Practical guidance for the estimation and allocation of environmental capacity for aquaculture in tropical developing countries (TROPECA)

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This research is dedicated to the fond memory of Dr Ta Khac Thuong, a collaborator on this project from the University of Fisheries, Vietnam, who died in 2004. Not only was he an excellent scientist, but perhaps more importantly, a wonderful companion.

Acknowledgements

This research has been a long and complex collaboration – between researchers in different countries, and between researchers, farmers, extension workers and government officers. Many people in Vietnam, Bangladesh and the UK have contributed time and effort to assisting with the research, through workshops, meetings, and on farms. This report cannot do justice to all of this activity, but we take the opportunity here to thank everyone who has been involved.

Disclaimer

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Contents

1 Summary

Background and rationale
Aquaculture is developing very rapidly in Asia, and has already been associated with environmental degradation. The concept of environmental capacity, and the suggestion that it might be used as a strategic tool or framework for environmental management of aquaculture, has been aired widely at aquaculture meetings at global and Asia regional level. The need to engage farmers themselves more directly in taking collective responsibility for environmental management has also been identified repeatedly, given the substantial cumulative impacts that can arise from large numbers of small farms.

Aims and outputs
This collaborative research project was designed to explore the possible value and application of the concept of environmental capacity at grass roots level in tropical developing countries, both in relation to aquaculture where there are already signs of environmental degradation, and as a preventive tool in less developed areas where significant future development and/or intensification is possible or likely. It was designed to compare this strategic and predictive approach with frameworks based on more traditional monitoring and adaptive management techniques.

The project was also designed to explore more generally mechanisms for engaging groups of farmers in co-operative environmental management – in other words raising awareness of both their responsibility for the wider environment, and the benefits that might arise from improved management, and facilitating the development of farmer based institutions and mechanisms to address these and related issues.

While the project necessarily addressed soil and water quality within individual farms (ponds or cages), the main focus was on *the quality of the wider environment*, and the *relations between a group of farmers and this wider environment* – for example a large pond, a canal and pond complex, or a coastal bay or lagoon.

More specifically, the project sought to deliver the following outputs (see Logical framework, annex 1 for the full text):

1. Enhanced understanding amongst collaborators, other scientists, and regional professionals of the applicability of simple environmental capacity models and/or adaptive management approaches in providing effective environmental management of key tropical aquaculture systems.

2. Identification and review of strengths and weaknesses of alternative biological and physical environmental indicators and their potential role in the development of practical environmental quality standards for a range of tropical habitat types associated with aquaculture.

3. Enhanced understanding amongst collaborators, other scientists and regional professionals of the applicability of alternate planning instruments to allocate environmental capacity and control development for aquaculture in tropical developing countries.

4. Practical strategies and management plans for promoting aquaculture equitably within environmental capacity for two or more case studies.

5. Enhanced capacity to plan and manage tropical aquaculture equitably within environmental capacity on the part of key government departments and agencies regionally, nationally and internationally.

Approach and methodology

Five case studies were selected representative of a range of agro-ecosystems, aquaculture systems, and social conditions:

- Cage aquaculture of spiny lobster (*Panulirus*) in marine cages in Khanh Hoa, South Central Vietnam
- Semi intensive shrimp culture (*P. monodon*) in brackishwater ponds in Dosun, Haiphong, northern Vietnam;
- Improved extensive shrimp culture within a wider rice cultivation zone in Can Gio, southern Vietnam;
- Improved extensive shrimp farming (in alternation with rice) near Khulna, Bangladesh
- Multiple use ponds, Rajshahi, Bangladesh

In all cases we used a standard approach or research framework, while still allowing substantial flexibility to allow local research managers to tune and adapt their research to the particular needs and opportunities which arose. We were concerned to engage farmers themselves from the outset, and to allow them to take some part in guiding the broad direction of the research.

The common framework or "tropeca approach" was as follows:

1. Analyse local ***issues and institutions*** relating to management of individual farms and the wider environment, and engage with farmers in developing a research program to address these.
2. Identify existing and potential farmer level ***indicators*** of performance and environmental quality – at farm level and in the wider environment.
3. Develop an understanding of the ***hydrodynamics*** of the wider aquatic system – flows, currents, tides, volumes and depths.
4. Assess ***water and soil quality*** and their variation over the cropping cycle, and highlight any issues or problems.
5. Develop ***environmental capacity models***. There are four basic elements or levels of analysis which may be appropriate according to circumstance:
    1. *Nutrient budget*/*mass balance* estimates (inputs, outputs, residual) for the whole aquatic system, and where appropriate sub-components, for the pond/cage and for the wider aquatic system
    2. *Flushing rate* of ponds, and wider aquatic system
    3. Nutrient *dispersion/mixing/accumulation* within the wider aquatic system
    4. *Nutrient assimilation*
6. Facilitate the development of a farmer ***group management agreement***, drawing, where relevant and feasible, on the indicator and environmental capacity analysis.

This approach was, by necessity, poorly defined at the start of the project, and evolved steadily through exchange between case research managers over the course of the project. In this sense the approach was an evolving guidance framework, and also an *output* of the project. The relative emphasis afforded these 6 components varied significantly from case to case, reflecting variations in conditions, capacity, and perceptions of value.

Project management

This research is the result of collaboration between 8 organisations, around 15 researchers and several research assistants. Primary responsibility for case research lay with national case research managers, while Nautilus Consultants played a co-ordinating and background research role. There are undoubtedly significant difficulties in conducting this type of research, but the breadth of perspective gained is invaluable, and there was substantial mutual learning and capacity building. Specific problems encountered included:

- Two of the cases suffered significant setbacks in terms of staff turnover (Dosun, Can Gio).
- The “wider aquatic system” at Dosun was radically changed during the project through the commissioning of new water supply and effluent canals;
- One of the collaborators from University of Fisheries (Dr Thuong) sadly died;
- One case had to be changed mid-way through the research for local political reasons.

Main findings

The “Tropeca approach” has been successful in terms of gaining the trust and involvement of fish farmers, raising awareness of environmental issues, and facilitating the development of local environmental management initiatives.

Farmer engagement

All projects experienced high levels of interest and co-operation from farmers. The initial issues identification and discussion workshops were all very successful, with farmers delighted to have researchers ask them what they thought were the issues, and what ought to be done – within the overall scope of environmental and water resource management.

This necessarily created a dilemma in some cases, since that which the farmers wished to see undertaken did not always fit with the project logical framework. We compromised in several cases, tracing a difficult path between required project outcomes and local relevance. In practice we would have preferred to have had the freedom to respond more directly to farmers’ needs and concerns. Clearly there is a dilemma here, and good research needs to be well planned. However, we feel that if research is to be truly supportive of development the balance should shift to more needs orientated, adaptive and flexible research.

The approach we used is notably different from “the livelihoods approach” where researchers attempt a comprehensive analysis of livelihood systems which is then used to improve understanding and guide research. Our experience was that farmers are very well placed to identify problems and opportunities much more directly and simply through discussion with researchers.

Indicators
Farmers are familiar with, and use in day to day management, a wide range of indicators of environmental quality and performance, demonstrating their understanding of the importance of soil and water quality for successful production. This applies to both pond water and water in the wider environment. Some indicators are common to all cases; others are unique to a particular situation. From the perspective of management many of the indicators are weak in so far as they are indicators of poor conditions, rather than indicators of problems to come. They serve to inform crisis management rather than prevent future problems. Nonetheless they have significant value in management terms and we have brought these together as a comprehensive set. Some deserve further research in terms of their utility and application.

Water and soil quality
Water quality was far from optimal in most cases, despite the relatively extensive systems (other than lobster cage culture) being studied. Very high phosphorus levels (around 8 times recommended) were found in one of the multiple use freshwater ponds. Ammonia levels were very high – exceeding recommended levels - in both supply and pond water of shrimp ponds near Khulna. Water quality in and around the lobster cages at Xuan Tu bay declined significantly over the project life. Water quality at Dosun on the other hand improved over the project life, probably related to improvements in the canal system. Nutrient levels were also high in sediments, although less than expected from the nutrient budgets (see below).

Nutrient budgets
Nutrient budgets were developed for all cases and served as simple and interesting starting points for exploring water quality and nutrient use within the system. Nutrient budgets can also be discussed simply with farmers - in terms of inputs, outputs, and residuals - and have immediate resonance in terms of farm management and economics.

The major finding here was that a very large proportion of input phosphorus appears to be retained within the pond systems, although it does not seem to be accumulating significantly in the sediment. Further work is underway to examine the degree to which this loss can be explained in terms of bound phosphorus. However, it is notable that many other studies of nutrient budgets in ponds also appear to “lose” phosphorus. It is clear that these processes are not fully understood, and/or the water and sediment sampling methods are inadequate to identify all forms of phosphorus. Given the apparently very large accumulations, and the possibility that some of this may be regenerated at some point in the future, further technical research is required.

Dispersion models
Most case studies did not progress as far as the development of dispersion models and/or did not prioritise these. The pond and canal systems were analysed using a “Russian doll” approach: analysis at pond level; analysis at canal subsystem level; analysis at a higher level etc. At each scale, mixing within the system, and water/sediment conditions were assumed to be uniform. Of course this is far from reality, but dispersal modelling would have been extremely complex and arguably unnecessary. The mass balance analysis alerts to possible general problems; observation (including use of indicators) can be used to alert to local accumulations. In any case, water quality in some of the pond systems was strongly affected by inputs to the system from outside – in terms of both sediment and nutrient. Modelling the exchange, oscillation, deposition of sediment and associated nutrients within sub-

systems was considered beyond the scope of the research, and inappropriate in terms of the project’s capacity building objectives.

The exception to this was Xuan Tu lobster village where dispersion of waste was an obvious issue of concern to farmers, and where the farms acted as a clear point source within an otherwise relatively pristine environment. In this case models developed by the Institute of Aquaculture could be applied relatively simply.

Environmental capacity

Environmental capacity can be estimated simply and roughly from mass balance and flushing models. If nutrients are accumulating at a significant rate within the wider system, then capacity is being exceeded and problems are likely sooner or later. Assimilation within the system should be taken into account in these estimates, and this is not easy. Assimilation rates for carbon may approximate to something between 3 and 5g/m^2/day according to the limited literature available for tropical systems. Estimates are also available with respect to denitrification. Phosphorus stays in the system, but typically accumulates mainly in its unavailable form in sediments.

However, while our nutrient budget estimates suggest a relatively rapid accumulation of phosphorus in the pond systems, this is not borne out in the field samples, suggesting either weakness in the estimates or in the sampling. . Work undertaken by CRSP has also often shown an apparent “loss” of phosphorus within pond systems, suggesting the analytical techniques may be inadequate.

