence some stakeholders and members of the local study team felt that not enough time was allocated to digest the large amount of information processed by the study (see Chapters 5 and 6, Box A.5.1-A.5.3 and A.6.1-A.6.5), and it was not always possible to draw the lessons from one phase and fully carry improvements through into the next. In Laos particularly, the adequate balance for allocation of resources (especially time) between capacity building and actual assessment activities was difficult to find. In response time allocation was assessed several times through evaluation of stakeholder understanding against the required progress needed for the production of outputs.

The human resources required in the commitment and involvement of a range and number of experts, stakeholders and policy makers was also relatively high: attendance at four to five workshops was expected from local stakeholders, and one to two for national representatives (first and last). For this case study, a minimum period

of 12 weeks (instead of 10 in Laos and 9 in Sri Lanka) would have been more appropriate.

Of course more time and resources allocated to both country case studies would have facilitated more detailed assessment of the nature, determinants and distribution of impacts, for example: the number and location of fishing households potentially negatively impacted by dam construction particularly in Laos; the conflicts of interest between irrigated farming and fishing in Sri Lanka; the severity of irrigation impacts in terms of lost income earning potential, assessed relative to returns to labour and capital in alternative livelihoods, before and after irrigation development. However the costs of such information must always be weighed against its incremental utility for decision-making. The two studies here were thus representative of the majority of environmental impact assessments for development projects of this scale.

More time should also be allocated in promoting the study, informing potential participants of its relevance and purpose in order to enhance the commitment and representation of stakeholders in each relevant sector and at all institutional levels (see also Section 7.4.3.2). While the Lao national representatives showed a strong interest and suggested organizing training courses for uptake of the approach, the lack of commitment from the Sri Lankan national irrigation agencies was in contrast. The effort needed to create awareness and generate political commitment at all levels of government for processes of this nature should not be underestimated. However rather than just insufficient promotion, the outcome in Sri Lanka was likely to result from an overall lack of institutional support as developed below. This shows that political will is generally a critical requirement.

7.4.3.2 Genuine institutional support

In Laos and Sri Lanka, key issues tended to be identified at local level and this was also where the complexity of interactions and trade-offs could best be investigated and understood. Commitment from stakeholders was thus expected to be higher at

local levels (comprising communities, district and provincial agencies). Most local stakeholders attended a series of seven workshops in Laos and four in Sri Lanka, and a few local representatives of the different sectors also participated to the final workshop. Attending the series of workshop was thus demanding of their time.

It was clear however that adequate representation from the level of governance with authority for resource allocation or policy decisions was also essential, particularly during the problem identification and decision-making phases (first and final workshops). During these phases, expression of local and national or regional concerns and interests could interact and drive the process of identification and selection of key issues. Similarly for the decision-making, consideration of impacts assessed at local level and respective mitigation and enhancement measures had to take account of broader issues (for example the plan to build another dam in a catchment upstream, and at a larger scale in the future development of the whole river basin likely to offer other sources of employment) with respective tradeoffs.

Therefore successful use of the approach depends on first ensuring that there is adequate awareness and strong institutional support for its use at appropriate levels of governance, with recognition of the importance of integrating fisheries concerns into the planning of irrigation or other water resource developments. Responsibility and true commitment are required and the roles of all stakeholders and policy makers should be clearly defined at each stage of the process. At the end of the implementation, results on impacts and their management implications should be submitted to national level irrigation and water resource managers for adoption and integration at policy level. Ultimately this type of approach and procedure for impact assessment would need to be institutionalised (or adjusted to the EIA guidelines already widely institutionalised) within relevant government agencies so that it gains adequate prioritisation in the future and possibly leads to institutional uptake.

7.4.4 Priority research needs

7.4.4.1 Specific needs from the case studies

Further areas of research for improvement of assessment and management outputs have been identified throughout the studies. In addition to the larger time and space coverage suggested in the following section, more detailed assessment would be required in some priority areas as follows:

- identification and experimentation of agricultural practices that preserve fish production in farmed fields;
- determination of maximum reservoir drawdown to sustain fisheries;
- assessment of optimized allocation of reservoir water to irrigated agriculture and fisheries;
- evaluation of adequate timing of sand-bar breaching to satisfy (or compromise) farmers' and fishers' needs in the lagoons of Sri Lanka; along with the management of drainage water to minimise impacts on the lagoon ecology and surrounding environment (wildlife reserve);
- identification of scenarios of evolution of the role of fisheries in rural livelihoods and strategies in the process of socio-economic development of the area initiated by irrigation development;
- nature of institutional rules for regulating fisheries exploitation when and where overexploitation is likely to occur i.e. at critical points in the irrigation system (bottlenecks such as culverts), and when excessive drawdowns in reservoirs and lagoons increases efficiency of fishing;
- conflict resolution mechanisms to sustain management measures in lagoons and reservoirs.

More detailed assessment would be required, of the number and location of fishing households potentially negatively impacted by dam construction particularly in Laos, or by conflicts of interest between irrigated farming and fishing particularly in Sri Lanka. In addition, the severity of these impacts in terms of lost income earning

potential should be assessed relative to returns to labour and capital in alternative livelihoods, before and after irrigation development.

7.4.4.2 Increase in time and space coverage

A particular limitation recognized here is that project impact assessments may neglect important cumulative or counter-acting impacts of irrigation, or other water resource developments, on natural resources and livelihoods at the river basin scale. More comprehensive assessment of the impacts on fisheries at the scale of the whole river basin is also required, rather than just the catchment of one tributary (Laos) or of a larger river (Sri Lanka).

However, the approach used in these studies will inevitably be more difficult to apply at river basin scale given the increased number of potential interest groups, the increasing number and complexity of the possible range of issues (e.g. Lankford 2002), and potential data requirements. Similarly there may be a need to extend the time horizon of the assessment, seeking to predict ecological changes and socio-economic trends for periods of ten years or more into the future, but with comparable practical difficulty.

The possibility of up-scaling the outputs of the approach (for example, its potential application and feasibility at a river basin level) should be analysed in further research and experimentation. Strategic assessments at river basin scale (see for example, Sadler & Verheem 1996) can be efficiently informed by catchment results for selected projects in the river basin. Generally future study of impacts on fisheries of irrigation schemes and other water resource developments at broader scales will help to inform policies and measures for their management.

7.4.4.3 Incremental improvement of the approach

Further improvement of the approach is expected from an incremental progress guided by the adaptive and iterative approach. Lessons drawn from each case study have the potential to improve its design (this is likely to decrease with the multiplication of case studies), outcomes and management of its implementation. This includes the development of specialist assessments and specific tools and methods relevant to the impact assessment.

Completion of other case studies will continue to both broaden and deepen the knowledge on the nature and magnitude of the impacts of irrigation on fisheries. Implementations in contrasting natural environments not only in rice-based systems (e.g. with different farming practices; different degrees of irrigation and agriculture development) but also in other agro-ecosystems, are likely to provide further lessons and insights on the nature and magnitude of impacts. These would support further testing of the robustness of the APIA approach.

Chapter 8 - Conclusions

This research has investigated the nature and magnitude of the impacts of irrigation and proposed an impact assessment approach that supports the management and decision-making for irrigation projects with respect to fisheries. Emphasis was placed on the production of fisheries and their role and importance in rural livelihoods within rice-based farming systems. The review of literature and the three impact assessments in Laos and Sri Lanka have provided new perspectives on the impacts of irrigation on fisheries with implications for the management and decision-making of irrigation development, agriculture and fisheries. The results and lessons drawn from these case studies highlighted future challenges raised by the APIA approach and identified key areas for further research.

8.1 New perspectives on the impacts of irrigation on fisheries

The quantitative assessment in Laos revealed that weirs had no significant impact on aquatic habitat but caused a significant decline in fish catch partly explained by a reduction in fishing effort. Dams significantly reduced riverine habitat and led to a redistribution of catch and fishing effort from non-reservoir habitats into reservoirs, but no overall changes in catch or effort occurred. The redistribution reflected a response to fishing opportunities in the reservoir rather than a loss in productivity in non-reservoir habitats.

The ex-ante impact assessment in Laos showed that the net impact of the planned medium-scale irrigation project was predicted to be positive, and this was explained by both biophysical and livelihood factors. Rainfed rice fields dominate the floodplain habitat and their contribution to fisheries production will be largely

unaffected as long as current agricultural practices with significant storage of water in the field during the wet season, are maintained. The majority of households in the project area will benefit from irrigated farming, and fishing can be maintained. However disaggregation of results by location and socio-economic groups revealed some negative impacts, notably on the landless or land deficient households, more heavily dependent on fishing but more remote from the reservoir.

The ex-post impact assessment in Sri Lanka showed that the medium-scale irrigation project had a modest positive impact on pre-existing fisheries in aggregate. However the disaggregation of results by location and socio-economic group revealed negative impacts on the production of the downstream ancient reservoirs and lagoons. This has affected the importance and roles played by fisheries in rural livelihoods, in particular their role of safety net in ancient reservoirs and their specialized income generating function in the lagoons. Improvements in the management of water have the potential to mitigate these impacts in the ancient reservoirs and lagoons.

