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Promotion of sustainable capture fisheries and aquaculture in Asian reservoirs and lakes

Upali S. Amarasinghe[1], Annie Duncan[2,†], Jacques Moreau[3], Fritz Schiemer[4], David Simon[5,*] & Jacobus Vijverberg[6]
[1]*Department of Zoology, University of Kelaniya, Kelaniya, Sri Lanka*
[2]*Royal Holloway Institute for Environmental Research, Royal Holloway University of London, Egham, Surrey, TW20 0EX, U.K.*
[3]*Institut National Polytechnique de Toulouse ENSAT, B.P. 107, Auzeville Tolosane, F-31326 Castanet Tolosan, France*
[4]*Department of Ecology and Conservation Biology, University of Vienna, A 1090, Austria*
[5]*Centre for Developing Areas Research, Department of Geography, Royal Holloway, University of London, Egham, Surrey TW20 0EX, U.K.*
[6]*The Netherlands Institute of Ecology, Centre for Limnology, Rijkstraatweg 6, 3631 AC Nieuwersluis, The Netherlands*
*(*Author for correspondence)* *†Deceased.*

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Abstract

A collaborative international project funded by the European Union's INCO-DC programme is undertaking limnological, fish biological, environmental and socio-economic research in five tropical lakes and reservoirs in Sri Lanka, Thailand and the Philippines over the period 1998–2001. The aim is to determine their trophic structure and their capacity to sustain both their existing fisheries and present and future aquaculture. In some cases, these activities could potentially be expanded for the benefit of rural communities and of the local market within the bounds of social and environmental sustainability. This paper describes the concepts and methods involved in this innovative multidisciplinary project which aims to integrate limnological, fisheries and socio-economic issues in a comparative approach involving Asian and European research teams.

Introduction

Asian reservoirs are rarely, if ever, constructed for fisheries purposes alone, being usually designed as multifunctional structures for irrigation to enable a second annual rice crop, the generation of hydroelectric power and the provision of water for domestic and industrial use. Nevertheless, fisheries yields and the income generated from these contribute significantly to the total income arising from reservoirs (Petr, 1985; Pawaputanon, 1986) and particularly for rural communities where government investment is limited or is being reduced in terms of structural adjustment and related policies. Moreover, during the last 20 years, the use of reservoirs' for aquaculture has contributed increasingly to the enhancement of protein production as well as to increased incomes in rural areas where both are needed (Costa-Pierce & Soemarwoto, 1990). However, the uncontrolled development of aquaculture in cages and pens can cause an imbalance in aquatic ecosystems and a deterioration of the capture fisheries. This effect is due to high organic loading from added feed and additional fish excretion and faecal production, or to the extensive coverage of the reservoir surface area by cages and the consequent interference with natural movements and reproduction of the native fish species (Delos Reyes, 1993; Pullin et al., 1993). Although seldom considered seriously in the past, the importance of integrating the socio-economic issues associated with aquacul-

ture development into a more holistic approach is now becoming more widely appreciated in different contexts (e.g. Davies & Afshar, 1993; Lightfoot et al., 1993; Thomas, 1994; Bailey et al., 1995; Chen et al., 1995; Hoque, 1995; Naegel, 1995; Ulluwishewa, 1995; Toufique, 1997).

In terms of such a holistic approach, optimised management may be promoted by using scientific information to assess the limits of biological productivity of particular local reservoirs to support environmentally sustainable capture fisheries and aquaculture development. The economic and social viability of given levels of these activities are also assessed as an integral part of the methodology. In terms of general current sustainable development thinking in the context of the South (Simon, 1989, 1999; Redclift & Sage, 1994; Pugh, 1996; Chambers, 1997; Twyman, 1998; Granfelt, 1999), it is now increasingly accepted that the objective in relation to fisheries should be to help empower rural fisherfolk through the generation of knowledge and resources to control their own fisheries yield in a sustainable manner and without causing a deterioration of their own aquatic resources (Davies & Afshar, 1993; Lightfoot et al., 1993; Hoque, 1995; Ulluwishewa, 1995; Amarasinghe & De Silva, 1999). In other words, relevant information for participatory local management should be generated, preferably through participatory methods that enhance skills and confidence. This information needs to be made available in forms appropriate to local populations and to decision makers, governments and/or development agencies and other institutions with responsibilities for the sustainable exploitation of these aquatic resources.