Either way, the apparent accumulation of phosphorus in the pond systems, including relatively extensive systems is a cause for concern, although it might also be considered an opportunity in some cases. In the freshwater pond system for example, the accumulation of P suggests that sediment management to release nutrients might be a better way forward than continuing with standard fertilisation regimes. In the rice-shrimp systems release of P from sediments could enhance rice yields and allow for reduced inputs.

In the case of lobster cages in Xuan Tu our model suggests that environmental capacity was probably exceeded at some point in the last three years, and this prediction is borne out by the water quality data which shows significant decline in recent years. This suggests that the simple mass balance/flushing model is a useful predictive tool and could probably be applied in other situations. The model is precautionary in so far as it does not take account of nitrogen assimilation in sediment beneath the cages. However – as noted above, phosphorus in the sediment is not assimilated, and there is always the danger of re-suspension and wider impacts on the bay if adequate nitrogen is already available.

In the case of Xuan Tu we were also requested by the provincial Peoples Committee to make some relatively simple estimates of sustainable cage density. This we have been able to do, based on the sediment dispersal model mentioned above. We anticipate guidelines and regulations based on these estimates within a broader set of guidance being developed by farmers and local government in Khan Hoa.

Nutrient discharge to the wider environment

The highest nutrient levels in the water discharge from pond systems was for *extensive* systems in Bangladesh. Nutrient levels were actually lower in the more intensive (semi-intensive) systems studies in Vietnam. In other words, intensive fertilisation of paddy and paddy-shrimp systems generates a higher dissolved nutrient load on the wider environment than does moderate feeding of shrimp on pelleted feeds in semi-intensive systems.

Management implications

- The typical classification of shrimp farms as intensive, semi-intensive and extensive, and the assumption that more intensive means more polluting is misleading. Well fertilised extensive systems can be at least as polluting as more intensive systems. The degree to which a system is polluting depends entirely on nutrient management and utilisation efficiency.

- While these aquaculture systems typically extract less than 50% of input nutrients, this is mainly an internal problem: in our case studies rather little is flushed to the wider environment.

- Farmers must take care of organic matter and nitrogen build up even in extensive systems. Low DO and nitrite spikes are potentially (and in the case of Khulna actually) serious.

- Although residual phosphorus may be difficult to re-use or assimilate in other crops such as seaweed or rice, there is significant potential for reducing nitrogen fertilisation.

General conclusions

The adaptive approach taken to this research (adaptation to local conditions; steady refinement of research focus through the project) has yielded useful and practical results in a relatively short time frame. While this adaptive approach has meant that some of the scientific data is less thorough and consistent than would have been the case if the project had been driven by mainly scientific objectives, we believe that this weakness is more than outweighed by the awareness and capacity building outputs of the project.

The estimates of environmental capacity are very rough, with substantial residuals and uncertainty, but their development with close farmer cooperation has improved understanding of the nature of nutrient dynamics in the wider environment, and raised awareness amongst farmers of the possibility of forward thinking and precautionary management.

Local environmental management initiatives are underway in three of the case study areas, building on this learning. Monitoring, using simple indicators at key locations within the systems should allow for some testing of the assessments and on-going engagement of farmers in environmental management.

The nutrient budgets for the wider environment have also raised important questions relating to the fate of phosphorus in tropical pond, paddy and canal systems.

A key output of this project is ***practical guidance***. Our experience in undertaking the research suggests that detailed technical guidance on estimating environmental capacity through the use of empirically validated theoretical models is of limited value in many situations, and only useful for the most highly developed systems, the most impacted systems, and where significant resources are available. Applying the “Tropeca approach” as it has evolved over the course of the project (as described above) does appear to have significant merit and is much more widely applicable. The general guidance on applying the approach offered in Annex 2 is now being adapted at local level in both Vietnam and Bangladesh. The core of this approach is simple and can be widely disseminated: *engage farmers in developing simple nutrient budgets as a framework for discussing possible environmental problems and appropriate management measures.* In some cases farmers may then be able to develop their own management protocols and/or use nutrients more efficiently. In other situations, local government or government agency may need to facilitate this process and develop co-management frameworks. In the extreme…government may need to intervene to estimate and "allocate" capacity. In practice, environmental capacity was only clearly being exceeded in one case study (lobster cages) - and this has already become an issue for government intervention with guidance solicited from the project researchers.

2 Background and rationale

2.1 The problem

There is a widespread tendency for successful aquaculture development (irrespective of scale) to exceed environmental capacity in developed and developing countries. This negatively impacts the sustainability of aquaculture itself, through poor productivity and disease, and may negatively impact other users of the shared natural resource system.

The consequences can be severe in social and economic terms. In the case of small scale shrimp farming which has developed very rapidly in Vietnam in recent years, crop failure rate, in extensive as well as more intensive systems, is commonly more than 50%, corresponding to significant financial loss, and in many cases debt and worsening poverty. This contrasts sharply with the tremendous benefits successful aquaculture can bring. Failure rate is at least partly related to the very high concentration of development, declining water quality, and environmental capacity issues.

Cage culture is also now developing rapidly with strong government backing, and can be highly profitable. It has also begun to impact on water quality, farm performance and the interests of other users.

The rate of increase in aquaculture production in Bangladesh is less rapid than in Vietnam, but is rapid nonetheless, especially in some coastal areas. Furthermore, freshwater pond use in most of Bangladesh is highly intensive, often involving a range of aquaculture and other activities. When overloaded with nutrients these systems are vulnerable to eutrophication and collapse with negative consequences for aquaculture and other uses. Conflicts between different users are widespread, and often relate to water quality issues.

A fuller discussion of these problems can be found in Tropeca working paper 3

2.2 The inadequacy of traditional solutions

Two main types of approach – and a range of hybrids - have been developed to address these issues in both developed and developing countries:

- the *responsive approach* where management systems and regulations are developed once a serious problem has become widely recognised; and
- the *precautionary approach* where regulation and control seek to ensure that problems do not arise.

From a management perspective a key feature of the social and environmental impacts of aquaculture, especially in developing countries, is that they are cumulative: insignificant in relation to most small developments, but increasingly serious as the sector grows. At some point the capacity of the environment to cope with the pressure – from nutrients, from chemicals, from habitat destruction, from alien species etc - is exceeded, and water quality declines; disease becomes endemic; other interests are compromised. Environmental capacity has been reached or exceeded. “Responsive” regulatory approaches, and Western style farm-level EIA are totally inadequate to address cumulative issues - especially in developing countries (Hambrey 2000).

Furthermore, regulatory approaches – whether precautionary or responsive – have tended to fail in developing countries for a wide range of reasons (Harrington 1999; Claridge 1996; Van Houtte 2001):

- Inappropriate, ambiguous or a lack of legislation
- Inappropriate or lack of environmental standards
- Weak environmental regulatory institutions
- Ineffective or non-existent law enforcement
- Lack of technical and financial resources
- Lack of effective land use and resource allocation controls
- Conflict between law enforcement and other government functions
- Production dominated by hard-to-monitor small-scale farms
- Public sentiment favours economic development over environmental protection

In some cases the failure of conventional approaches to regulation and management, coupled with the magnitude of the problems, has led to more desperate measures, and outright bans have become relatively common, with examples in India, Thailand, and Ecuador. Whether these bans have solved environmental and resource use conflict issues is open to question, but they have undoubtedly been associated with significant negative socio-economic impacts. Any approach which can pre-empt such problems will be welcome.

Article 9 of the FAO Code of Conduct for Responsible Fisheries (FAO 1995) requires member States to develop an appropriate legal and administrative framework to facilitate the development of responsible aquaculture. The focus however is on encouraging states to help the farmers help themselves as it recognises that 'command and control' measures are rarely effective and 'soft laws' such as codes of practice developed primarily by the industry itself are more likely to have a positive impact.

Ideally we need a more informed precautionary approach based on improved understanding of environmental limits (environmental capacity), *and/or* a more sensitive responsive approach which can recognise early warning signals and put in place management systems before the problems become too serious. The concept of environmental capacity is central to both approaches.

2.3 The concept of environmental capacity

Article 9.1.2 of the FAO Code of Conduct for Responsible Fisheries requires that "States should promote the responsible development and management of aquaculture, including an advance evaluation of the effects of aquaculture development on genetic diversity and ecosystem integrity, based on the best available scientific information". Such an evaluation has little meaning unless the effects can be measured, acceptable limits to change agreed, and management strategies to prevent breach of these limits put in place.

Environmental capacity is defined by GESAMP (1986) as "a property of the environment and its ability to accommodate a particular activity or rate of an activity…without unacceptable impact". The concept is therefore central to the promotion of sustainable aquaculture development, and the implementation of the FAO Code. Importantly, it requires us to address the cumulative impacts of the whole sector (and in its most comprehensive form *all* economic activity) on the ecosystem within a specified area.

A recent GESAMP (2001) report suggests environmental capacity in relation to aquaculture may be interpreted as:

- The rate at which nutrients are added without triggering eutrophication; or
- The rate of organic flux to the benthos without major disruption to natural benthic processes

More practical interpretations of particular relevance to the situation in developing countries include for example:

- The rate of organic (or nutrient) flux into a defined aquatic system without reducing aquaculture productivity
- The rate of organic (or nutrient) flux into a defined aquatic system without negatively affecting the interests of other resource users

The concept of environmental capacity can, however, be expanded to include impacts that are more difficult to quantify such as reductions of natural habitat or even loss of scenic value due to visual impacts.

There are two basic requirements for the effective application of the concept of environmental capacity to the planning and management of aquaculture development:

1. The ability to measure the rate of environmental change and relate this to activities such as aquaculture
2. The determination of what amount of environmental change is acceptable, i.e. developing an environmental quality standard (EQS)

2.4 The human dimension

Although environmental capacity and carrying capacity are scientific concepts, they incorporate a strongly subjective dimension. The definition of 'acceptable change to the environment' and the definition of environmental quality standards, although informed by science, must rest on subjective judgement.

Various criteria may be applied to determine *what is acceptable*. In order to implement our commitment to maintain ecosystem integrity we need sub-objectives and/or indicators of ecosystem integrity. These sub-objectives might include, for example, water quality (as required for a range of economic and leisure activities including aquaculture); natural productivity; biodiversity; assimilative capacity. Since these objectives may be competing rather than mutually reinforcing (e.g. maximising productivity may not equate with maximising biodiversity or maintaining water quality for a particular activity) we need a decision making process which deals with multiple objectives bounded by absolute limits (beyond which ecosystems and most of their productive and or assimilative functions break down).

While it is for scientists to inform on the rate processes, dynamics, indicators, and absolute limits; it is for the various interest groups or their representatives to make the trade-offs between objectives within these acceptable boundaries, and to set socially and economically appropriate targets for environmental indicators. These targets will ultimately be informed through an understanding of the nature and consequences of environmental change on the one hand, and the nature and distribution of resulting costs and benefits between interest groups over time.