The three case studies revealed the possibly counter-intuitive results that the aggregate impact of irrigation development on fisheries production in an affected catchment can be neutral or positive and not always damaging. This is because of the existence of compensation mechanisms originating partly in the biophysical environment and in the exploitation patterns of aquatic resources. In particular the creation of a significant reservoir fishery may entirely or partially compensate for losses in production elsewhere in the catchment, especially in the floodplain downstream of the dam. Compensation mechanisms may also originate in the variety of roles played by fisheries in rural livelihoods. In particular their tendency to have open access and relatively low costs of entry could match the needs of vulnerable groups otherwise neglected or adversely affected by irrigation.

While the mitigation of irrigation impacts has tended to focus on the infrastructure and engineering measures, and on restoration of river flow downstream of the scheme, the case study results showed that the management of irrigation and agricultural

practices may impact fisheries more severely than the irrigation infrastructure. In both Laos and Sri Lanka the most important fisheries occur outside the river *per se* that is in the floodplain and rice fields in Laos, and in the reservoirs and lagoons in Sri Lanka. These aquatic habitats are not uniquely dependent on the river flow and its migratory species. Maintenance of these habitats to preserve the major proportion of fisheries production requires improved management of irrigation water in rice fields, in the small and medium-scale reservoirs, and improved management of drainage flows.

In conclusion, rice farming irrigated systems can support significant aquatic resource production and play various and important roles in rural livelihoods of the respective catchment area. Because important fisheries can continue to co-exist with irrigation development, the management of the impacts of irrigation development on fisheries has the potential to increase the overall economic and social benefits of an irrigation project.

8.2 Challenges raised by the adaptive, participatory and integrated assessment (APIA) of impacts

The APIA approach was evaluated for its operation, performance and impact in the two country case studies. In Laos, the strong need for capacity building and the reliance on international expertise for the production of assessment results characterized the process. In the study of management measures, the approach revealed a large bias in the benefits expected from reservoir fish farming, and highlighted the need to diversify management solutions though improvement of the irrigation system design and management. The interest by national representatives suggested potential impact of the approach through development of institutional uptake. This first test case provided numerous lessons for improvement of the approach.

In Sri Lanka, the participation of stakeholders broadened the scope of the assessment by considering strong livelihood issues in the ancient reservoirs and the lagoons, and by identifying recurrent conflicts between fishers and farmers. During implementation, the approach reduced these conflicts, and enhanced the commitment of stakeholders to seek out management options exploiting the complementarities between irrigation and fisheries. However the lack of participation by the irrigation national representatives limited the performance of the management recommendations and their potential impact.

The adaptive, participatory and integrated assessment approach has provided new insights and perspectives on the impacts of irrigation on fisheries. This resulted from the broader scope and coverage of the impact assessment, the participation of stakeholders and the management orientation of the assessment. The approach revealed that management solutions exist by analyzing fisheries within the larger context of irrigated farming systems.

However increased complexity and uncertainty in the impact assessment may affect the production of assessment results and their required level of scientific rigor. While participation of stakeholders is desirable, their contribution can impede the impact assessment process and increase the time and human resource required. In addition the perceptions of the relative importance and value of impacts will vary among different stakeholder groups. Tensions can arise and be difficult to manage, and the consensus may be difficult to achieve, if attainable at all.

The approach has been functioning within existing social and political structures, accepting the constraints, risks and biases this may bring, but seeking to address these through scientific analysis, communication and transparency. Although structured by a sequential process, the approach is open and flexible and requires genuine institutional support. The approach and the management of its implementation are thus more challenging and risk-taking than conventional reductionist impact assessments.

8.3 Implications for the management and decision-making of irrigation development

Assessment results revealed that when fisheries interests are taken into account in irrigation system design, operation and management, rice farming systems can significantly contribute to fisheries production. Although irrigation development may help stimulate the rural economy leading to new livelihood opportunities, some livelihood functions of fisheries need to be preserved, in particular for the landless ~~of~~ or land deficient households. The management of irrigation impacts on fisheries thus needs to take account of multiple and competing water uses within a catchment and possibly at river basin level.

This involves processes that can recognize and resolve tradeoffs between competing interest groups in the management of irrigation and water resources more widely. Tradeoffs and potential conflicts are likely to arise if rice cultivation practices change in Laos, and if the needs of fisheries in water allocation from reservoirs and management of lagoons are not adequately taken into account in Sri Lanka.

Such tradeoffs and decision-making will also depend on local and national development priorities. While irrigated agriculture is generally assigned a key role in driving the economic and social development of areas suited for it, the management of irrigation projects must at least ensure that negatively affected groups are not made significantly worse off without adequate mechanisms for compensation and the mitigation of impoverishment. Also that too strong a disparity in the distribution of benefits and costs does not create or exacerbate recurrent conflicts. Therefore management and policy responses must be both cross-sectoral and differentiated by location and socio-economic groups.

8.4 Further research

Further research is needed on the nature and magnitude of impacts and on the impact assessment approach. Research needs identified refer to both specialist assessments and the impact assessment approach.

Specialist assessments should focus on appropriate farming practices in Laos, and on water management in reservoirs and lagoons in Sri Lanka. Further assessment of the impact of reservoir level drawdown on fish populations is required to define minimum water level in the reservoirs and optimize allocation of reservoir water to agriculture and fisheries. In the lagoons, the study of management options for inflows of drainage water (with respective quality) is needed to support the restoration of the shrimp fishery.

These assessments should include the respective adjustments in water management and tradeoffs in terms of water allocation with multiple users, especially irrigated agriculture. The case studies were carried out at catchment level, and did not address the potential cumulative and synergistic impacts of irrigation development on fisheries at a river basin scale. The project level results provided in the thesis can contribute to such assessments.

Process assessment, and monitoring and evaluation of the irrigation scheme construction (in Laos), and irrigation operation and management in both country case studies are required. The existence of negative impacts at a disaggregated level calls for regular monitoring through differentiation by location and socio-economic status and gender. This should also ensure that implementation of management recommendations are performing as expected.

Improvement and refinement of the APIA approach is expected through the use of further case study outcomes and lessons. Multiplication of case studies in various and contrasting natural and social environments will help to both broaden and deepen the

knowledge on the nature and magnitude of impacts of irrigation on fisheries, and contribute to an incremental improvement of the integrated and participatory approach.

References Cited

Abbot, J. and Guijt, I. 1998. *Changing views on change: Participatory Approaches to Monitoring the Environment.* Sustainable Agriculture and Rural Livelihoods Discussion Paper No.2, IIED, London, UK.

Adams, W. 2000a. *Downstream Impacts of Dams*. Prepared for the WCD Thematic Review I.1: Social Impacts of Large Dams Equity and Distributional Issues. University of CambrAdams, W. 2000b. *Social Impacts of Large Dams: Equity and Distributional Issues.* Prepared for the WCD Thematic Review I.1: Social Impacts of Large Dams Equity and Distributional Issues. University of Cambridge, UK

ADB 1987. *Environmental guidelines for selected agricultural and natural resources development projects*. Environment Unit Infrastructure Department.

ADB 2004. *Water and Poverty*. ADB "Water for All" Series. Asian Development Bank, Manila, The Philippines.

Allen, W.J. 2001. *Working together for environmental management: the role of information sharing and collaborative management.* PhD thesis, Massey University, Palmerston North, New Zealand

Allison, E. H. and Ellis F. 2001. The livelihoods approach and management of small-scale fisheries. *Marine Policy,* 25: 377-388.

Almeida, O.T., Lorenzen K, McGrath D.G. 2002. *The role of the fisheries sector in the regional economy of the Brazilian Amazon*, 2nd International Large River Symposium, Rome, FAO.

Amarasinghe, U.S. 1998. Reservoir Fisheries Management in Sri Lanka: Achievements, Mistakes and Lessons for Future. *International Review of Hydrobiology*, 83 (Special Issue): 523-530.

Amarasinghe, U.S. 2002. The fishery and population dynamics of Oreochromis mossambicus and Oreochromis niloticus (Osteichthyes, Cichlidae) in a shallow irrigation reservoir in Sri Lanka. *Asian Fisheries Science*, Vol.15, No.1

Anon., 2000a. *Technical Report of the Huay Thouat Irrigation Project - Feasibility Study*. Institute of Irrigation Technology, Irrigation Department. Hanoi, Viet Nam.

Anon., 2000b. *National Water Resources Policy and Institutional Arrangements*. Water Resources Council and Secretariat, Government of Sri Lanka.

Arrington, D.A. and Winemiller, K.O. 2004. *Organisation and maintenance of fish diversity in shallow waters for tropical floodplain rivers*. In: Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II. Welcomme R. and T. Petr (Eds.), FAO Regional Office for Asia and the Pacific, RAP Publication, Bangkok, Thailand: 25-36.