The necessary information for such scientifically-based management – linked to local knowledge and experience – is both complex and multidisciplinary and requires an ecosystems approach (Schiemer & Duncan, 1988). Limnological study will define the biological, chemical and physical nature of each reservoir, as well as its hydrological regime including those elements imposed by humans. Knowledge of the fish population dynamics of both commercially exploited as well as currently unexploited species, is essential. This has three applications: to assess the levels of current exploitation relative to maximum sustainable yield, to assess the potential of harvesting additional species (subject to practicability and socio-cultural acceptability), and to assure biodiversity conservation. Information is also required about the local market, including whether fish yields are acceptable, meet current demand, and provide sufficient income to fisherfolk and aquaculturists. We hope to discover what factor(s) limit(s) the income of artisanal fisherfolk: poor biological productivity, unacceptable fish species, inappropriate fishing methods, poorly developed local market facilities, social attitudes to freshwater fish, waterborne diseases, dangerous wildlife, or some combination of these.

Such questions can be answered only by simultaneous studies of limnology, fisheries and socio-economic development. This is precisely the objective of the international 'FISHSTRAT' project currently being funded by the European Union's INCO-DC programme, and which forms the subject of this paper. The project's formal title is *Strategies for partitioning the productivity of Asian reservoirs and lakes between capture fisheries and aquaculture for social benefit and local market without negative environmental impact.* A key objective of the intra- and international comparative methodology is to ascertain the relative importance of local conditions and more generic factors governing the current dynamics in a representative sample of five tropical Asian reservoirs and lakes. The dearth of such comparative work, especially in conceptually rigorous as opposed to essentially descriptive terms, has recently been remarked upon by Talling & Lemoalle (1998). Nevertheless, we are sensitive to the necessity of avoiding simplistic (over-)generalisations.

Development of the concept leading to the project

It is well known that, due to the nature of the work involved, limnology, fisheries and the socio-economic aspects of the life of fishing communities in lakes and reservoirs are often investigated in a compartmentalised manner. A handful of comprehensive studies of tropical lakes and reservoirs such as Parakrama Samudra (Schiemer, 1983) and Tissawewa (Pet et al., 1996) in Sri Lanka, and Kariba on the Zambezi River (Moreau, 1997), have dealt with trophic dynamics in lacustrine habitats and their associated fisheries. There has also been a recent emphasis on the incorporation of socio-economic issues in fisheries development strategies (Pomeroy, 1991; Berkes, 1996; Baijot et al., 1997; Nathanael & Silva, 1998).

This study links three diverse disciplines, namely limnology, fisheries and socio-economic development, drawing on the extensive experience of an international group of scientists. Reservoir resources in tropical Asia are used for multiple purposes, such as

irrigation and the generation of electricity, which may affect the nutrient dynamics on which primary productivity and fish production depend. Furthermore, intensive exploitation of the reservoir resources by establishing cage culturing changes the trophic status of the reservoirs. People are, therefore, active and often important players in the ecological dynamics of these water bodies. Changes in the attitudes, needs and aspirations of the human populations which utilise the reservoirs' resources will bring about changes in the fish community composition and nutrient dynamics in ecosystems being assessed by this project.

As such, single-disciplinary studies and the traditional monospecific approach to fisheries management (Gulland, 1983) are no longer adequate. Therefore, using more systems-oriented trophic modelling methodologies for aquatic ecosystems (Christensen & Pauly, 1993) and simulation models for aquatic ecosystems (Walters et al., 1997), the human impact on reservoir ecosystems can be evaluated. These are then combined with appropriate socio-economic methods, such as baseline surveys of littoral communities and in-depth research on fishing, aquaculture and fish marketing, to achieve a distinctive and holistic approach. The major features of this project are shown in Figures 1 and 2.