A range of tools are now available, ranging from highly formal to highly informal and flexible, to facilitate decision making in the face of uncertainty and multiple objectives. While these are used increasingly in planning, and especially in respect of major controversial development projects, they have so far been applied very little to address the more subtle but equally important issues associated smaller scale but cumulative developments.

The process of determining environmental processes and standards in relation to local needs fits well with the widely held view – and international policy – which seeks to promote resource user responsibility for environmental management. The rationale for this is that:

- the resource user is dependent on the quality of the environment and has a direct economic interest in maintaining its quality;
- resource users are particularly well placed to monitor their own environment;
- there is little alternative: government regulatory approaches are typically ineffective in developing countries with large numbers of small scale producers

The main constraints to successful local user environmental management are:

- Lack of awareness and understanding of environmental processes;
- Lack of local institutions to agree on appropriate standards and delivery mechanisms for aquatic systems or farm groups;
- The priority afforded to short term interests (or necessity) by most business enterprises, and by the very poor.

2.5 The role of models and indicators

Scientists have expended considerable efforts to underpin better decision making in relation to environmental management of aquaculture, including significant efforts related to environmental capacity. Work has progressed mainly on two fronts:

- modelling nutrient accumulation and dispersal within aquatic systems (offering the basis for prediction and precautionary management); and
- identifying indicators of environmental quality (allowing for more timely response to emerging environmental problems).

2.5.1 Modelling

Most modelling work has been carried out in Western countries – especially the UK and Norway – although detailed work is currently being undertaken in China (www.ecowin.org). Approaches range from simple mass balance models to highly sophisticated dispersion, dilution and assimilation models, sometimes linked with physiological and ecosystem type models. Some of these are now routinely applied to environmental assessment and monitoring of cage fish farming in Norway, the UK, Canada, US, Chile, Australia and New Zealand. These approaches are reviewed in detail in Tropeca Working Paper 1.

There is tremendous potential for using models to predict environmental effects, to inform farmers and other resource users, and to set agreed upper limits to aquaculture and other resource use activities to ensure that environmental quality does not deteriorate below unacceptable levels (Gowen 1994; Rydin 1998; Barg 1992; GESAMP 1986, 2001).

On the other hand there are dangers in over-reliance on these models:

- They are only useful if institutions exist which can use them effectively.
- The more sophisticated models are very expensive to develop and refine.
- There is a danger that model predictions are taken as definitive and objective, when most are very approximate, based on many assumptions; and predictions may be swamped by seasonal events such as flooding.
- Complex models may confuse and alienate the resource user, and strengthen the notion that environmental management is something for scientists and governments to deal with, not for the farmer.

It is also widely recognised that developing these models cannot be a one-off exercise. Monitoring is still required, and the models should then be refined in the light of experience. In other words they should be used as part of an iterative and adaptive management process.

2.5.2 Indicators

Indicators are essential to validate models where these have been developed, and to allow for an assessment of the degree and significance of environmental degradation, and ideally of the "proportion" of environmental capacity which is being exploited by resource users.

Farmers use simple and practical indicators of water quality and stock health implicitly or explicitly during routine farm management. They will commonly also use indicators of supply water quality before water exchange events. Scientists and regulatory agencies typically use a different set of indicators to assess or monitor water quality and other dimensions of environmental quality.

The choice of indicator relates to both practical issues and the interests of the observer. Oxygen levels (associated with health) or water colour (associated with food supply) are typically important for aquaculturists, while biodiversity may be of interest to tourists. Chlorophyll a is sometimes a key indicator for biologists and oceanographers seeking to understand broad ecosystem status .

In practice these indicators are often closely related or even correlated, but scientists and farmers tend to stick to their own for practical and theoretical reasons or even a lack of understanding of each others point of view. This is a lost opportunity: user indicators are typically simple, cheap, and associated with a vast amount of anecdotal knowledge and information; scientists' indicators attempt to be more objective and useful for comparing different systems or monitoring overall condition through time. Bringing them together, assessing environmental trends using both, will enhance both farmer and scientists understanding, and engage farmers or other users more directly in monitoring and pre-emptive adaptive management.

In general, biological indicators (indicator species) are attractive from a management perspective especially in developing countries. Laboratory analyses are not normally required; farmers can "measure" and use them for their own management purposes; and they often offer an insight into longer term trends.

2.6 Experience in developing countries

Although there is widespread reference to sustainable aquaculture development in developing country aquaculture development policy, most policy and regulation – where it exists - is targeted at individual farms rather than the wider aquatic system. As noted above, because of the sheer numbers of farms and limited resources, this approach has tended to fail. Furthermore, cumulative impacts are not normally addressed.

There are some exceptions. In Thailand, there are several Government/World Bank/Royal projects which seek to address wider issues through the provision of infrastructure (water supply and effluent systems) and associated management systems. These are generally considered to be successful, but are expensive and apply to a very small percentage of farmers. Similar, mainly private sector funded "nucleus estate" systems have often failed for management reasons.

These problems and inadequacies are currently being addressed to some degree through national and local codes of conduct. The problem – especially at the small farmer level – is that farmer concern and understanding is relatively low. Furthermore codes typically focus on individual farmer behaviour rather than group protocols or management systems.

In China, a major on-going research project (Sustainable options for People, catchment and Aquatic Resources in China – see www.ecowin.org/china and www.bioqiang.org for details) explores the application of a range of physiological and carrying capacity models to large intensively used bays. These models are also linked to socio-economic indictors and models of environmental economics to utilize the integrated aquatic culture more effectively to benefit local producers in the long term. Whether the results will be used effectively to inform policy and management remains to be seen.

Overall however, the vast majority of aquaculturists in Asia are operating under what is, on paper, a regulatory system – typically with defined acceptable effluent standards and in some cases design or management requirements. In practice most small farmers are individualists who do as they wish, and governments lack the will or the resources to implement regulations on any but the largest farms.

3 Project purpose

It is clear from the above that:

- There are significant environmental and resource use problems associated with the rapid development of aquaculture in developing countries, and these are associated with substantial social and economic costs, especially to poor producers;
- Existing reactive and regulatory approaches to environmental management are largely unworkable, and inadequate to address cumulative and wider aquatic system issues in tropical aquaculture;
- The concept of environmental capacity offers a possible framework for raising awareness amongst producers of the need to cooperate and work together to address wider environmental issues;
- A range of models and adaptive management approaches have been developed by scientists and policy makers which seek to manage aquaculture

within environmental capacity. There is an opportunity to test some of these out in practice in a rapidly changing developing country context;

- In order to stay within carrying capacity, there will be, in many cases the need to manage and possibly limit the scale, density and intensity of aquaculture and other uses of shared water resources. This has implications for the allocation of access and use rights, and cuts across the key issues of equity and poverty.

The ***purpose*** of the project, as set down in the project memorandum is:

to increase the sustainability of aquaculture development in tropical developing countries

This will be achieved through enhanced capacity of national professionals to understand and estimate environmental capacity and to use this information to inform development plans and management regimes.

Project outputs

- Enhanced understanding amongst collaborators, other scientists, and regional professionals of the applicability of simple environmental capacity models and adaptive management approaches in providing effective environmental management of key tropical aquaculture system.

- Identification and review of strengths and weaknesses of alternative biological and physical environmental indicators and their potential role in the development of practical environmental quality standards for a range of tropical habitat types associated with aquaculture.

- Enhanced understanding amongst collaborators, other scientists and regional professionals of the applicability of alternate planning instruments to allocate environmental capacity and control development for aquaculture in tropical developing countries.

- Collaborative case-study based practical strategies for promoting aquaculture equitably within environmental capacity developed.

- Enhanced capability to plan and manage tropical aquaculture equitably within environmental capacity on the part of key government departments and agencies regionally, nationally and internationally

The project logical framework is presented in annex 1

4 Research collaboration and management structure

This research was set up as a collaborative exercise involving Nautilus Consultants, The University of Stirling, and five partner institutions in Vietnam and Bangladesh. A local research manager ran each of the five case studies. The principal investigator (Dr John Hambrey) guided, facilitated and coordinated the development of research plans; Nautilus Consultants managed financial and administrative issues, and Dr Trevor Telfer provided additional technical advice and expertise, especially in relation to modelling.

The five case study managers and associates were:

- MrLe Anh Tuan, University of Fisheries, Nha Trang, Vietnam
- Dr Vu Dung, Nguyen Thi Thu Hien, Centre for Brackish Water Fisheries Research, Research Institute for Aquaculture No.1, Hanoi, Vietnam
- Mr Nguyen van Tu, University of Agriculture and Forestry, Ho Chi Minh City
- Mr Muhammud Abdur Rouf, University of Khulna, Bangladesh
- Dr Niamul Naser, Department of Zoology, University of Dhaka, Bangladesh

5 Research activities and methodology

The detailed methodology relating to each case study is set down in the case reports (Annex 2-6). The common broad approach encompassed the following stages:

1. Literature review
2. Country workshops on the applicability of environmental capacity concepts to aquaculture development and management in target countries and selection of case studies
3. Engagement of local farmers and other stakeholders, issues identification and institutional analysis (workshops, meetings)
4. Characterisation of system hydrodynamics
5. Joint (with farmers) identification of indicators of water quality, stock health and performance
6. Water and soil quality analysis over two production cycles
7. Estimation of nutrient budgets for individual farms and wider aquatic systems
8. Appraisal and where appropriate application of mass balance, flushing rate and dispersal/dilution models
9. Broad assessment of nutrient budget, environmental capacity issues, and management needs
10. Development of draft user management plan

Within this broad framework the research was adapted, in terms of emphasis and detail, according to local needs and perspectives – as identified at local workshops and meetings between project scientists, farmers, and other stakeholders, and as agreed with the project management team. This flexibility was bounded only by the core requirement to address environmental management issues which applied to the wider aquatic system – or to a group of farmers – rather than to individual pond or farmer.

This flexibility generated some weaknesses from a traditional scientific research perspective, but significant strengths in terms of addressing local practical needs, and building strong relationships between scientists and user groups. Given the focus on “practical guidance” for this research this compromise was both necessary and desirable.

5.1 Literature review

The technical literature review centred around three broad themes, for each of which a comprehensive working paper was generated:

1. Environmental capacity in the management of aquaculture and its potential application in developing countries;
2. Environmental indicators for sustainable aquaculture development
3. Environmental capacity modelling

In addition a country paper was produced for Vietnam:

4. The status of aquaculture and environmental management issues in Vietnam

In the case of Bangladesh the recent Fisheries Sector Review (Fisheries Futures) served a similar function of providing the national context for the research.