Arthington, A.H., Bunn, S.E., Pusey, B.J., Blühdorn D.R., King J.M., Day J.A., Tharme R.E. and O'Keeffe J.H. 1992. *Development of a holistic approach for assessing environmental flow requirements of riverine ecosystems*. In: Pigram JJ, Hooper BP (Eds.) Proceedings of an international seminar and workshop on water allocation for the environment. November 1991. The Centre for Water Policy Research, University of New England. Armidale, Australia. 282 pp.

Arthington, A.H., Lorenzen, K., Pusey, B.J., Abell, R., Halls, A., Winemiller, K.O., Arrington, D.A. and Baran, E. 2004. *River fisheries: ecological basis for management and conservation.* In: Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume I. Welcomme R. and T. Petr, Eds., FAO Regional Office for Asia and the Pacific, RAP Publication, Bangkok, Thailand: 21-60.

Arthington, A.H., Tharme, R.E., Brizga, S.O., Pusey, B.J. and Kennard, M.J. 2004. *Environmental flow assessment with emphasis on holistic methodologies.* In: Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II. Welcomme R. and T. Petr, Eds., FAO Regional Office for Asia and the Pacific, RAP Publication, Bangkok, Thailand: 37-65.

Baird, I.G., Flaherty, M.S. and Phylavanh, B. 2000. *Rythms of the river: Lunar phases and small cyprinid migrations in the Mekong River.* Champassak

Province, Lao PDR, CESVI Project for environmental protection and community development in the Siphandone wetland. 42 pp.

Baelde, P. 2001. *Using Fishers' Knowledge goes beyond filling Gaps in Scientific Knowledge - Analysis of Australian Experience*. Putting Fishers' Knowledge to Work. N. Haggan, C. Brignall, L. Wood (Eds.). FCRR 2003, 11(1).

Bakker, M., Barker, R., Meinzen-Dick, R. and Konradsen, F. (Eds.) 1999. *Multiple uses of water in irrigated areas: a case study from Sri Lanka.* SWIM Paper 8. IFPRI-IWMI, Colombo, Sri Lanka.

Bakker, M. and Matsuno, Y. 2001. *A framework for valuing ecological services of irrigation water; a case of an irrigation-wetland system in Sri Lanka.* Irrigation and Drainage Systems 15: 99-115.

Balzer, T., Balzer, P. & Pon S. 2002. *Traditional Use and Availability of Aquatic Biodiversity in Rice-based Systems; 1. Kampong Thom Province, Kingdom of Cambodia*. Food and Agriculture Organisation of the United Nations, Rome, Italy

Bambaradeniya, C.N.B. & Amerasinghe, F.P. 2003. *Biodiversity associated with the rice field agroecosystem in Asian countries: A brief review.* Working Paper 63. Colombo, Sri Lanka: International Water Management Institute

Baran, E. and Baird, I.G. 2001. Ecological approaches of flood-fish relationships modeling in the Mekong River. National workshop on Ecological and Environmental Modeling. 3-4 September 2001, University Sains Malaysia, Penang, Malaysia.

Baran, E., Makin, I. and Baird, I.G. 2003. Bayfish: A model of environmental factors driving fish production in the lower Mekong Basin. WorldFish Center, Penang, Malaysia.

Bayley, P.B. 1988. Accounting for effort when comparing tropical fisheries in lakes, river-floodplains and lagoons. *Limnol. Oceanogr.*, 33, 963-972.

Beam, J.H. 1983. The effect of annual water level management on population trends of White Crappie in the Elk City Reservoir, Arkansas. *North American Journal of Fisheries Management,* 3: 34-40.

Béné, C. 2003. When Fishery Rhymes with Poverty: A First Step Beyond the Old Paradigm on Poverty in Small-Scale Fisheries. *World Development,* 31(6): 949-975.

Béné, C. and Neiland, A.E. 2003. *Contribution of Inland Fisheries to Rural Livelihoods in Africa: Empirical Evidence from the Lake Chad Basin Areas.* Second International Symposium on the Management of Large Rivers for Fisheries, Phnom Penh, Cambodia.

Bergkamp, G., McCartney, M., Dugan, P., McNeely, J. and Acreman, M. 2000. *Dams, Ecosystem Functions and Environmental Restoration.* Prepared for the World Commission on Dams (WCD), Thematic Review, Environmental Issues II.1. World Commission on Dams, Cape Town, South Africa.

Bernacsek, G.M. 1984. *Dam design and operation to optimize fish production in impounded river basins, based on a Review of the Ecological Effects of Large Dams in Africa.* CIFA Tech. Pap.No.11. FAO Rome

Beveridge M.C.M. and Muir J.F. 1997. *Environmental impacts and sustainability of cage aquaculture in Southeast Asian lakes and reservoirs.* In: Ecological Aspects of Fish Production in SE-Asian Lakes and Reservoirs. W. van Densen & M. Verdegen (Eds.). Wageningen Agricultural University, Netherlands.

Biggs, S.D. 1989. *Resource-poor farmer participation in research: a synthesis of experiences from nine agricultural research systems.* OFCOR Comparative Study Paper No.3, ISNAR.

Bizer, J.R. 2000. *International Mechanisms for Avoiding, Mitigating and Compensating the Impacts of Large Dams on Aquatic and Related Ecosystems and Species.* Prepared for IUCN / UNEP / WCD. World Commission on Dams, Cape Town, South Africa.

BMZ 1995. *Environmental Handbook.* Documentation on monitoring and evaluating environmental impacts. Volume II: Agriculture, Mining/Energy, Trade/Industry. German Federal Ministry for Economic Cooperation and Development

Bovee, K. D., B. L. Lamb, J. M. Bartholow, C. B. Stalnaker, J. G. Taylor, and J. Henriksen, 1998. *Stream Habitat Analysis Using the Instream Flow Incremental*

Methodology. Biological Resources Discipline Information and Technology Report USGS/BRD-1998-0004, Viii +131 p.

Brigham, M.E. 1994. *Pesticides detected in surface waters and fish of the Red River of the North Drainage Basin*. North Dakota Water Quality Symposium Proceedings, March 30-31, 1994, Fargo, North Dakota, North Dakota State University Extension Service: 256-269.

Brizga, S.O., Arthington, A.H., Choy, S.J., Kennard, M.J., Mackay, S.J., Pusey, B.J., Werren, G.L. 2002. *Benchmarking, a 'top-down' methodology for assessing environmental flows in Australian rivers*. Unpublished Paper. Environmental Flows for River Systems Working Conference and Fourth International Ecohydraulics Symposium. 3-8 March 2002, Cape Town, South Africa.

Bruckmeier, K. 2005. Interdisciplinary Conflict Analysis and Conflict Mitigation in Local Resource Management. *Journal: AMBIO: A Journal of the Human Environment* 34(2): 65-73.

Bunn S.E. & Arthington A.H. 2003. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management,* 30: 492-507.

Campbell, J. and Salagrama, V. 2000. *New Approaches to Participation in Fisheries Research*. Rome: FAO and SIFAR, 56 pp.

Campbell, B, Sayer, J.A., Frost, P., Vermeulen, S., Ruiz Perez, M., Cunningham, A. and Prabhu, R. 2001. Assessing the Performance of Natural Resource Systems. *Conservation Ecology* 5(2):22.

Carpenter, S. R., and Cottingham, K. L. 1997. Resilience and restoration of lakes. *Conservation Ecology* [online]**1**(1): 2.

CAWM 2005. Comprehensive Assessment of Water Management in Agriculture http://www.iwmi.cgiar.org/assessment

Central Bank of Sri Lanka 2001. *Annual Report 2001.* Colombo, Sri Lanka.

Central Bank of Sri Lanka 2002. *Economic and Social Statistics of Sri Lanka 2002.* Volume XXIV, ISSN 1391-3611. Statistics Department, Colombo, Sri Lanka.

Chandrasiri, J. K. 1986. *Socio-Economic Conditions of Inland Fishermen in Sri Lanka: A Pre-Project Study of Five Major Reservoirs in the Hambantota*

District. Agrarian Research and Training Institute, Colombo, Sri Lanka. No.73, 95 p.

Chao, L.N., Sonnenschein, L. and Dowd, S. 1999. *Project PIABA. Developing toward a sustainable natural resource in Amazon freshwater fisheries.* Bio-Amazonia Conservation International, Brookline, Maine and Universidade do Amazonas, Manaus, Brazil, 34 pp.

Chong, C.K., Ahmed, M., Valmonte-Santos, R.A. and Balasubramanian, H. 2003. *Review of Literature on Values of Inland Capture Fisheries and Dams Construction at the Lower Mekong and Ganga Basins.* WorldFish Centre, Penang.

Claridge, G.F. (Compiler) 1996. *An inventory of Wetlands of the Lao PDR.* IUCN, Bangkok, Thailand.

Clay, C.H. 1995. Design of Fishways and Other Fish Facilities, Boca Raton, Louisiana, USA: Lewis Publishers.

Coates, D. 2002. *Inland capture fishery statistics of Southeast Asia: Current status and information needs.* Asia-Pacific Fishery Commission, Bangkok, Thailand. RAP Publication No. 2002/11, 114 p.