The reservoirs being researched

The five water bodies considered here were selected in order to represent a wide range of productivities and trophic structures of fish communities, and also a variety of direct and indirect impacts from human activities in their catchment areas. This should enable us better to understand the impact of limited biological productivity upon commercial fish yields as well as the extent of any unexploited fish populations.

The three similar-sized Sri Lankan reservoirs, Victoria, Udawalawe and Minneriya, have very different characteristics, whereas Ubolratana reservoir in northeast Thailand is very much larger (Table 1). Lake Taal, in the Philippines, is different from the other water bodies by being a natural and deep crater lake with an active volcano on its central island. The lake lies only a few metres above sea level and the Pansipit River links its southwestern corner to the sea, providing an important fish migratory route. The lake's western and northwestern littoral zones, in particular, are currently colonised by extensive aggregations of floating cages and fish pens (Aypa et al., 1999).

All five water bodies support active artisanal fisheries. In Sri Lanka, the fisheries are based on Tilapiine fish and carp, whereas Clupeids contribute a significant proportion of the catch in Thailand and the Philippines (Chookajorn et al., 1994; Duncan, 1999).

The partnership

The partner institutions within this Project are from the United Kingdom, Austria and France, together with collaborating scientists from The Netherlands and the Czech Republic in Europe, and from Sri Lanka, Thailand and the Philippines in Asia (Table 2).

This partnership fullfils the requirements of the balance between member states and non-member states and between Europe and tropical countries which is favoured by the European Union's funding bodies. The partners are involved to varying extents in 5 main tasks as represented in Figure 3. The partnership originates from active scientific co-operation over the last 20 years between the Asian and European institutions and individuals (Vide Schiemer, 1983, 1996; Newrkla & Duncan, 1984; Schiemer & Duncan, 1988; Amarasinghe et al., 1989; Moreau & De Silva, 1990; Pet et al., 1996; Amarasinghe et al., 1997; Piet & Vijverberg, 1998 on Sri Lanka; De Silva et al., 1991; Chookajorn et al., 1994; Moreau & Sricharoendham, 1999 on Thailand, especially Ubolratana; and Pauly et al., 1988; Moreau et al., 1990; Pauly et al., 1992; Soriano et al., 1992; Moreau et al., 1993 on the Philippines).

It should be noted that, in Sri Lanka, the partners are universities and a tertiary research institute whereas, in Thailand, the National Inland Fisheries Institute (NIFI) is part of the Department of Fisheries of the Royal Government specifically charged with reservoir fisheries management. In the Philippines, the partners are of various origins: The National Institute of Biology, University of the Philippines, Diliman, is involved in fundamental research, whereas the Bureau of Fisheries and Agricultural Resources (BFAR) and the Philippine Council for Aquatic and Marine Research and Development (PCAMRD) are both governmental agencies, involved mainly in applied studies of fisheries and socio-economics.

The participation of the Asian partners is essential to the success of the research project because of their local knowledge, including socio-cultural and economic aspects of communities surrounding the water bodies. They are undertaking regular field studies

Table 1. Characteristics of reservoirs in the study

Name of lake and country	Area (ha)	Mean (and maximum) depth (m)	Comments
Sri Lanka			
Victoria Reservoir	2270	36.5 (105)	Hydroelectric reservoir in hill country, impounded in 1984
Minneriya Reservoir	2251	4.0 (11.7)	Ancient irrigation reservoir in low country, impounded in 276AD and restored in 1903
Udawalawe Reservoir	3362	5.5 (15.3)	Irrigation reservoir in low country, impounded in 1964/68
Thailand			
Ubolratana Reservoir	41 000	5.5 (16.0)	In NE Thailand, impounded in 1965 and has a large pelagic zone. Clupeid fishery
Philippines			
Lake Taal	26 350	65.0 (198)	A natural lake with an active volcano. Clupeid fishery

Note: There is substantial variation in depth in all the water bodies, and a seasonal drawdown of up to 2.5 m within the four reservoirs.