These papers were circulated to all partner researchers to develop overall capacity to deliver the aims of the project.

Towards the end of the project a technical theoretical working paper was commissioned to shed light on some of the issues raised by the water quality analysis and nutrient budget developed for the alternating rice-shrimp system in Bangladesh:

5. Nutrient Cycling in Flooded Production Systems

All of these papers are included in the appendices

5.2 Country workshops and selection of case studies

Initial research planning workshops were held in both Vietnam and Bangladesh. These served firstly to allow for wide ranging debate and discussion of the practical application of environmental capacity concepts to aquaculture management in the target countries, and secondly to make a locally informed selection of case studies. The workshops included the research team and other interested aquaculture researchers and managers, and government representatives.

Five case studies were selected representative of a range of agro-ecosystems, aquaculture systems, and social conditions:

1. Cage aquaculture of spiny lobster (*Panulirus*) in marine cages in Khanh Hoa, South Central Vietnam
2. Semi intensive shrimp (*P. monodon; P. vannemei*) culture in brackishwater ponds in Dosun, Haiphong, northern Vietnam;
3. Improved extensive shrimp culture within a wider rice cultivation zone in Can Gio, southern Vietnam;

4. Improved extensive shrimp farming (in alternation with rice) near Khulna, Bangladesh
5. Multiple use freshwater ponds, Rajshahi, Bangladesh

5.3 Engagement of local farmers and other stakeholders, and institutional analysis

Our objective in this research was to generate results which would have meaning for and be of practical use to fish farmers in developing countries. We also wished to use the research as a stimulus and framework for strengthening management capacity and institutions. Gaining support and "buy-in" from farmers was therefore crucial to the success of the project, as was an understanding of existing institutions of relevance to wider aquatic resource management. Project managers went through a staged process to achieve these objectives:

1. Exploratory discussions ("sounding out") with local NGOs (Bangladesh), key farmers and other stakeholders; and identification of "case study area".
2. Local meetings to explain and discuss the broad objectives of the project - which in simple terms were presented as:
    - improved management of the shared aquatic system;
    - exploration of applicability and value of scientific tools and models
    - strengthened user management capacity and institutions.

   These workshops also served as a form of "awareness-raising" of the idea of environmental limits to aquaculture and other activities, and shared use of aquatic resources.
3. Local workshop to identify key issues and concerns
4. Institutional analysis drawing on the meetings, workshops and discussions with individuals, NGOs and government officials

A variety of techniques were used to draw out opinions and identify key issues, including mapping of local resources, issue prioritisation, matrices, Venn diagrams etc

5.4 Characterisation of hydrography

All research managers were asked to develop, with the users, simple maps and diagrams of the wider aquatic system corresponding to the selected case study area. Basic rough information was requested on depth, water flows, tides, water exchange protocols etc.

As the project progressed this information was refined in line with expected value, feasibility and evolving priorities.

5.5 Joint identification of indicators

Improved environmental management must be anchored either on effective monitoring and appropriate response, or on predictive models – or both; and an important output of the project was to gain a better feel for the strengths and weaknesses of these two approaches.

A key initial strength of the monitoring approach is that farmers themselves can easily understand and become engaged in the process. Most farmers already have their own indicators of water quality and stock health.

The project sought to build on and develop this knowledge through:

- Identification of existing indicators of stock performance and environmental quality, and discussions with farmers of possible new ones;
- Cross referencing of these indicators with each other, and with more objective scientific measures, especially those which might relate to overall nutrient status

It was notable that there is a dearth of literature relating to soil/sediment and water quality indicators for tropical countries and that further research is needed.

5.6 Water and soil quality analysis over two production cycles

Data on water quality, and to a lesser extent soil/sediment quality, was collected at strategic locations within individual farms and in the wider aquatic system over two seasons. In most cases the key parameters were total phosphorus and total nitrogen, since these were required to develop basic mass balance models and nutrient budgets. However, a wide range of other data was collected according to local need and capacity, including, for example, ammonia nitrogen, organic matter, and BOD.

The methodology is described in the case study reports.

A problem arose in one case study, where the water supply and drainage system was changed after year one, meaning that water quality data was not comparable over the two years. However, this did provide some information on the impact of the improved system on water quality

5.7 Estimation of nutrient budgets

Information was collected on total nutrient inputs and outputs to and from individual farms/ponds (phosphorus, nitrogen, and in some cases organic matter), and the wider aquatic system. A summary of the main conversion factors used is presented in table 1.

In addition to generating valuable scientific information, this also provided a useful framework for discussions with farmers, allowing for a much more detailed insight into the day to day management of the ponds, cages and wider aquatic system, and opportunity to discuss the pros and cons of alternative management strategies.

5.8 Appraisal and application of mass balance, flushing rate and dispersal/dilution models

From the scientific perspective, a critical part of the approach was to try to use relatively simple and often incomplete data to build models which would:

- Highlight existing or potential future problems related to nutrient imbalance or accumulation in the system, or in critical parts of it;
- Provide “early warning” of possible system overload (i.e. exceeding environmental capacity);
- Identify opportunities for improved nutrient and water quality management throughout the system.

In order to do this nutrient budget information was brought together with information about system hydrography, estimated flushing rates, and water/sediment quality data. Nutrient budgets together with flushing rates allow for estimates of water quality and/or accumulation of nutrients within the system. Water and sediment quality data – coupled with environmental indicators - can be used to “ground truth” or cross check these estimates.

In the case of cage culture in Khan Hoa, these mass balance and flushing rate approaches were supplemented with simple dispersion modelling in the wider environment around the farms.

5.9 Updated assessment of key issues, management needs and development of draft user management plan

Drawing on all of the above information and analysis, key environmental management issues (both problems and opportunities) were revisited, and new ones identified and discussed. This was done by the team of collaborating scientists at the project final workshop, and subsequently at final “field workshops” with collaborating farmers and other stakeholders..

In all cases this was followed by facilitation of the development of local user management plans.

5.10 Rights allocation issues

Allocation rights issues arose as serious issues in two case studies: lobster farming in Xuan Tu lagoon, and multiple use of ponds in Rajshahi, Bangladesh. In the latter case there is potential to address this through the local management plan. In the former case, there is a need to limit development in some way, with implications for allocation rights. The Provincial government has recognised this need and is currently seeking technical advice on issues of density and spacing from the project scientists. The social issues related to rights allocation are highly political, and beyond the scope of the project in terms of time.

Table 1: Nutrient content of Inputs and outputs

	N content (% dry matter)[1]	P content (% dry matter)	Moisture content (%)	reference
Xuan Tu case study				
Trash fish and molluscs (lobster feed)	2.10	0.17		Project analysis
Trash fish (snail feed)	2.54	0.21		Project analysis
Pellet feed (shrimp)	6.62	1.66		Commercial data
Spiny lobster	3.59	0.30		(Boi, 2000)
Snail	1.42	0.11		Project analysis
Shrimp	2.90	0.34		Jackson et al 2003
Household solid waste	1.86 kg N/person/yr (a)	0.37kg P/person/yr (b)		a) Sogreab 1974; b) padilla et al 1997
Domestic sewage	4kg/person/yr	1kg/person/yr		World bank 1993
Detergent		1kg/person/yr		World bank 1993
Doson Case study				
Shrimp	2.89	0.28		Project analysis
Seed (?)	2.4	0.4		Project analysis
KP type pellet feed (shrimp)	6.4	1.7		Commercial data
Trash fish	2.72	0.5		Lab analysis
Snail	2.4	0.3		Lab analysis
NPK fertilizer	16	8.7		Commercial data
Urea fertilizer	45	0		Commercial data
manure	1.36	0.49		Project analysis
Water supply	0.084	0.0028		Project analysis
rainfall	0.025	0		Project analysis
Putia village case study				
Mango leaf	1-1.5	0.08-0.175		Young & Koo 1969
FW hycinth	1.7	0.43	92.7%	Kwang Lic 1985 AIT thesis AE 85-28
Compost manure	1.83	0.59	81%	Kwang Lic 1985 AIT thesis AE 85-28
Water spinach	1.4	0.03	91.2%	
Duckweed	0.8-7.8	0.03-2.8	86-97%	Landolt & Kandeter 1987
Clarias batrachus	8.5%	2.1%	71.8%	Hossan 1988 AIT thesis
Manure				“
Dairy cattle	0.5	0.86	85%	“
Beef cattle	0.7	0.215	85%	“
Poultry	0.559	0.41	72%	“
Swine	0.129	0.33	82%	“
Sheep	1.4	0.215	77%	“
Duck	3.2	1.6	?75%?	“
Cow	1.1	0.21	79.6	”
Rice bran	1.6	0.4	9.2%	“
urea	46	0		“
TSP	0	20.64		Commercial data
Cyprinids, Tilapia	9.7	1.5		Sterner and George 2000
Can Gio case study				
Shrimp (harvest)	2.9	0.34		Jackson et al 2003. Aquaculture 218, 397-411
Shrimp fed (Tom boy Co.)	38-42% protein	1.5		
general				
Birch leaves	11mg/g		C/N 45.4	
Hawaian montane forest	.33%	0.027		

[1] Except as otherwise indicated

6 Research outputs

6.1 The Tropeca Approach

A key output from the project has been the testing and refining of a broad approach to strengthening environmental management of aquaculture in developing countries through:

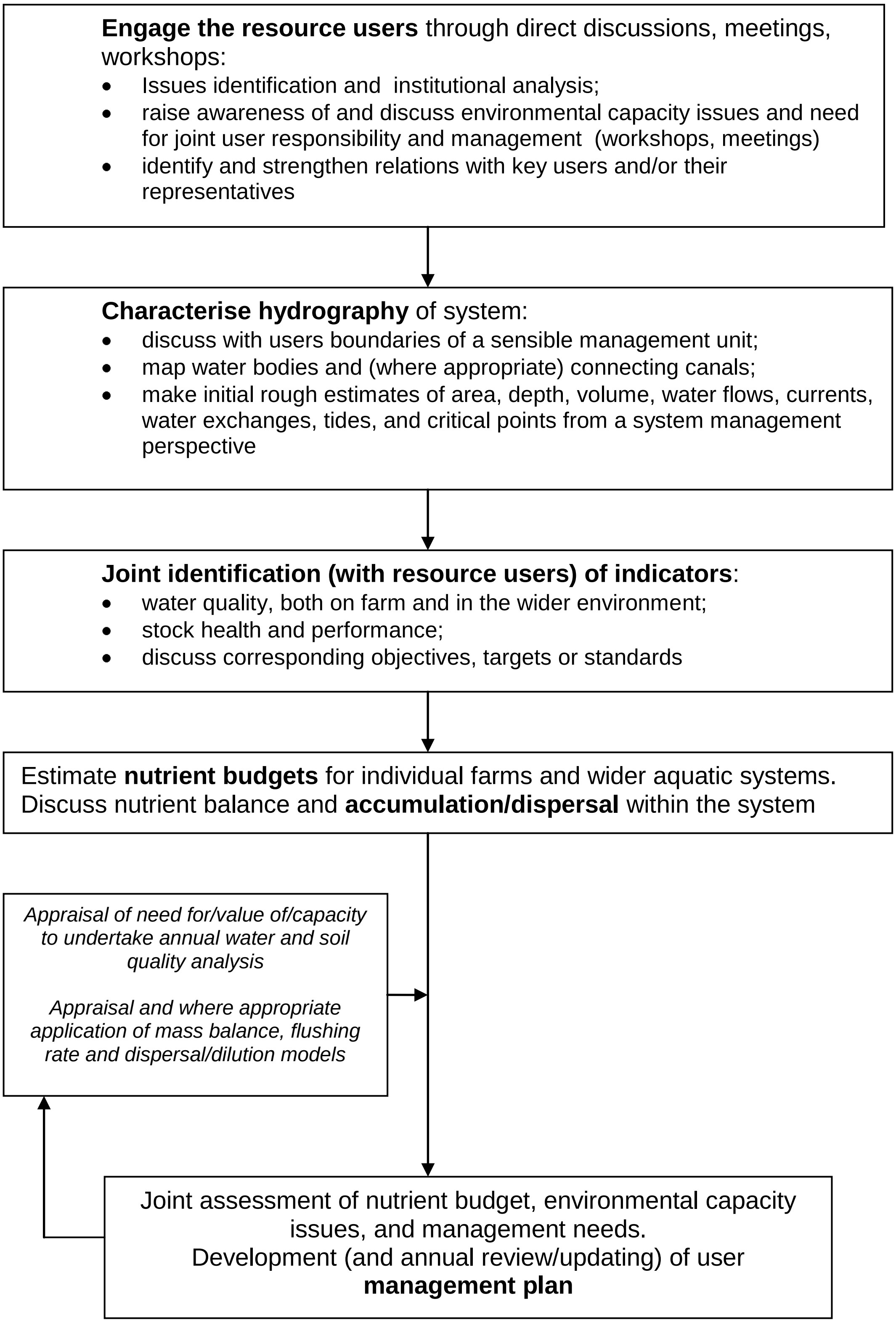
- Working collaboratively with local scientists, farmers and other aquatic resource users;
- Using the idea of environmental capacity as a framework for awareness raising, discussion, research and action to improve local user led management systems;
- Applying current scientific understanding and approaches to assessing environmental capacity where these are likely to be cost effective and appropriate in terms of delivering better management;
- Constantly adapting and refining the approach as required by local circumstances

The approach has been described in detail in the methodology section and is summarized in the diagram (Figure 1) below. Its long term success and value remains to be seen, but the outcome of most case studies has been positive, with farmers themselves appreciative of the sensitive and adaptive approach taken, and management plans generated by resource users in 3 out of five cases.

The approach has involved intensive working of scientists with resource users. Clearly resources will not be available to pursue such an intensive approach on a wider scale. The basic approach is however relatively simple, and we are currently exploring mechanisms to disseminate this approach more widely through training of extension officers and key farmers/resource users.

In some cases this approach will lead to the identification of environmental limits to production (or inputs) implying the need to limit production per farm, and/or to limit entry, or access to resources. This has both political and technical dimensions, and any management system and associated decision making procedures set up must encompass both.

Figure 1: The Tropeca Approach



6.2 Issues and institutions analysis

All case studies undertook preliminary informal meetings and a local community workshop to explore existing aquaculture management issues and associated institutions and procedures (or lack thereof), and opportunities for improvement.

The focus of these discussions was on environmental issues, but other issues were discussed to get a general feel for the broader management context, and the priorities of local people. These meetings were well attended and led to the identification of a wide range of issues and possible solutions, many of which related to water quality, water management, disease and stock performance. A list of the main issues arising is presented in table 2.

Table 2: Key issues for resource users in five case studies

Khulna	Putia	Can Gio	Xuan Tu	Dosun
Disease	Breeding of Tilapia from cages in carp polyculture pond	Disease	Deteriorating water quality	Disease, seed quality
Water quality	Plankton blooms and fish kills	Water quality – in ponds and in supply canal	High cost of cages in deeper water	Deterioration in water quality through culture cycle
Water depth (too shallow)	Water depth (too low in summer)	Lack of knowledge (stocking density, feed, water exchange)	Conflicts with snail (Babylonia) farmers (disease, pollution, siting) fishing (navigation) and shrimp farmers (chemicals, pollution?)	Low DO, especially during heavy rain and before sunrise.
Water logging	Variable cage fish performance in different ponds		Seed quality and quantity	High nitrite associated with low DO
Irregular water supply	Inadequate knowledge of fish food and feeding; conflict between use of food for fish v. humans		market	Rapid changes in salinity; halocline development in pond
Rate of chemical usage	Erosion of pond bank through human activity associated with cage care		Lack of knowledge, training	Death of shrimp related to misuse of chemicals
Poor water quality management			Over-fishing	Infected pond water exchange
Lack of knowledge/training				
Politics and power hierarchies				

SWOT analysis of the existing management systems was also undertaken at some meetings, and proved extremely useful in terms of identifying possible future management initiatives.

Following on from the identification of issues, broad agreement was sought on environmental objectives, associated indicators, and both management and research opportunities and priorities. Interestingly, the main indicators suggested by farmers for environmental quality were growth, survival, production and earnings, though some water quality indicators were also mentioned. Not surprisingly, farmers and other resource users interest in environmental quality relates directly to economic performance.

What is striking about these results is the universal problem of disease or mass mortality, and the equally universal awareness of its relation with water management and/or quality. Equally striking was that despite this there was very little in the way of existing initiatives for improved joint management of water quality. There was also rather limited awareness of the possibility that farmers themselves were polluting the wider aquatic environment, and this was at least one factor causing deterioration in water quality.

Also notable was that in most cases there were already in place management institutions and systems that could in theory deliver better water quality management. What was lacking was the will and capacity to get everyone round the table to agree on what should be done. There was also a tendency in several cases for resource users to blame others for water quality problems, rather than seek to improve their own performance. Objective information on the relative importance of the various factors and activities affecting water quality was not available. There was no basis for improved management. There was no basis for allocating responsibility.

6.3 Indicators

Indicators used by farmers to assess pond and canal environmental conditions in the different cases studies are presented in Table 3.

Although there are similarities between these indicators, there are also differences. Of particular note is the perception that the aquatic plant *Cata saola* is considered an indicator of good conditions in Bangladesh, while aquatic plants or seaweeds are considered a sign of poor nutrient status and potential for mass mortality in Vietnam. This difference may relate to pond depth and climatic conditions. Although it is probable that aquatic macrophytes reduce pond fertility and the abundance of plankton – and may periodically decay creating poor conditions - they may also serve an important function of shade and shelter for the shrimp in the hot shallow ponds in Bangladesh.

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Table 3: Indicators used by farmers to assess and monitor environmental quality

Khulna	Can Gio	Putia	Xuan Tu	Dosun
Water smell	Transparency (high in supply water = good)	Brownish or yellowish green colour suitable for cage culture	Black bottom sediment/mud	Brown yellow colour after pond fertilisation (good)
Water (supply) typically whitish, sometimes reddish;	Presence of small fish (e.g. *Mugil*) in supply water	Bright/dark green not suitable for cage culture	Off-smell of sediment/water	Green colour once established (good)
Pond water changes from green to blue-green to muddy in typical crop cycle	Green colour and 30-40cm transparency (indicating suitable culture conditions)	Fish at surface indicates unfavourable conditions	Large concentrations of polychaetes	Turbid-brown-yellow + luminescence (bad)
Oily surface layer associated with disease	Shrimp movement and behaviour	Water and mud smell		Deep blue/brown accumulating at pond corner – bad – high temperature and excess nutrients
Tealeaf colour may protect shrimp from mortality?	Clean gills	transparency		Milky, sometimes brown and red (protozoa and zooplankton take over)
Gassing – indicating far too much organic sediment	Algal growth on shell			Shrimp movement and behaviour
After exchange – may be followed by mass mortality	Slimy, dark green colour			Snails (*Cerithidia*)
Shrimp drift with water inflow indicates disease	Orange colour			Aquatic plant (bottom living)- poor food
Shrimp die after heavy rain	Transparency less than 20cm			
High salinity; low depth; heat all cause mortality in dry season. Saline bubbles	Floating ferrous layer			
Aquatic plant *Cata saola* source of food and shelter in dry season	Black mud			
Vegetation round pond edge indicates good soil and water quality	Small snail			

In practice, the project researchers also identified a range of other indicators that could be used in water quality management (Table 4)

Table 4: Other indicators that could be or were used in water quality management

Indicator	Indicator of
Cyanophyta	low salinity, high nutrient
Zooplankton	May carry disease
Phytoplankton-zooplankton ratio (1billion:1) green water; sechi 30-40cm	Fertile stable pond system
Snails (*Cerithidia*), annelid and polychaete worms	Excessive organic matter (although worms provide good nutrition for larger shrimps)
Bottom weed and clear water	Unfavourable conditions – low fertility and lack of food
Crustacea (abundant copepods, cladocers, crabs etc)	Often associated with disease
Green	Green algae
Yellow brown	Diatoms and/or rotifers
Brown	Cladoceran
Whitish-grey	Protozoa and zooplankton, copepopds?
Blackish, clear, pungent smell	Bloom collapse

Experienced farmers are alert to water quality changes and have a relatively effective set of indicators. However, while there are clear indicators associated with unfavourable conditions, what seems to be lacking from a management perspective is a more sensitive indicator of imminent excess plankton bloom likely to be followed by a crash, although it may be that the longer term enrichment indicators (snails, worms, black smelly sediment etc) are sufficient.