Coates, D. 2003. *An overview of inland capture fishery statistics of Southeast Asia. In New Approaches for the Improvement of Inland Capture Fishery Statistics in the Mekong Basin.* Ad-hoc expert consultation, Udon Thani, Thailand, 2-5 September 2002.

Coates, D., Poeu, O., Suntormtatana, U., Thang Tung, N. and Viravong, S. 2003. *Biodiversity and Fisheries in the Lower Mekong Basin.* Mekong River Commission, Phnom Penh, Cambodia.

Coche A.G. 1967. Fish culture in rice fields, a world-wide synthesis. *Hyrobiologia*, 30(1): 1-44

Collinson P. and E. Tollens, 1994. *The impacts of the International Agricultural Research Centers: Measurement, Quantification and Interpretation.* Issues in Agriculture No.6

Comprehensive Everglade Restoration Plan 2005. http://www.evergladesplan.org

Costanza, R., d'Arge R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M. 1997. 'The value of the world's ecosystem services and natural capital', *Nature*, Vol. 387, p. 253.

Cowx, I.G. 1991. *Catch effort sampling strategies and their application in freshwater fisheries management*. Fishing News Books, Blackwell Science, Oxford, 420 pp.

Cowx, I.G. 1999. An appraisal of stocking strategies in the light of developing countries constraints. *Fisheries Management and Ecology*, 6: 21-34.

Cowx, I.G. and R.L. Welcomme (Eds) 1998. *Rehabilitation of Rivers for Fish.* A study undertaken by the European Inland Fisheries Advisory Commission of the Food and Agriculture Organisation of the United Nations (FAO). Fishing News Books. Blackwell Science, Ltd. London. 260 p.

Crawford, S. and Ostrom, E. 1995. A Grammar of Institutions. *American Political Science Review* 89: 582-600.

Department of Census and Statistics 1999. *District Profile of Labour Force in Sri Lanka 1997.* Colombo, Department of Census and Statistics, Ministry of Finance and Planning.

De Silva, S.S. 1985. Observations on the abundance of the exotic cichlid *Sarotherodon mossambicus* (Peters) in relation to fluctuations in the water-level in a man-made lake in Sri Lanka. *Aquaculture and Fisheries Management* 16, 265-272. Department of Zoology, University of Ruhuna, Matara, Sri Lanka.

De Silva, S.S. 1988. *Reservoirs of Sri Lanka and their fisheries*. FAO Fisheries Technical Paper 298. Food and Agriculture Organization of the United Nations, Rome.

DFID 1999. Sustainable Livelihoods Guidance Sheets. Department for International Development, London.

DFID/FAO 2000. *Interagency experiences and lessons.* From the forum on operationalizing Sustainable Livelihoods approaches. Pontignano (Siena) 7-11 March 2000. FAO: Rome

Department of Census and Statistics 1999. *District Profile of Labour Force in Sri Lanka 1997.* Colombo, Department of Census and Statistics, Ministry of Finance and Planning.

Dudgeon, D. 2000. The ecology of tropical Asian rivers and streams in relation to biodiversity conservation. *Annual Review of Ecology and Systematics* 31: 239-263.

Dudgeon, D. 2003. Clinging to the wreckage: unexpected persistence of freshwater biodiversity in a degraded tropical landscapes. *Aquatic Conservation. Marine and Freshwater Ecosystems*, 13, 93-97.

Eberhardt L.L. & Thomas J.M. 1991. Designing environmental field studies. *Ecological Monographs*, 61, 53-73.

Efron B. & Tibshirani R.J. 1993. *An introduction to the Bootstrap*. Chapman & Hall, London, UK.

English, M.J., Solomon, K. H., and Hoffman, G.J. 2002. A Paradigm Shift in Irrigation Management. *J. Irrigation and Drainage Engineering*, ASCE. Vol. 28, No 5. (Invited paper for Jubilee Year Edition)

ESCAP-UN 1990. *Environmental Impact Assessment: Guidelines for Agricultural Development.* Economic and Social Commission for Asia and the Pacific, Bangkok. Environment and Development Series: ST/ESCAP/783

EU 1993. *Environmental Procedures - The Integrated Approach.* The European Union, Brussels, Belgium.

Falkenmark, M. 2003. *Water Management and Ecosystems: Living with Change.* TEC Background Paper 9: 27.

FAO 1993. *The State of Food and Agriculture 1993.* FAO Agriculture Series No.26. Food and Agriculture Organisation of the United Nations, Rome, Italy.

FAO 1995. *Environmental Impact Assessment of Irrigation and Drainage Projects.* Food and Agriculture Organisation of the United Nations, Irrigation and Drainage Paper 53.

FAO 1996. FAO Technical Guidelines for Responsible Fisheries: Precautionary approach to capture fisheries and species introduction. FAO Technical Report No.2, Food and Agriculture Organisation of the United Nations, Rome, Italy.

FAO 1997. FAO Technical Guidelines for Responsible Fisheries: Inland Fisheries. FAO Technical Report No.6, Food and Agriculture Organisation of the United Nations, Rome, Italy.

FAO 2000. The State of World Fisheries and Aquaculture. Food and Agriculture Organisation of the United Nations, Rome.

FAO 2003. *Land, Food and Water.* Food and Agricultural Organization of the United Nations (FAO), Rome, Italy

FAO 2004. *Statistical Yearbook 2004.* Food and Agricultural Organization of the United Nations (FAO), Rome, Italy

FAO/DVWK 2002. *Fish passes: Design, dimensions and monitoring*. Rome, FAO, 119 pp.

FAP 17 1995. *Flood Action Plan.* Final Report, Main Volume. Overseas Development Administration, London, UK.

Fell, A. and Sadler, B. 1999. Public Involvement in Environmental and Assessment Management: A Preview of IEA Guidelines and Good Practice. *Environmental Assessment*, 7(2): 36-39.

Fernando, 1993. Rice field ecology and fish culture: an overview. *Hydrobiologia*, 259, 91-113.

Finlayson, C.M. and Spiers, A.G. (Eds) 1999. *Global review of wetland resources and priorities for wetland inventory.* Supervising Scientist Report 144 / Wetland International Publication 53, Supervising Scientist, Canberra.

de Fraiture, C., Molden, D., Amarasinghe, U. and Makin, I. 2001. PODIUM: projecting water supply and demand for food production in 2025. *Phys. Chem. Earth,* B 26, 869-876

Froese, R. & Pauly, D. 2004. FishBase. www.fishbase.org Los Banos, Philippines.

Garaway, C.J. 1999. *Small waterbody fisheries and the potential for community-led enhancement: case studies in Lao PDR*. PhD Thesis, University of London, London, UK.

Garaway, C.J and Arthur, R.I. 2004. *Adaptive learning: a practical framework for the implementation of adaptive co-management. Lessons from selected experiences in South and South-East Asia*. MRAG Ltd., London, UK.

de Graaf, G., Born, B., Kamal Uddin, A.M. & Marttin, F. 2001. *Floods Fish and Fishermen.* The University Press Ltd., Dhaka, Bangladesh.

Greif A. and Laitin D. 2004. A theory of endogenous institutional change. American *Political Science Review*, 98(4): 1-20.

Gregory, R. & Guttman, H. 2002. *The ricefield catch and rural food security.* In Rural Aquaculture. P.Edwards, D.C. Little & H. Demaine (Eds.). CABI Publishing, Wallingford, UK.

Guegan, J.F., Lek, S. and Oberdoff, T. 1998. Energy availability and habitat heretogeneity predict global riverine fish diversity. *Nature*, 391: 382-384.

Guijt, I. & Gaventa, J. 1998. *Participatory Monitoring and Evaluation: a Literature Review.* IDS Policy Briefing. Institute of Development Studies, University of Sussex, Brighton, UK.

Guttman, H., 1999. *Rice Field Fisheries: A Resource for Cambodia.* NAGA the ICLARM Quarterly 22(2): 11-15.

Halim, Y., Marcos, S.A., Rizkalla, S. and El-Sayed M, Kh. 1995. *The impact of the Nile and Suez canal on the living marine resources of the Egyptian Mediterranean waters.* In: Effects of riverine inputs on coastal ecosystems and fisheries resources, FAO Fisheries Technical Paper 359, Rome, Italy.

Halls, A.S., Hoggarth, D.D. and Debnath, K. 1998. Impacts of flood control schemes on river fish migrations and species assemblages inBlangladesh. *Journal of Fisheries Biology,* 53 Suppl. A: 358-380.

Halls, A.S., Hoggarth, D.D. and Debnath, K. 1999. Impacts of hydraulic engineering on the dynamics and production potential of floodplain fish populations in Bangladesh. *Fisheries Management and Ecology,* 6: 261-285.

Halls, A.S., Kirkwood, G.P. and Payne, A.I. 2001. A dynamic pool model for floodplain river fisheries. *Ecohydrology and Hydrobiology,* 1: 323-339.