Table 2. Institutional collaboration within the FISHSTRAT partnership

Partner	Institution(s)
Partner 1 United Kingdom (Co-ordinator)	Royal Holloway Institute for Environmental Research and Dept. of Geography, Royal Holloway, University of London *Subcontractors* • Netherlands Institute of Ecology • Institute of Hydrobiology, Czech Academy of Sciences, Ceske Budejovice, Czech Republic
Partner 2 Austria	Department of Zoology, University of Vienna • Department of Limnology, University of Innsbruck
Partner 3 France	Tropical Fisheries Unit, Institut National Polytechnique, Toulouse
Partner 4 Sri Lanka	Department of Zoology, University of Kelaniya *Subcontractors* • Institute of Fundamental Studies, Kandy • Department of Fisheries Biology, University of Ruhuna
Partner 5 Philippines	University of the Philippines, Diliman, Quezon City (UPD) • Bureau of Fisheries and Aquatic Resources (BFAR) • Philippines Council for Marine and Aquaculture Research and Development (PCAMRD)[a]
Partner 6 Thailand	National Inland Fisheries Institute, Department of Fisheries, Bangkok

[a] Assumed Philippine Co-ordinatorship on 1 January 2000.

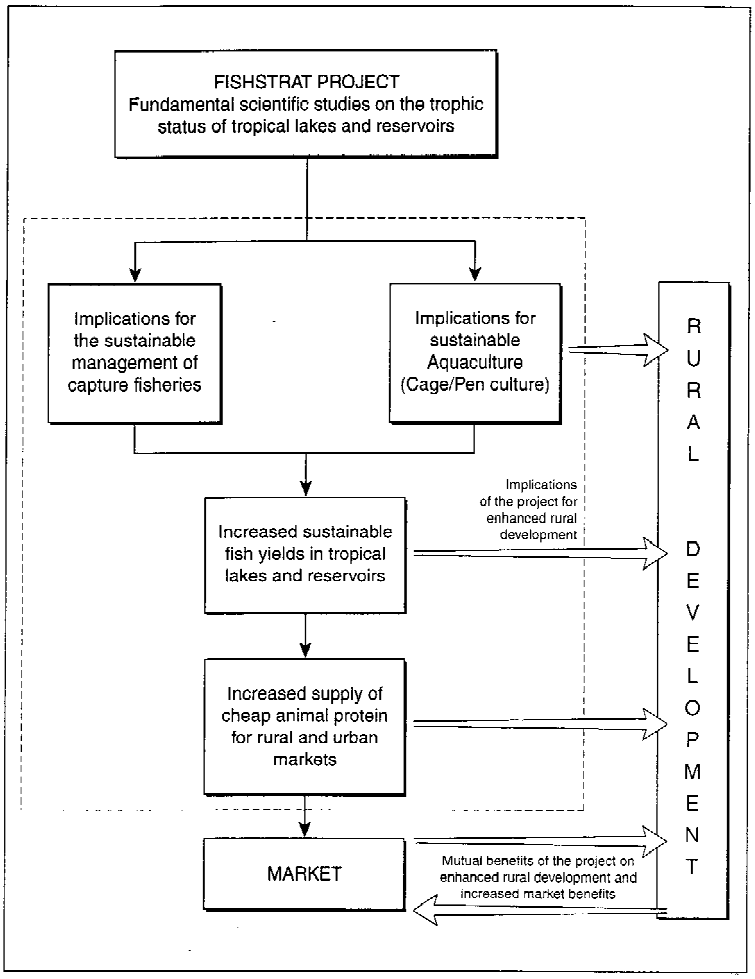

Figure 1. Integrated research to strengthen rural development and the market through scientific co-management of inland fisheries.

in order to obtain comprehensive information about the seasonal variation and dynamics of the respective ecosystems. Where possible, research for this project is being integrated into their existing monitoring programmes to rationalise resource use and maximise returns to investment. Technical and methodological training of junior staff, research assistants and post-graduates during joint field visits with the European team members is contributing to local capacity enhancement.