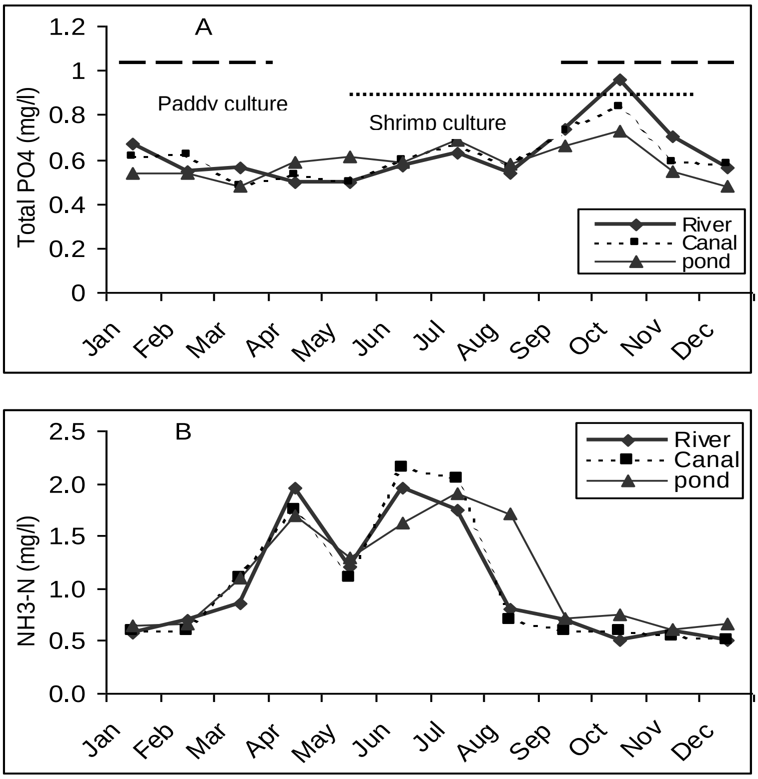
6.4 Nutrient levels and seasonal variation

6.4.1 Brackishwater pond aquaculture

Khulna (shrimp alternating with rice) was the least intensive of the brackishwater pond systems studied, with stocking density of shrimp only 1-2 PL/m^2. Surprisingly however, nutrient levels were among the highest of all the systems studied, and are summarized in Figure 2 (a and b).

The figures are surprising from several perspectives. Firstly, it is sometimes assumed in Bangladesh that shrimp show poor growth because of low pond fertility. This is clearly not the case. Typical "safe" nutrient levels for the water column in pond aquaculture are 0.2-0.5mg/l total P and 1-3mg/l total N. The figures above suggest at least these levels and probably higher. 2mg/l of ammonical nitrogen is high by any standard. The ponds are therefore well fertilized and should be achieving yield rates consistent with those expected for fertilized ponds with limited feeding.

Figure 2. Fluctuation of nutrients throughout the year in river, canal and ponds. Average monthly data for Khulna case study



It is also surprising is that the nutrients in the river are so similar to those in the pond, apart from August-September. There are three explanations for this:

- the water quality in the canals and river is dominated by nutrients from shrimp and paddy fields;
- the water throughout the system is dominated by water quality determined upstream;
- the pattern of water quality in ponds and wider environment is coincidental.

The fact that the quality of pond outlet water is typically higher than the quality of canal/river water at least through the earlier parts of the production cycle (see annex), suggests that the nutrients in river water are determined upstream and are not dominated by shrimp culture practice. The peak in P concentration in October is consistent with TSP applications to recently planted paddy.

It is arguable that these nutrient levels are potentially dangerous and may be related to mass mortality incidents which are not uncommon for these farmers. Mass mortality typically occurs when water is exchanged or when there is heavy rain. These changes in salinity and/or mixing of cleaner water with water high in organic matter or ammonia may result in either or both low dissolved oxygen or a “nitrite spike” (see Arah, 2005 annex 10). The behaviour of shrimp on these occasions is consistent with nitrite poisoning, and is not consistent with the introduction of disease – the commonly assumed cause. This suggest that farmers are overfertilizing (especially urea) in a doomed attempt to increase production. Lower fertilisation rates coupled with small quantities of higher quality feed may well offer a much better and lower risk return.

It is interesting to compare these results with those from Dosun, Northern Vietnam (Figure 3, 4). This is a more intensive system reliant to a large degree on artificial pelleted and trash fish feeds (stocking density typically 12/m^2). Nonetheless, nutrient levels are generally substantially *lower* than those in the more "extensive" system in Bangladesh, and although disease is common, mass mortality associated with water quality problems is not.

In other words the widespread tendency to consider intensive feeding as a greater environmental threat needs to be evaluated more carefully. Intensive fertilization – especially when associated with paddy as well as shrimp – needs equally careful management.

The impact of the new water supply system in Dosun is significant, and illustrates well the degree to which water quality (nitrogen) in ponds had become dominated by poor water quality in the old canals, presumably caused by the build up of nutrients in the sediments. The lesser impact on Phosphorus suggests that P build-up in the old sediment was not being released on a significant scale, and this is consistent with theoretical considerations (see Arah op cit).

Note that the figures below are for total N and P whereas those for Khulna refer to ammoniacal Nitrogen and Phosphate.

Figure 3. Fluctuation of nutrients (Total Nitrogen) over two production cycles for the Dosun case study.

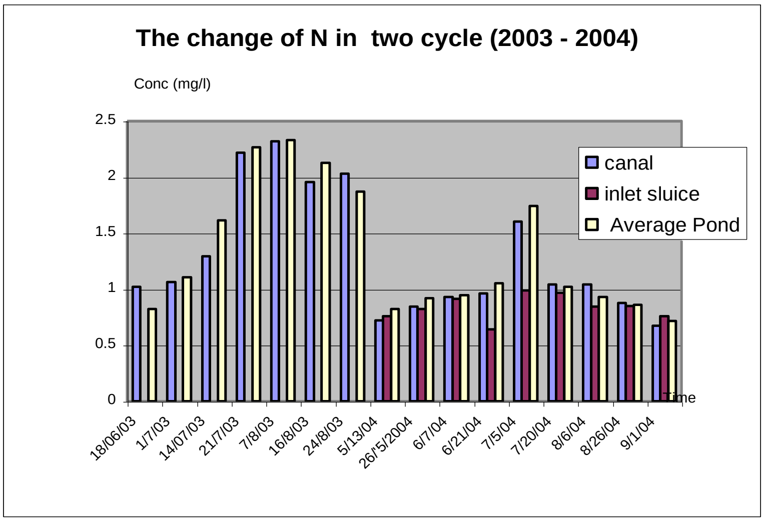
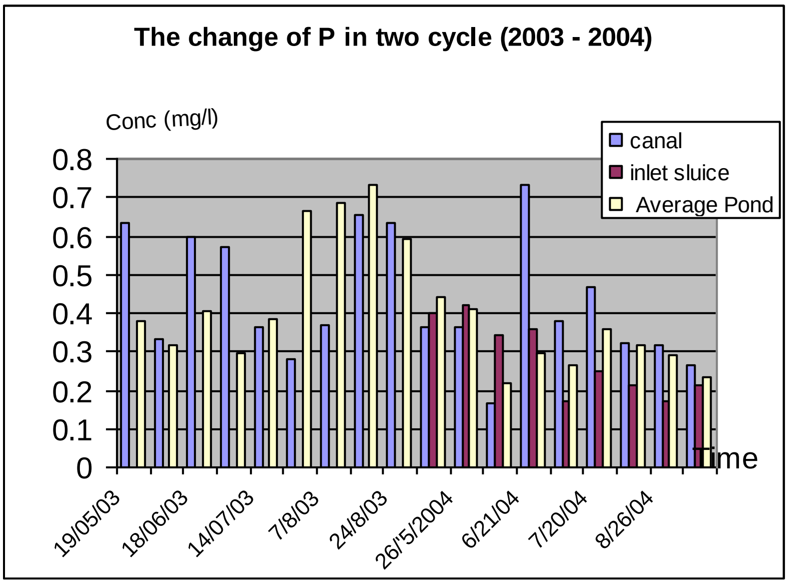


Figure 4: Fluctuation of nutrients (Total Phosphorus) over two production cycles for the Dosun case study



Note. *The large reduction in nutrient levels in the second cycle is related to the construction of new water supply system in 2003.*

The third case study involving Shrimp - Can Gio – also operated an "improved extensive system" with modest stocking density (9PL/m2) similar to Dosun and pellet feeding. Ammonia nitrogen levels were typically below 0.3mg/l in the ponds, though occasionally up to 0.6mg/l in the supply canal. These are substantially lower than those recorded in the more "extensive" system in Bangladesh. However, the higher ammonia concentrations sometimes recorded in the canals suggest organic matter build up there: farmers take care to manage their own ponds – but fail to clear accumulated sediment and maintain water quality in the supply canals. This has served as a focus for discussion with farmers as part of developing better management protocols.

6.4.2 Cage culture of lobsters in Khanh Hoa

Not surprisingly the results are very different from the cage culture case study. In this case cages are sited in an open lagoon system. Water samples were taken along transects from shore to open water and from dense cage culture to more dispersed cage culture (Figure 5). The results are striking (Figure 6), and show a steady build up of nutrients in the water column over time, and increasing from more open and less developed sites to more inshore and developed sites. There is a threefold difference between the least and most polluted sites.