Halls A.S. and Welcomme R.L. 2003. Dynamics of river fish populations in response to hydrological conditions: A simulation study. Paper submitted to the Second International Symposium on the Management of Large Rivers for Fisheries. Phnom Penh, Mekong River Commission.

Hardin G. 1968. The Tragedy of the Commons. *Science* 162: 1243-8

Harwood, R.R. and Kassam, A.H. (Ed.) 2003. *Research Towards Integrated Natural Resources Management. Examples of Research Problems, Approaches and Partnerships in Action in the CGIAR.* Interim Science Council, Centre Directors Committee on Integrated Natural Resource Management. Consultative Group on International Agricultural Research, FAO, Rome.

Haylor, G. S. and Bhutta, M.S. 1997. The role of aquaculture in the sustainable development of irrigated farming systems in Punjab. *Pak. Aquacult. Res.* 28: 691-705.

Health Canada 1999. *Canadian Handbook on Health Impact Assessment. Roles of the Health Practioner.* Vol.3, Draft. A report of the Federal/Provincial/Territorial Committee on Environmental and Occupational Health. Minister of Public Works and Government Services Canada 99-EHD-235.

Heckman, C.W. 1974. The seasonal succession of species in a rice paddy in Vientiane, Laos. *Internationale Revue des Gesamten Hydrobiologie*, 59, 489-507

Heckman, C.W. 1979. *Rice field ecology in Northeastern Thailand: The effect of wet and dry seasons on a cultivated aquatic ecosystem.* Junk Publishers, The Hague, The Netherlands.

Heeks, R. 1999. *The Tyranny of Participation in Information Systems: Learning from Development Projects*. Development Informatics. Working Paper Series, Paper No.4. Institute for Development Policy and Management, UK.

Hess, L.W., Schlesinger, A.B., Herganrader, G.L., Reetz, S.D. and Lewis, H.S. 1982. *The Missouri River study: Ecological perspectives.* In: L.W. Hesse, G.L. Hergenrader, H.S. Lewis, S.D. Reetz & A.B. Schlesinger (Eds.). The Middle Missouri River. The Missouri River Study Group. Lincoln, NE, Nebraska Game and Parks Commission. pp. 287-301.

Hirsch, P. 2001. Globalisation, regionalization and local voices: The Asian Development Bank and rescaled politics of environment in the Mekong region. *Singapore Journal of Tropical Geography*, 223: 237-251.

Hirsch, P. 2004. The politics of fisheries knowledge in the Mekong River Basin. In: Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II. Welcomme R. and T. Petr, Eds., FAO

Regional Office for Asia and the Pacific, RAP Publication, Bangkok, Thailand.: 91-101.

Hoggarth, D. D., Cowan, V.J., Halls A.S., Aeron-Thomas M., McGregor J.A., Garaway C.J., Payne A.I. and Welcomme R.L. 1999. *Management Guidelines for Asian Floodplain River Fisheries.* FAO, Rome, Italy.

Holling, C.S. (Ed.) 1978. *Adaptive Environmental Assessment and Management*. John Wiley, New York, USA.

Hook, D.D. 1993. Wetlands: history, current status and future. *Environmental toxicology and Chemistry*, 12, 2157-2166.

Hopkins, S. 1995. *The Economy. Laos: A country case study.* A.M. Savada. Federal Research Division, Library of Congress, Washington D.C., USA.

Hughes R. 1998. *Environmental Impact Assessment and Stakeholder Involvement.* Environmental Planning Issues No.11, International Institute for Environment and Development, London, UK.

Hussain, I. and Hanjra, A. 2004. Irrigation and Poverty Alleviation: Review of the Empirical Evidence. *Irrigation and Drainage,* 53: 1-15 (2004). Wiley and Sons Ltd.

IRRI 1999. *Rice facts.* Web site of the International Rice Research Institute, Manila, The Philippines.

ICID 1993. *The ICID Environmental Check-list to Identify Environmental Effects of Irrigation, Drainage and Flood Control Projects.* International Commission on Irrigation and Drainage (ICID)/HR Wallingford, UK.

IIMI. 1995a. *Kirindi Oya Irrigation Settlement Project: Project impact evaluation study*. Vol.I: Main report (final). International Irrigation Management Institute. Colombo, Sri Lanka: 118.

IIMI. 1995b. *Kirindi Oya Irrigation Settlement Project: Project impact evaluation study*. Vol.II: Annexes (final report). International Irrigation Management Institute. Colombo, Sri Lanka: 355.

IIMI and FAO 1995. Tranferring Irrigation Management Responsibility in Asia: Results of a Workshop on Expert Consultation on Irrigation Management

Transfer in Asia, 25-29 Sept. 1995, Bangkok and Chiang Mai. Joost C.m Geijer M.A., Svendsen M., Vermillion D.L. (Eds.). IIMI and FAO, Rome, Italy.

Irland, L.C. & Vincent R. 1974. Citizen Participation for Public Land Managers. *Journal of Range Management,* 27(3).

Jackson, D.C. 1991. *Social and cultural values of turbid, warmwater streams and their fisheries in the Southeastern U.S.* In: Cooper J.L.& Hamre R.H. (eds). Proceedings of the Warmwater Fisheries Symposium I. USDA Forest Service General Technology Report RM-207: 169-174.

Jackson, D.C. and Marmulla, G. 2001. *The influence of dams on river fisheries.* In FAO Fisheries Technical Paper 419: 1-44.

Jayakody, D.S. 1993. *Causes or Decline of Finfish and Shellfish Catches of Three Selected Lagoons: Malala, Rekawa and Mawella on the South Coast of Sri Lanka and the current Status.* Annual Scientific Sessions (pp. 11-13), National Aquatic Resource Agency, Sri Lanka.

Jensen J.G. 2001. Managing Fish, Flood Plains and Food Security in the Lower Mekong Basin. *Water Science and Technology*, 43(9): 157-164.

JICA 1992. *Environmental Guidelines on JICA Development Study for Agricultural and Rural Development Projects.* Japanese Institute of Irrigation and Drainage, Tokyo, Japan.

Jinapala, K. 1994. Joint Management Committees. *Economic Review*, 20(6):20-21.

Jinapala, K., Brewer, J. D. and Sakthivadivel, R. 1996. *Multi-level participatory planning for water resources development in Sri Lanka.* IIED. Sustainable Agriculture Programme. 20 p. (Gatekeeper series no.62), London, UK.

Jordan, F. and Arrington, D.A. 2001. Weak trophic interactions between large predatory fishes and herpetofauna in the channelised Kissimmee River, Florida, USA. *Wetlands,* 21(1): 155-159.

Joyeux, J.C. and Ward, A.B. 1998. Constraints on coastal lagoon fisheries. *Advances in Marine Biology*, 34: 73-199.

Jul-Larsen, E. and van Zwieten P. 2002. *African Freshwater Fisheries: What Needs to be Managed?* Naga and Worldfish Center Quaterly 25(3&4), 35-40.

Junk, W.J., Bayley, P.B. and Sparks, R.E. 1989. The Flood Pulse Concept in River-Floodplain Systems. In: Doge, D.P. (Ed). Proceedings of the International Large River Symposium (LARS). *Can.J.Fish.Aquat.Sci.,* Vol. 106: 110-127.

Karr, J.R. and Chu, E.W. 1999. Restoring Life in Running Waters: Better Biological Monitoring, Island Press, Washington DC, USA.

Key, P., Fulton, M., Harman-Fetcho, J.A., Mcconnell, L.L. 2003. Acetylcholinesterase Activity In Grass Shrimp And Aqueous Pesticide Levels From South Florida Drainage Canals. *Archives Of Environmental Contamination And Toxicology*. 45:371-377.

Kichuki, M., Barker, R., Weligamage, P. and Samad, M. 2002. *The irrigation sector in Sri Lanka: Recent investment trends and the development path ahead.* Research Report 62. International Water Management Institute, Colombo, Sri Lanka.

King, J., Tharme, R., and Brown, C. 1999. *World Commission on Dams Thematic Report: Definition and Implementation of Instream Flows*. Final Draft. Prepared by Southern Waters Ecological Research and Consulting under contract to World Commission on Dams, Cape Town, South Africa. 64 pp.

Kinzig, A.P. 2001. Bridging Disciplinary Divides to Address Environmental and Intellectual Challenges. *Ecosystems*, 4: 709-715.

Koohafkan & Furtado 2004. *Traditional Rice Fish Systems and Globally Indigenous Agricultural Heritage Systems (GIAS).* FAO Rice Conference 04/CRS.17, 12-13 Feb. 2004, Rome, Italy.

Kottelat, M. 2001. *Fishes of Laos.* WHT Publications, Colombo, Sri Lanka.

Kremer, A. 1994. *Equity in the fishery: a floodplain in N.E. Bangladesh.* Research Paper R94E, Centre for Development Studies, University of Bath, Bath, UK.

Kurihara, Y. 1989. Ecology of some rice fields in Japan as exemplified by some benthic fauna, with notes on management. *Internationale Revue der gesamten Hydrobiologie,* 74: 507-548.