Implementation of the project

The total duration of the project is 42 months from January 1998, divided into three phases: *Phase 1* (7 months) has already been completed. This culminated in a partnership meeting and workshop at the Institute of Fundamental Studies in Kandy (Sri Lanka) in April 1998, during which the scientific programme was discussed and agreed by everybody, overcoming the problems of different languages and cultural background. Some 35 protocols and questionnaires were produced, with the principal objective of ensuring the compatibility of data and results across the three countries. This necessitated careful discussion and planning, with consensus-based decision-making in order to maximise the level of understanding of research methods and commitment by all concerned, in view of the diversity of backgrounds, disciplines, sensitivities and priorities of participants, as well as of conditions in the five water bodies. Initial training in the latest hydro-acoustics techniques and in participatory socio-economic research methods was also provided.

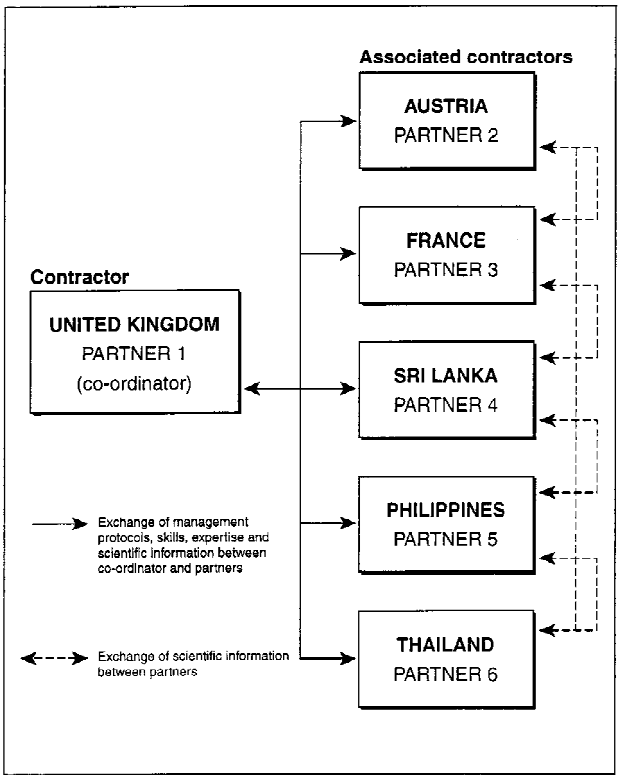

Figure 2. FISHSTRAT organisational and management framework.

Phase 2 (20 months) began on 1st August 1998. During this phase, field investigations by the Asian partners of three of the five tasks quoted above have started in all five water bodies i.e. trophic studies, fish and fisheries and socio-economics. Field investigations involving the European partners together with Asian colleagues took places in February/March, July/August (and socio-economics in Sri Lanka also in December) 1999 and in February 2000. They carried out specific aspects of limnological, fisheries and socio-economic development research, and held the first workshop, on limnology, in Bangkok immediately after the final field visit.

Phase 3 (15 months) will be devoted to data analysis and workshops in order to merge the data collected by specialists in the various disciplines into a consistent set of information for all three countries which will form the basis of the proposed guidelines for improved management strategies and of their translation into suitable format for local people. For that purpose, a specific workshop will be organised in Sri Lanka at the end of the project in order to disseminate the key results to representatives of various institutions in charge of fisheries and aquaculture management and development in the three countries.

An important characteristic of the project is that all information is contributing to a centralised Project Database which is being managed by the co-ordinating institution (Royal Holloway) and is made available to every partner. In addition, regular progress reports will ensure that active analysis of the results is a continuing process and that the whole partnership is kept informed of progress.