Figure 5. The lobster village and associated sampling transects

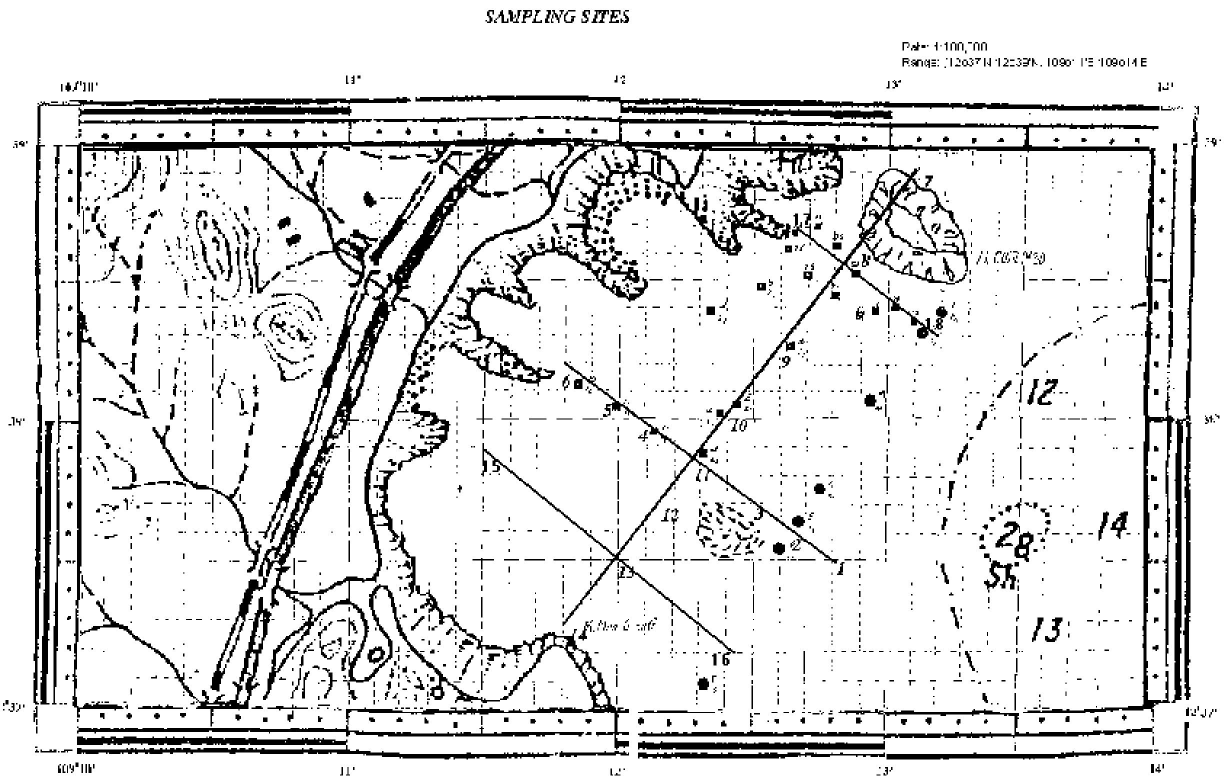
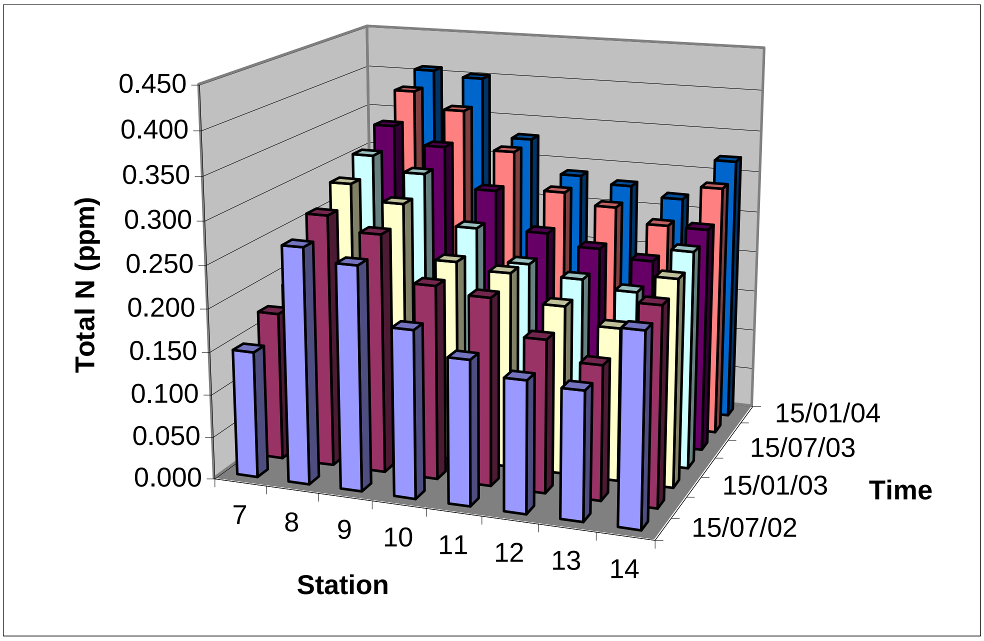


Figure 6. Variation in total nitrogen concentration in water over time and along transects



Although levels of total nitrogen are not as high as in the brackish-water systems they are high for a marine coastal system, and high for a water quality sensitive animal such as *Panulirus*. Not surprisingly, disease levels have increased significantly over the same period, and it is reasonable to assume that water quality (as well as stock density) has played its part in reducing the animals' resistance.

6.4.3 Multi-user freshwater pond

Ammonia concentrations in the ponds at Putia village were generally within desirable acceptable range - typically less than 1 mg/l with occasional values of 1.6mg/l. Total phosphorus concentrations on the other hand were very high – rising to well over 4mg/l (compared with recommended levels of <0.5) in September/October. This phosphorus is largely derived from the addition of TSP applied to boost production of carp fingerlings. Clearly the ponds are being over-fertilised[2], and this accounts in large measure for the regular problems of phytoplankton blooms and collapses, and the problems this then causes for the small scale cage culturists.

6.5 Environmental capacity issues

6.5.1 Nutrient budgets and mass balance calculations

Given farmer and other stakeholder knowledge relating to inputs and yields, and estimates of water exchange rates for individual ponds, groups of ponds, and the wider system, rough nutrient budgets can be estimated. These are invaluable in terms of identifying potential problems, resolving conflicts, and identifying opportunities to both improve environmental quality and/or improve the efficiency of resource use. Without very detailed sampling and analysis these are likely to be very rough; and this needs to be understood by all those involved. But this does not undermine their value – if important issues or questions arise in relation to particular components further more focussed work or exchange of information can be initiated.

Brackishwater pond aquaculture

Nutrient budgets were developed for all three brackishwater shrimp aquaculture systems. They are summarised in table 5.

Input loading
In terms of nitrogen inputs the overall nitrogen loading was broadly similar for Dosun ("semi-intensive") and Khulna ("extensive" at around 50kg/ha/yr, though Dosun had a slightly higher contribution from feed, and Khulna had a greater input from the water supply. This relates to a single crop of shrimp for Khulna and an average 1.3 crops per year for Dosun. Inputs of nitrogen were much higher for Can Gio at 253kg/ha/yr (2 crops per year) but with a significant contribution – 18% - from the water supply. Fertiliser was less important in this system (19kg/ha/yr compared with >30kg/ha/yr for the other two systems).

[2] Assuming no immediate loss to the sediments the total annual application of 330kg TSP (68kgP) would correspond to a concentration of nearly 3mg/l (1.25ha; 2m average depth) to which would be added any regeneration from the pond bottom

Phosphorus inputs were again highest for Can Gio (49.5kg/ha/yr), though not on a per crop basis. A loading of 32kg/ha/yr was estimated for Khulna – relatively high for a single crop, and related almost entirely to the use of triple superphosphate (TSP) fertilizer.

Nutrient recovery

In the case of Dosun 30% of nitrogen and 12% of phosphorus were recovered in harvested shrimp, crab, fish and seaweed. Very little of the residual was flushed to the wider environment – a mere 3.2kg/ha/yr(6%) of nitrogen and 0.8kg/ha/yr (5%) of phosphorus. Most – 53% of input nitrogen and 81% of input phosphorus appears to have been retained in the system or lost through denitrification. Recovery was somewhat worse for Khulna, with 26% of nitrogen and 6% of P recovered in harvested shrimp and fish. 46% of N and 92% of P was retained within the system. In Can Gio a greater proportion of P was recovered in the harvested shrimp (17%) and 12% of phosphorus was discharged to the wider environment through water exchange.

Overall then roughly 40-50% of nitrogen and 70- 90% of phosphorus was retained in the aquatic system, with a corresponding loading of 24-149kg N /ha/yr and 12-35kgP/ha/yr. Given the water quality data, the bulk of this must be residing in the sediment, with the potential to cause problems in the future. The problem might be considered a lesser issue in Khulna: the nutrients could be used in the rice crop. In practice, because the phosphorus in particular is not in a readily available form, fertilisation is repeated in the rice crop.

Several conclusions can be drawn from this information.

- The typical classification of shrimp farms as intensive, semi-intensive and extensive, and the assumption that more intensive means more polluting is misleading. Well fertilised extensive systems can be at least as polluting as more intensive systems. The degree to which a system is polluting depends entirely on nutrient management and utilisation efficiency.

- While these aquaculture systems typically extract less than 50% of input nutrients, this is mainly an internal problem: in our case studies rather little is flushed to the wider environment.

- Farmers must take care of organic matter and nitrogen build up even in extensive systems. Low DO and nitrite spikes are potentially (and in the case of Khulna actually) serious.

- Although residual phosphorus may be difficult to re-use or assimilate in other crops such as seaweed or rice, there is significant potential for reducing nitrogen fertilisation.

An outstanding question remains: are these systems exceeding environmental capacity? In so far as there appears to be a steady accumulation of nutrients, the answer would appear to be yes. However, as yet there is no sign that this accumulation is seriously affecting water quality (except for Khulna where in pond accumulation is compounded by very high nutrient levels in input water) and in general water quality standards are not being exceeded. Impacts on the wider environment are trivial – indeed in some cases effluent water is of a higher standard than influent water. Is accumulation of organic matter and associated nutrients in ponds and system canals a problem? Potentially, yes, and farmers themselves are interested in where it is going. In can Gio for example a large amount of the accumulation is occurring in the shared effluent channels, and these are beginning to have negative effect on supply water.

We may therefore conclude that the expression "environmental capacity" has rather little meaning in practice in these situations. The key is to understand the particular constraints, risks and opportunities presented by nutrient accumulation in sediments.

Table 5 Nutrient budgets for three brackish water shrimp pond systems

DO SON (av 1.3 crops per year)

	Nitrogen		Phosphorus	
INPUTS	kg N/ha/y	%of total	kg P/ha/y	% of total
feed	19.2	38.1	2.8	18.3
fertiliser	31.1	61.5	12.6	81.5
seed	0.0	0.0	0.0	0.0
water supply	0.2	0.4	0.0	0.2
rainfall	0.0	0.0	0.0	0.0
run off	0.0	0.0	0.0	0.0
Total inputs per year	50.5		15.5	
OUTPUTS				
harvested shrimp	5.4	18.1	0.7	14.4
mortalities shrimp	2.2	7.5	0.3	6.6
harvested Crab	1.4	4.6	0.2	4.1
Mortalities -crab	0.0	0.0	0.0	0.0
harvested fish	3.0	10.0	0.3	5.4
mortalities fish	0.3	0.9	0.0	0.6
harvested seaweed	5.4	18.2	0.6	10.9
denitrification	3.0	10.0		
total nutrients removed	20.7		2.2	
waste water	0.2	0.8	0.4	7.2
harvest drainage	3.0	10.0	0.4	7.8
Total outputs in water	3.2		0.8	
Total outputs per year	24.0		2.9	
Balance	26.6	kg N/ha/y	12.5	kg P/ha/y
	52.6	% of input	81.1	% of input

KHULNA (av 1 crop per year)

		Nitrogen		Phosphorous	
INPUTS		kg N/ha/y	% of total	kg P/ha / y	% of total
feed	Homemade	8.2	15.5	1.9	5.8
	MOC	3.0	5.7	1.0	3.1
	Fish meal	0.2	0.4	0.2	0.5
fertiliser	Urea	25.7	48.4	0.0	0.0
	TSP	0.0	0.0	23.7	73.8
	Cowdung	8.1	15.4	3.5	10.8
seed		0.0	0.0	0.0	0.0
paddy stable		1.7	3.2	1.4	4.4
water supply		5.8	11.0	0.4	1.2
rainfall		0.3	0.5	0.1	0.3
run off					
Total inputs per year		53.0		32.1	
OUTPUTS					
shrimp	harvested	7.8	27.0	0.7	29.3
	mortalities	1.9	6.6	0.2	8.3
fish	harvested	5.9	20.4	1.1	45.8
	mortalities	0.6	2.0	0.1	4.2
denitrification		6.9	23.9		
total nutrients removed		23.1		2.0	
water	waste water	5.7	19.7	0.4	16.7
	harvest drainage	<0.1	<0.1	<0.1	<0.1
Total outputs in water		5.8		0.4	
Total outputs per year		28.8		2.4	
Balance		24.2	kg N/ha/y	29.6	kg P/ha/y
		45.7	% of input	92.4	% of input