Kularatne, M.G. 1999. *"Fishermen Without Fish". The Effects of Productivity Decline in Lagoon Fisheries on a Fishing and Farming Community and its Use of Natural Resources: A Case Study of Malala Lagoon, Hambantota, Sri Lanka.*

International Institute for Aerospace Survey and Earth Sciences. Enschede, The Netherlands: 118.

Lankford B. 2002. *Irrigated Livelihood Trends in River Basins - Implications for Policy.* Third WaterNet/Warfa Symposium: Water Demand Management for Sustainable Development. Dar es Salaam.

Larinier, M. 2000. Dams and Fish migration. Prepared for the WCD Thematic Review II.1: Dams, ecosystem functions and environmental restoration. Working paper of the World Commission on Dams. WCD, Cape Town, South Africa.

Larinier, M. and F. Travade, 1999. La dévalaison des migrateurs: problèmes et dispositifs. In: Bulletin Français de Pisciculture. Vol. 353/354: 181-210.

Lawler, S.P. 2001. Rice fields as temporary wetlands. Israel Journal of Zoology, 47: 513-528.

Lemly, A. D., Kingsford, R. T. and Thompson, J. R. 2000. Irrigated Agriculture and Wildlife Conservation: Conflict on a Global Scale. Environmental Management, 25(5):485-512.

Leeuwis, C. 2000. Reconceptualizing Participation for Sustainable Rural Development: Towards a Negotiation Approach. *Development and Change*, 31: 931-959. Blackwell Publishers, Oxford, UK.

Lipton, M., Litchfield, J. and Faurès, J.M. 2003. The effects of irrigation on poverty: A framework for analysis. *Water Policy*, 5 (5-6): 413-427.

Little, D.C., Murray, F.J., Kodithuwakku, S.S. 2001. *Understanding Demand: How the Poor Benefit from Tilapia Production in the Northwest Dry Zone of Sri Lanka.* E-conference Proceedings: Aquatic Resources Management for Sustainable Livelihoods of Poor People. DFID/ICLARM, Manilla, Philippines.

Liu, J. 2001. Integrating Ecology with Human Demography, Behavior, and Socioeconomics: Needs and Approaches. *Ecological Modelling,* 140: 1-8.

Lindeman, R.L. 1942. The trophic-dynamic aspect of ecology. *Ecology*, 23: 399-418.

Loneragan, N.R. and Bunn, S.E. 1999. River flows and estuarine ecosystems: Implications for coastal fisheries from a review and case study of the Logan River. *Southeast Queensland. Australian Journal of Ecology*, 24: 431-440.

Lorenzen, K., De Graaf, G. and Halls, A.S. 2003. *A biomass dynamics model for assessing interactions between fisheries and water management in highly seasonal water bodies.* Imperial College London, London, UK.

Lorenzen, K., Nguyen Khoa, S., Garaway, C., Chamsingh, B., Litdamlong, D., Siebert, D. and Innes Taylor, N. 2000. *Impacts of Irrigation and Aquaculture Development on Small-Scale Aquatic Resources.* Final Technical Report, DFID Project R7793, Imperial College London, London, UK.

Lorenzen, K, Smith, L.E.D., Burton, M., Nguyen Khoa, S. and Garaway, C.J. 2004. *Guidance Manual on the Management of Irrigation Development Impacts on Fisheries.* Imperial College London, London, UK.

Lucas, M.C. and Baras, E. 2001. *Migration I. Freshwater Fishes.* London, Blackwell Science. 419 pp.

Mayoux, L. 2001. *What do we want to know? Selecting indicators*. The Enterprise Development of Impact Assessment Information Service (EDIAIS), UK.

Martin, D.B., Mengel, L.J., Novotny, J.F. and Walburg C.H. 1981. Spring and summer water levels in a Missouri River reservoir: Effects on ages-0 fish and zooplankton. *Transaction of the American Fisheries Society,* 110: 370-381.

Mazumder, D. and Lorenzen, K. 1999. Developing aquaculture of small native species (SNS) in Bangladesh: village level agroecological change and the availability of SNS. *NAGA and The ICLARM Quaterly,* 22(3): 20-23.

McAllister D.E., Hamilton A.L. and Harvey B. 1997. Global freshwater biodiversity: Striving for integrity of freshwater systems. *Sea Wind,* 11(3): 1-139

McAllister, D.E., Craig, J.F., Davidson, N., Delany, S. and Seddon, M. 2001. *Biodiversity Impacts of Large Dams.* Background Paper 1, Prepared for IUCN/UNEP/WCD. WCD, Cape Town, South Africa.

McArthur, J.D. 1997. *Stakeholder rules and stakeholder analysis in project planning: a review of the approaches in three agencies.* World Bank, ODA and NRI. Discussion Paper No.73, Development and Project Planning Centre, University of Bradford, Bradford, UK.

McCartney, M.P., Sullivan, C. and Acreman, M. 1999. *Ecosystem impacts of large dams.* Report for the IUCN, The World Conservation Union and the World Commission on Dams, Cape Town, South Africa: 74.

McCully, P. 1996. *Silenced rivers: the ecology and politics of large dams*. Zed Books, London, UK.

Meusch, E. 1996. *Participatory assessment of rice field fisheries in Atsapanthong District, Savannakhet province, Lao PDR*. MS Thesis. Auburn University, Auburn, AL, USA.

Miranda, L.E. 2000. *A review of guidelines and criteria for managing reservoirs and associated riverine environments to benefit fish and fisheries.* Contributing paper to the WCD thematic review: Dams ecosystems and environmental restoration. 53 pp.

Molden, D. 1997. *Accounting for water use and productivity.* SWIM Paper 1. International Water Management Institute, Colombo, Sri Lanka.

Molden, D., Rijsberman, F., Matsuno, Y. and Amerasinghe, U. 2000. *Increasing water productivity: a requirement for food and environmental security.* International Water Management Institute, Colombo, Sri Lanka.

Murray, F., Koddithuwakku S. and Little D.C. 2000. *Fisheries marketing systems in Sri Lanka and their relevance to local reservoir fishery development.* Reservoir and Culture-based Fisheries: Biology and Management, S.S. De Silva (Ed.). Proceedings of an International Workshop, 15-18 Feb., Bangkok, Thailand.

Naiman R.J. and Descamps H. 1997. The ecology of interfaces: Riparian zones. *Annual Review of Ecology & Systematics*, 28: 621-658.

Naiman R.J., Bunn S.E., Nilsson C., Petts G.E., Pinay G. and Thompson L.C. 2002. Legitimizing fluvial ecosystems as users of water: An overview. *Environmental Management* Vol.30, No.4, pp. 455-467.

NARA 1997. *Sri Lanka Fisheries Year Book.* Socio-economic and Marketing and Research Division, National Aquatic Resources Research Development Agency, Sri Lanka.

National Statistical Centre 2000. *Basic Statistics of the Lao PDR 1975-2000.* State Planning Committee, Vientiane. 162 p.

Neiland, A.E. (Ed.) 1997. *Traditional management of artisanal fisheries in N.E. Nigeria. Final Report.* DFID Research Project No.R5471. CEMARE Report R.43. Portsmouth, University of Portsmouth, UK.

Neiland, A. and Béné C. 2003. *Review of River Fisheries Valuation in West and Central Africa.* Background paper commissioned by the World Fish Center for the Water, Ecosystems and Fisheries Review Workshop, Phnom Penh, 15-17 February 2003, 27 p.

Neis, B., Felt, L.F., Haedrich, D.C., Schneider, D.C. 1999. *An Interdisciplinary Method for Collecting and Integrating Fishers' Knowledge into Resource Management.* In: Fishing Places, Fishing People: Traditions and Issues in Canadian Small-scale Fisheries. D. Newell & R.E. Ommer (Eds), Univ. of Toronto Press, Toronto, 217-238.

Neis, B., Pitcher, T. and Johannes, R. (Eds) 2001. *Putting Fishers' Knowledge to Work.* Blackwell Science, Oxford, UK.

Nguyen-Khoa, S. and Smith, L.E.D. 2004. Irrigation and Fisheries: Irreconcilable Conflicts or Potential Synergies? *Irrigation and Drainage,* 53: 415-427.

Nguyen-Khoa, S., Smith, L.E.D. and Lorenzen, K. 2005a. *Adaptive, Participatory and Integrated Assessment of the Impacts of Irrigation on Fisheries: Evaluation of the Approach in Sri Lanka.* Working Paper 89, International Water Management Institute, Colombo, Sri Lanka.

Nguyen-Khoa, S., Smith, L.E.D. and Lorenzen, K. 2005b. *Impacts of Irrigation on Inland Fisheries: Appraisals in Laos and Sri Lanka.* Comprehensive Assessment Research Report 7, Comprehensive Assessment Secretariat, Colombo, Sri Lanka.

Nissanka, C., Amarasinghe, U.S. 2001. *Effect of hydrological regimes on fish yields in reservoirs of Sri Lanka.* International Workshop, Bangkok, Thailand. 15-18 Feb. 2000. ACIAR Proceedings No.98, 384 pp.