Current and expected results

Several results have already appeared progressively during the main period of research activity.

A quantified assessment of the existing levels of fish grazing upon phyto- and zooplankton from environmental impact indicators and size structure of the plankton. This will act as a check of the applicability of environmental assessment indicators in tropical reservoirs and lakes.

The applicability of scientific acoustics for fish stock assessment in tropical water bodies of differ-

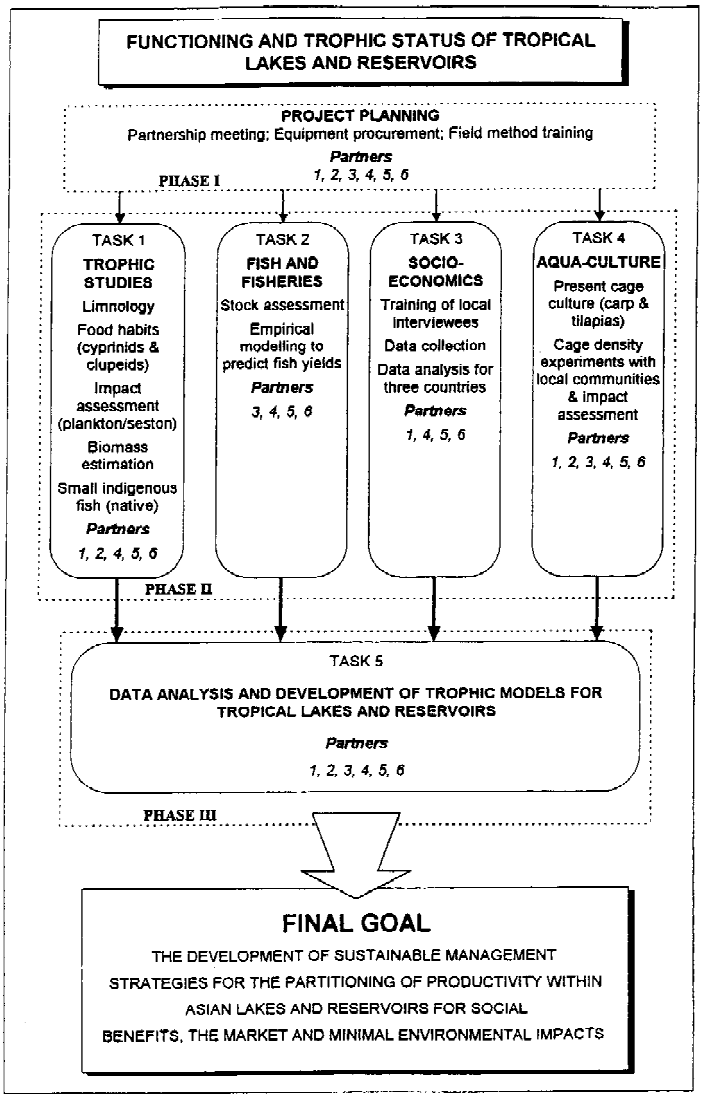

Figure 3. Internal structure of principal project tasks and associated responsibilities.

ent trophic status, limnology and climatic conditions is currently being demonstrated. It will lead, among other things, to a quantitative evaluation of the unexploited fish resources, if any, in each water body.

The possibilities of theoretical predictions of the potential yield of commercial and potentially commercial fish species based on population analysis of commercial yields of other abundant species. This involves modelling exercises using multiple regression analysis (Moreau & De Silva, 1990) and neural networks (Lae et al., 1999).

A trophic classification of the five studied water bodies applicable for tropical reservoirs and lakes in general. This will be obtained through various means of ecosystems analysis. Among them we will use the ECOPATH model and software as already performed for artificial Asian lakes (Chookajorn et al., 1994) in order to express quantitatively the trophic relationship among groups which have been investigated during the Project and to assess the possible influence of variations of the fishing effort and of important ecological changes occurring in the lake on the structure of the whole ecosystem (Walters et al., 1997, 1998). This will result in an understanding of freshwater tropical Asian reservoir and lake ecosystems of different trophic status, including the effects of humans on the ecosystem through both fisheries and aquaculture, as well as other activities affecting the water bodies.