Nissanka, C., Amarasinghe, U.S. and De Silva, S.S. 2000. Yield predictive models for the Sri Lankan Reservoir Fishery. *Fisheries Management and Ecology,* 7: 425-436.

NOAA 1994. *Guidelines and Principles for Social Impact Assessment.* Prepared by the Interorganisational Committee on Guidelines and Principles for Social Impact Assessment. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, USA.

ODA 1995. *Guidance note on how to do stakeholder analysis of aid projects and programmes.* Overseas Development Administration, Social Development Department, UK.

Oglesby, R.T., Carlson C.A. and McCann, J.A. 1972. River ecology and man. Academic press, New York.Ormerod S. J. 2003. Restoration in Applied Ecology: Editor's Introduction. *Journal of Applied Ecology,* 40(1): 44-50.

Orstrom, E. 1990. *Governing the Commons: the evolution of institutions for collective action.* Cambridge University Press, Cambridge, UK.

Orstrom, E. 1999. *Institutional Rational Choice: an Assessment of the Institutional Analysis and Development Framework.* In Sabatier Paul (Ed.), Theories of the Policy Process, Westview Press.

Pauly, D., Christensen, V., Guenette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J., Watson, R. and Zeller D. 2002. Towards sustainability in world fisheries. *Nature* 418: 689-95.

Pet, J.S., Gevers, G.J.M., Van Densen, W.L.T. and Vijverberg, J., 1996. Management options for a more complete utilization of the biological fish production in Sri Lankan reservoirs. *Ecology of Freshwater Fish,* 5: 1-14.

Petermann, T. 1996. *Environmental Appraisals for Agricultural and Irrigated Land Development. Guidelines for Planning and Management of Natural Resources.* GTZ-DSE 1996. DSE Mat-Nr. 72/01/96. GTZ, Germany.

Petts, G.E. 1984. *Impounded rivers*. Chichester, John Wiley & Sons Ltd., UK, 326 p.

Petr, T. (Ed.) 1985. *Inland fisheries in multi-purpose river basin development in tropical Asian countries: Three case studies*. FAO Fish.Tech.Pap., 265: 166 p.

Petr, T. 1998. Fisheries in reservoirs in the arid and semiarid zones of Asia. *International Review of Hydrobiology,* 83 (Special Issue): 591-598.

Petr, T. (Ed.) 2003. *Fisheries in irrigation systems of arid Asia.* FAO Fisheries Technical Paper No. 430. FAO, Rome, 150 p.

Petr, T. and Mitrofanov, V.P. 1998. The impact on fish stocks of river regulation in Central Asia and Kazakhstan. *Lakes & Reservoirs: Research and Management,* 3: 143-164.

Petr, T., Ismukhanov, K., Kamilov, B., Pulatkhon, D. and Umarov, P.D. 2004. *Irrigation systems and their fisheries in the Aral Sea basin, Central Asia.* In: Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II. Welcomme R. and T. Petr, Eds., FAO Regional Office for Asia and the Pacific, RAP Publication, Bangkok, Thailand: 223-242.

Phillips, M.J. 1990. *Environmental aspects of seaweed culture.* In: Proceedings of the Regional Workshop on the Culture and Utilisation of Seaweeds, Cebu City, Philippines, 27-31 August 1990. Regional Seafarming Development and Demonstration Project, *Technical Resource Papers*, 2: 51-62. Network of Aquaculture Centers in Asia-Pacific, Bangkok, Thailand.

Pitcher, T.J., Bundy, A., Perikshot, D, Hutton, R. and Pauly, D. 1998. *Measuring the Unmeasurable: a Multivariate and Interdisciplinary Method for Rapid Appraisal of the Health of Fisheries.* In: Reinventing Fisheries Management. Pitcher, Hart & Pauly (Eds). Chapman & Hall, London: 311-329.

Poate, C.D. 1996. *Designing Project Monitoring and Evaluation, Lessons and Practices.* No.8, OED, World Bank, Washington D.C., USA.

Pomeroy, R.S. and F. Berkes 1997. Two to Tango: the Role of Government in Fisheries Co-Management. *Marine Policy*, 21(5): 465-480.

Pomeroy and Rivera-Guieb 2005. *Fishery co-management: a practical handbook.* CABI Publishing, UK and USA, in association with International Development Research Centre, Canada, 235 p.

Porcher, J.P. and Travade, F 2002. *Fishways: Biological basis, limits and legal considerations.* In BFPP, Knowledge and Management of Aquatic Ecosystems. Special: Fishways: biological basis, design criteria and monitoring, pp.9-20.

Pretty, J. 1995. Participatory learning for sustainable agriculture. *World Development*, 23 (8): 1247-1263.

Pretty, J.L., Harrison, S.S.C., Sheperd, D.J., Smith, C., Hildrew, A.G. and Hey, R.D. 2003. River rehabilitation and fish populations: assessing the benefit of instream structures. *Journal of Applied Ecology,* 40: 251-265.

Pusey, B.J. and Arthington, A.H. 2003. Importance of the riparian zone to the conservation and management of freshwater fish: A review. *Marine & Freshwater Research,* 54: 10-16.

Pusey, B. J., Kennard, M.J. and Arthington, A.H. 2000. Discharge Variability and the Development of Predictive Models Relating Stream Fish Assemblage Structure to Habitat in North-Eastern Australia. *Ecology of Freshwater Fishes*, 9:30-50.

Rainboth, W.J. 1996. *Fishes of the Cambodian Mekong*. FAO, Rome, Italy.

RAMSAR 2000. *The Convention Work Plan 2000-2002. Strategic framework and guidelines for the future development of the List of Wetlands of international importance.* Vol.7. Proceedings of the 7th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands (10-18/05/99)

Ratner, B.D., Dang Thanh Ha, Kosal, M., Nissapa, A. & Chanphengxay, S. 2004. *Common waters on private lands: Challenges of wetlands governance in the Mekong Region.* Conference of the International Association for the Study of Common Property (IASCP), "The Commons in an Age of Global Transition: Challenges, Risks and Opportunities", 9-13 August 2004, Oaxaca, Mexico.

Reiser, D.W., Ramey, M.P. and Wesche, T.A. 1989. *Flushing Flows*. In: Alternatives in Regulated River Management. J.A. Gore and G.E. Petts (Eds), CRC Press, Boca Raton, Florida, USA.

Renwick, M.E. 2001. *Valuing water in irrigated agriculture and reservoir fisheries: a multiple-use irrigation system in Sri Lanka.* IWMI Research Report 51. International Water Management Institute, Colombo, Sri Lanka: 44 p.

Revenga, C., Brunner, J., Henninger, N., Kassem, K., Payne, R. 2000. *Pilot Analysis of Global Ecosystems: Freshwater Systems.* World Resources Institute, Washington DC., USA.

Rijsberman, F. and Molden, D. 2001. *Balancing water uses: Water for food and water for nature.* Thematic background paper. Secretariat of the International Conference on Freshwater, Bonn, Germany.

Robinson, C.T., Tockner, K and Ward, J.V. 2002. The fauna of dynamic riverine landscapes. *Freshwater Biology*, 47: 661-677.

Roger, P.A., Heong, K.L. and Teng, P.S. 1991. *Biodiversity and sustainability of wetland rice production: Role and potential of microorganisms and invertebrates.* In: The biodiversity of microorganisms and invertebrates. Its role in sustainable agriculture, ed. D.L. Hawksworth, Wallingford: CAB International (CABI)

Roggeri, H. 1995. *Tropical Freshwater Wetlands: A Guide to Current Knowledge and Sustainable Management*. Kluwer, Dordrecht, The Netherlands.

Rose, K.A., Cowan, J.H., Winemiller K.O., Myers, R.A. and Hilborn, R. 2001. Compensatory density-dependence in fish populations: importance, controversy, understanding and prognosis. *Fish and Fisheries* 2: 293-327.

Rosegrant, M. W., X. Cai, and S. Cline. 2002. *World Water and Food to 2025: Dealing with scarcity.* Jointly published by the International Food Policy Research Institute (IFPRI) and the International Water Management Institute (IWMI). IFPRI, Washington, D.C., USA: 322 p.

Ruddle, K. 1982. Traditional integrated farming systems and rural development: The example of rice field fisheries in Southeast Asia. *Agricultural Administration*, 10: 1-11

Ryder, R.A. 1978. *Fish yield assessment of large lakes and reservoirs: A prelude to management.* In: Ecology of Freshwater Fish Production, S.A. Gerking (Ed.). Blackwell Scientific Publications, London, United Kingdom, pp. 403-423.

Sadler, B. 1996. *Environmental Assessment in a Changing World. Final Report of the International Study of the Effectiveness of Environmental Assessment.* Canadian Environmental Assessment Agency and International Association for Impact Assessment, Ottawa, Canada.

Sadler, B. and Verheem, R. 1996. *Strategic Environmental Assessment: Status, Challenges and Future Directions.* Ministry of Housing, Spatial Planning and the Environment Publication No.53, The Hague, The Netherlands.

Sadler, B., Verocai I., Vanclay F. 2000. *Environmental and Social Impact Assessment for Large Dams.* Contributing Paper to the WCD Review on Large

Dams. Thematic Review V.2. World Commission on Dams, Cape Town, South Africa.

Sayer, J. and Campbell, B. 2003. *The Science of Sustainable Development: Local Livelihoods and the Global Environment.* Cambridge University Press, Cambridge, UK.

Scudder, T. and Conelly, T. 1985. *Management systems for riverine fisheries*. FAO Fish.Tech.Pap.No.263, Rome, Italy.

Sedell, J.R., Richey, J.E. and Swanson, F.J. 1989. The river continuum concept: a basis for the expected ecosystem behavior of very large rivers? *Canadian Special Publication of Fisheries and Aquatic Sciences*, 106: 49-55.

Senanayake, S.M.P. and Wijetunga, L.D.J. 1987. *A study on the employment generation in Kirindi Oya irrigation and settlement area.* ARTI Research Study No.79, Colombo, Sri Lanka: 85 p.

Shilklomanov, I.A. 1999. *World Water Resources. A new appraisal and assessment for the 21st century.* United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France.

Small, L.E. and Carruthers, I. 1991. *Farmer-financed irrigation: The economics of reform. Wye studies in agricultural and rural development.* Cambridge University Press, Cambridge, UK: 233 p.

Smith, L.E.D. 2004. Assessment of the contribution of irrigation to poverty reduction and sustainable livelihoods. *Water Resource Development*, 20(2), 243-257.

Smith, L.E.D., Nguyen-Khoa, S., Garaway, C.J. and Lorenzen, K. 2001. *The impact of technical change on rural livelihoods in a semi-subsistence Economy: Irrigation Developments and Aquatic Resource Use in Laos.* 74th Seminar on the European Association of Agricultural Economists, 12-15 September, London, Imperial College London, UK.

Smith, L.E.D., Nguyen-Khoa, S. and Lorenzen, K. 2005. Livelihood Functions of Inland Fisheries: Policy Implications in Developing Countries. *Water Policy,* 7(4): 359-384.

Stalnaker, C., Lamb, B.L., Henriksen, J., Bovee, K. and Bartholow J. 1995. *The instream flow incremental methodology: a primer for IFIM.* National Biological Service Report 29. 45 pp.

SUAN 1989. *SUAN-EAPI Exploratory workshop on Lao agroecosystems*. Southeast Asian Universities Agroecosystems Network, Khon Khen, Thailand.

Sultana, O. and Thompson, P.M. 1997. Effects of flood control and drainage on fisheries in Bangladesh and the design of mitigation measures. *Regulated Rivers: Research and Management,* 13: 43-55.

Sutawan, N. 2004. *In search for alternative concept of sustainable irrigated rice culture.* Document presented at the International Network for Water and Ecosystem in Paddy Fields (INWEPF), 01-02 Nov. 2004, Tokyo, Japan.

Tan, C.E., Cheaon, B.J., Sier, H.K. and Moulton, T. 1973. *A report on paddy fields fish production in Krian, Perak*. Ministry of Agriculture and Fisheries, Malaysia Bulletin 128.

Tharme, R.E. 1996. *Review of the International Methodologies for the Quantification of the Instream Flow Requirements of Rivers.* Water law review final report for policy development for the Department of Water Affairs & Forestry, Pretoria. Freshwater Research Unit, University of Cape Town, South Africa.

Tharme, R. E. 2003. A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. *River Research and Applications,* 19.

Tochner K. & Stanford J.A. 2002. Riverine flood plains: Present state and future trends. *Environmental Conservation*, 293: 308-330.

Tolmazin D. 1979. Black Sea – Dead Sea. *New Scientist*, 84: 767-769.

Tudawe, I. 1986. *Dietary intake and nutrition status survey.* ARTI Research Study No.70, Colombo, Sri Lanka: 88 p.

UN Millenium Project 2000. *Investing in Development: A Practical Plan to Achieve the Millenium Development Goals*. Communication Development Inc. Washington D.C.

Vanclay, 2000. *Social Impact Assessment*. Contributing Paper to the WCD Review on Large Dams. Prepared for Thematic Review V.2. World Commission on Dams, Cape Town, South Africa.

Vannote, R.L., G.M. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing 1980. The River Continuum Concept. *Canadian Journal of Fisheries and Aquatic Sciences*, 37: 130-137.

Vermillion, D. 1991. *The turnover and self-management of irrigation institutions in developing countries.* A discussion paper for the New Program of the International Irrigation Management Institute. Colombo, Sri Lanka.

Vigneux, E. and Larinier, M. 2002. Fishways: Biological basis, design, criteria and monitoring. *BFPP, Knowledge and Management of Aquatic Ecosystems*, Special Issue 364, Supplement.

Von Brandt, A. 1984. *Fish catching methods of the world.* Fishing News Books Ltd, London, UK: 1-418.

Walters, C. 1997. Challenges in Adaptive Management of Riparian and Coastal Ecosystems. *Conservation Ecology* 1(2):1.

Wanasinghe, A., Sumanasekera, H.D. and Wijetunga, D.M.A. 1983. *Kirindi Oya Irrigation and Settlement Project: Pre project socioeconomic conditions.* ARTI research study no. 59, Colombo, Sri Lanka: 122 p.

Ward, J.V., Tockner, K. and F. Schiemer, 1999. Biodiversity of floodplain river ecosystems: Ecotones and connectivity. *Regulated Rivers: Research & Management,* 15: 125-139.

Ward, J.V., Tockner, U., Uehlinger, U. and Malard, F. 2001. Understanding natural patterns and processes in river corridors as the basis for effective river restoration. *Regulated River: Research and Management*, 117: 311-323.

Warren, T.J., Chapman, G.C. and Singhanouvong D. 1998. The upstream dry-season migrations of some important fish species in the Lower Mekong River in Laos. *Asian Fisheries Science*, 11: 239-251.

WCD 2000. *Dams and Development – A New Framework for Decision Making*. The Report of the World Commission on Dams (WCD). Earthscan Publication Ltd, London and Sterling, VA.

WCMC 1998. *Freshwater biodiversity: a preliminary global assessment*. B. Groombridge and M. Jenkins (Eds.). WCMC & World Conservation Press, Cambridge,UK: 104 pp (+ 14 maps).

Welcomme, R.L. 1985. *River fisheries*. FAO Fisheries Technical Paper 262. FAO, Rome, Italy: 330 p.

Welcomme, R.L. 1995. Relationships between fisheries and the integrity of river systems. *Regulated Rivers: Research & Management*, 11: 121-136.

Welcomme, R.L. 2001. *Inland Fisheries: Ecology and Management*. Blackwell Science, Oxford, UK.

Welcomme, R.L and Hagborg, D. 1977. Towards a model of a floodplain fish population and its fishery. *Environmental Biology of Fishes*, 2: 7-24.

Welcomme, R.L. and Halls, A. 2004. Dependence of tropical river fisheries on flow. In: Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II. Welcomme R. and T. Petr, Eds., FAO Regional Office for Asia and the Pacific, RAP Publication, Bangkok, Thailand: 267-283.

Welcomme, R.L. and Petr, T. (Eds.) 2004. *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries*. Volumes 1 and 2. Mekong River Commission, Phnom Penh, Cambodia.

Weligamage, P. 2001. *Irrigation and Inland Fisheries in Sri Lanka: Mutually Coexisting Systems for Food and Livelihood Options for Local People*. 8th Sri Lanka Studies Conference, 7-10 November 2001, Jaipur, India.

Wiggins, S. and Shields, D. 1995. Clarifying the 'Logical Framework' as a Tool for Planning and Managing Development Projects. *Project Appraisal,* 10: 1.

Wiley, M. (Ed.) 1976. *Estuarine processes*. Academic Press, New York, USA

Winemiller, K.O. 2004. Floodplain river food webs: generalizations and implications for fisheries management. In: Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II. Welcomme R. and T. Petr, Eds., FAO Regional Office for Asia and the Pacific. RAP Publication, Bangkok, Thailand: 285-309.

World Bank 1993. *Public Involvement in Environmental Assessment: Requirements, Opportunities and Issues.* Environmental Assessment Sourcebook Update No.5. Environment Department, The World Bank, Washington D.C., USA.

World Bank 1996. *Handbook on: Participatory Irrigation Management.* The Economic Development Institute of the World Bank, Washington D.C., USA: 56 p.

World Bank 2003. *Lao PDR: Country Brief.* Regions and Countries, East Asia and Pacific. The World Bank, Washington D.C., USA.

World Food Summit 2002. *Report of the World Food Summit: 5 years later.* Food and Agriculture Organisation of United Nations, Rome, Italy.

Zhongping Z., Hemakumara M. Makin I. and Barker R.(Eds.) 2001. *Data Book: The Ruhuna Basin; IWMI Benchmark Basin in Sri Lanka* International Water Management Institute, Colombo, Sri Lanka.