A quantitative approach is being applied to the environmental impact of the aquaculture practices both in terms of modifications to water quality in the vicinity of the cages and in terms of ecological costs as assessed by using the concept of an ecological footprint (Kautsky et al., 1998), originally applied to the wider impact of cities (Pugh, 1996; Wackernagel & Rees, 1996). The utilisation of this concept will help to identify the development limitations of cage aquaculture in the reservoirs and the possible conflict with use of the primary productivity of the lake by both capture and aquaculture fisheries.

An updated knowledge of the socio-economic contexts within which fisheries development is currently taking place, including detailed understanding of the role of capture fisheries and aquaculture in each water body. Detailed interview and participatory observation-based surveys are being undertaken among adjacent communities in order to establish a socio-economic baseline, to analyse fishing operations, and to assess the nature and organisation of fish marketing. Initial results to date suggest both that there is great diversity of conditions within and between water bodies but that, on account of its considerably larger population and history of commercial fisheries, Lake Taal currently supports by far the greatest and most commercialised fishery. However, even here, fishing is commonly pursued as part of a multi-activity household strategy in combination with aquaculture, agriculture, livestock raising and/or wage labour.

In co-operation with local fisheries societies, local fishermen will be informed about the technological 'know-how' on the development of reservoir aquaculture systems.

Finally, the progressive formulation and dissemination of scientific management procedures in accessible formats for local communities and the relevant authorities. It will help to assess the potential for application of scientific management procedures by local fisheries societies in order to increase their income and enhance rural development. This point will be dealt with during a final workshop to be held in Kandy (Sri Lanka), specifically for potential users of the results of the project (see above).

Strategic (operational) criteria

The successful execution of such a highly diverse research agenda is strongly dependent on the following considerations.

The experience of managing such large international projects by the co-ordinating institution. Because of the necessity of frequent contacts with the EU authorities in Brussels and proper flexible financial management procedures, this institution has to be located in Europe.

The long experience of co-operative work already completed by leading colleagues and their institutions from Europe and tropical countries (in our case, Asian countries) before the beginning of the project.

The capacity of the partner institutions to keep reliable scientific and financial records and the experience of international co-operative research of the individual colleagues involved as well as their capacity to overcome language and cultural barriers.

The easy, quick and reliable communication among partners through electronic mail, and quick reply to the queries of the co-ordinator for proper dissemination of the information.

The awareness of everybody of the basics of the techniques used out of his/her specific research field in order to facilitate discussions among specialists of various disciplines.

Finally, the project will offer the Asian scientists facilities for, and experience in, publishing the results of their research work internationally so that their scientific expertise will be properly acknowledged and more widely known. This contribution to capacity building will commence with presentations of the research results to the international scientific community during international workshops and symposia, and through publication in international refereed journals.

Conclusion

This interdisciplinary study of five water bodies in three diverse South and Southeast Asian countries is designed to distinguish the relative importance of locally specific and more generically applicable issues and processes. As such, it represents a major advance over previous studies of single water bodies, even the few which have been interdisciplinary. Implicit in the previous sentence is a keen awareness of the need to avoid simplistic overgeneralisations about tropical Asia as a whole, let alone other regions. The project also integrates 'pure' and applied, policy-oriented research with the objective of promoting more environmentally, socially and economically sustainable utilisation of the capture fisheries and aquaculture. This should benefit not only the littoral communities de-

pendent on the resources and ecosystems concerned, but also the wider regional and national economies and societies.

It is expected that this project will lead to continuing scientific exchanges among the current partners after its completion. This should also help indirectly to achieve the main goal of the FISHSTRAT project, namely to offer scientific management procedures in a readily understandable format to local fisherfolk via their fisheries societies in order to help them to enhance earnings through increased yields and to improve rural conditions without negative environmental impacts.

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