CAN GIO (av 2 crops per year)

		Nitrogen		Phosphorous	
INPUTS		kg N/ha/y	% of total	kg P/ha / y	% of total
feed		189.7	74.7	45.0	90.9
fertiliser	(initial loading)	19.0	7.5	2.4	4.8
seed		0.0	0.0	0.0	0.0
water supply		45.2	17.8	2.1	4.2
Total inputs per year		253.9		49.5	
OUTPUTS					
shrimp		71.9	68.4	8.4	59.2
denitrification					
total nutrients removed		71.9		8.4	
water	waste water	22.4	21.3	3.2	22.5
	harvest drainage	10.8	10.3	2.6	18.3
Total outputs in water		33.2		5.8	
Total outputs per year		105.1		14.2	
Balance		148.8	kg N/ha/y	35.3	kg P/ha/y
		58.4	% of input	71.3	% of input

Multi-user pond in Bangladesh

Inputs into a multi-user freshwater pond in Bangladesh were relatively high: roughly 157-223kgN/ha/yr and 59-67kg P/ha/yr. Of this 50-60% of N and 12-19% of P was recovered in carp fingerlings and cage grown tilapia. The residual loading was 79-86kg N/ha/yr and 52-54kg P/ha/yr.

Again it is clear that we have plenty of nutrients, and indeed the water quality data, the incidence of toxic blooms, and indeed the normal guidance all suggest that these ponds are over-fertilized, at least with respect to Phosphorus. Given that 92% of the input P is in the form of TSP, this can easily be remedied.

It is also clear that at present stocking rates, the fish cages are making an insignificant contribution to pond nutrients (2.3% of N; 1.4% P) and therefore there is no need as yet to adjust fertilisation regime to take account of this.

Table 6 : Nutrient distribution in Pond A and Pond B, Putia, Bangladesh.

Pond A **1.25 Ha** **11 months** **Total 48 Cages**

Inputs	Kg	Cal wt	N% Cont	Kg N	% N	P% Cont	Kg P	%P
Tilapia fry	120	120	4.8	5.8	3.0	0.4495	0.5	0.7
Carp fry	300	300	4.8	14.5	7.4	0.4495	1.3	1.8
Fish feed	300	240	1.9	4.5	2.3	0.43	1.0	1.4
Leaf part feed	3470	867	1.4	12.1	6.2	0.03	0.3	0.3
Urea	330	330	46	151.8	77.2	0	0	0.0
TSP	330	330	0	0	0.0	20.64	68.1	92.0
Cow dung	900	801	0.8	6.5	3.3	0.27	2.2	2.9
Duck drop	600	120	0.9	1.1	0.6	0.44	0.53	0.7
Leaf	50	10	1.5	0.1	0.08	0.175	0.02	0.0
			Total N	**196.588**	100	**Total P**	**74.000**	100.0
Outputs								
Tilapia fish	1540	1540	4.8	74.6	76.0	0.44	6.9	76.0
Carp finger	485	485	4.8	23.5	23.9	0.44	2.2	23.9
			Total N	**98.071**	**100**	**Total P**	**9.102**	100

N left **98.5** **N Kg/ha/yr** **85.9**

P left **64.9** **P kg/ha/yr** **56.6**

Pond B **.35 ha** **8 months** **Total 21cages**

Inputs	Kg	Cal wt	N% /kg	Kg N	% N	P %/ Kg	Kg P	%P
Tilapia fry	45	45	4.8	2.2	2.8	0.4	0.2	0.9
Carp fingerlings	20	20	4.8	1.0	1.2	0.4	0.1	0.4
Fish feed	0	0	1.9	0	0.0	0.4	0.0	0.0
Leaf part feed	1300	325	1.4	4.5	5.8	0.0	0.1	0.4
Urea	232	150	46	69.0	**88.5**	0.00	0.0	0.0
TSP	232	110	0	0	0.0	20.6	22.7	**96.5**
Cow dung	150	127	0.8	1.0	1.3	0.3	0.3	1.5
Duck drop	100	20	0.9	0.2	0.2	0.4	0.1	0.4
Leaf	20	4	1.5	0.06	0.1	0.2	0.0	0.0
			Total N	**77.971**	100	**Total P**	**23.5**	100.000
Outputs								
Tilapia fish	540	540	4.843	26.1	54.5	0.44	2.4	54.5
Carp	450	450	4.843	21.8	45.5	0.44	2.0	45.4
			Total N	**47.9**	**100**	**Total P**	**4.4**	100

N left **30.0** **N Kg/ha/yr** **128.4**

P left **19.10** **P kg/ha/yr** **81.6**

Marine cage aquaculture

Table 7 provides estimates of inputs and outputs from lobster cage culture and other activities in a small semi-enclosed bay over several years. Unlike the other systems this is completely open to a high quality “wider environment”. Given information about the flushing rate of the bay, and taking appropriate water quality standards for a high quality marine environment, we have been able to estimate a rough value for environmental capacity (see Table *).

Table 7. Nutrient inputs and outputs (mt N/year) by year

	1998	*1999*	*2000*	*2001*	*2002*	*2003*
Lobster feed	52.9	80.7	105.8	109.5	112.0	192.1
Snail feed				0.3	7.6	13.3
Shrimp feed	9.5	7.8	6.8	5.7	5.4	5.4
Domestic sewage	26.9	27.7	28.3	29.3	29.3	29.9
Lobster Production	3.1	4.7	6.1	6.3	6.5	11.1
Snail production	0.0	0.0	0.0	0.0	0.3	0.5
Shrimp Production	2.8	2.3	2.0	1.7	1.6	1.6

Table *. Nutrient inputs and outputs and Environmental Capacity by year

	1998	***1999***	***2000***	***2001***	***2002***	***2003***
Nutrient inputs (mt N/yr)	89.2	116.1	140.8	144.8	154.3	240.7
Nutrient outputs (mt N/yr)	5.8	6.9	8.1	8.0	8.3	13.1
Pollution (mt N/yr)	83.4	109.2	132.8	136.8	146.0	227.6
Environmental capacity (mt N/yr)	469.0	469.0	469.0	354.9	317.4	182.2
Over load (mt N/yr)	-386	-360	-336	-218	-171	45

Lobster food is the dominant input into the system and this dominance has increased in recent years. These simple calculations have already been used to diffuse some developing tensions between lobster farmers and shrimp farmers (the former tending to blame the latter for water quality problems are now forced to accept that it is their responsibility).

The data also suggests that flushing is inadequate to remove the nutrients and that they will tend to accumulate around the cages and negatively affect water quality. This assessment is confirmed by the water quality data discussed above, and the increasing incidence of disease..

This simple budget and mass balance model has been used to raise awareness and strengthen user group responsibility for nutrient loadings. A variety of initiatives are now in place to reduce nutrient waste and to limit overall production, and the local government is exploring more formal limits to production and density.

6.6 Management initiatives

The lobster farmers of Xuan Tu village now have a well established organisation, and have actively engaged in and supported the research. They discuss and agree management protocols, liaise with local government, and meet to discuss a wide range of issues. It is probable that working with Tropeca has led to a strengthening of this group and an increased emphasis on environmental management. The farmers and the University of Fisheries are engaged in discussions over management of the sector as a whole in terms of cage location spacing, density and total production.

Farmers in the Dumuria district of Khulna, Bangladesh have formed an association during the course of the Tropeca project and have discussed environmental management issues with great interest. The impact of this on management protocols remains to be seen, but the issue of possible nitrite poisoning/low DO as the cause of mass mortality, and the abundance of nutrients in the system are both areas where action is likely, with potentially significant benefits.

In Dosun the project has stimulated a series of farmer and Government workshops to discuss water management issues, to develop new infrastructure and to agree management protocols.

In all of these cases the basic information on nutrient sources and sinks has been invaluable in terms of informing debate and helping to develop improved management protocols

6.7 Capacity building

Capacity building is referred to in three of the 5 project outputs and refers to collaborators, other scientists, regional professionals, government departments and agencies.

Collaboration and mutual capacity building with five research institutions has been broadly successful with all partners learning from each other, from NGOs (Bangladesh) and from farmers and other local stakeholders. Local research partners were impressed with the positive response from farmers and other resource users that arose directly from the participatory adaptive approach – asking farmers what the problems were, discussing how to tackle them, considering what scientific approaches might be valuable.

Government officials have been present at many of the workshops and have taken on board the TROPECA approach.

The bare numbers, in terms of people engaged with the project and awareness-raising more generally, are given in the table below **.

6.8 Discussion and conclusions

The adaptive approach taken to this research (adaptation to local conditions; steady refinement of research focus through the project) has yielded useful and practical results in a relatively short time frame. While this adaptive approach has meant that some of the scientific data is less thorough and consistent than would have been the case if the project had been driven by mainly scientific objectives, we believe that this weakness is more than outweighed by the awareness and capacity building outputs of the project.

The estimates of environmental capacity are very rough, with substantial residuals and uncertainty, but their development with close farmer cooperation has raised awareness of the possibility of forward thinking, and improved understanding of the nature of nutrient dynamics in the wider environment.

Local environmental management initiatives are underway in three of the case study areas, building on this learning. Monitoring, using simple indicators at key locations within the systems should allow for some testing of the assessments and on-going engagement of farmers in environmental management.

The nutrient budgets for the wider environment have also raised important questions relating to the fate of phosphorus in tropical pond, paddy and canal systems.

A key output of this project is ***practical guidance***. Our experience in undertaking the research suggests that detailed technical guidance on estimating environmental capacity through the use of empirically validated theoretical models is of limited value in many situations, and only useful for the most highly developed systems, the most impacted systems, and where significant resources are available. Applying the “Tropeca approach” as it has evolved over the course of the project does appear to have significant merit and is much more widely applicable. The general guidance on applying the approach offered in Annex 2 is now being adapted at local level in both Vietnam and Bangladesh. The core of this approach is simple and can be widely disseminated: *engage farmers in developing simple nutrient budgets as a framework for discussing possible environmental problems and appropriate management measures.* In some cases farmers may then be able to develop their own management protocols and/or use nutrients more efficiently. In other situations, local government or government agency may need to facilitate this process and develop co-management frameworks. In the extreme, government may need to intervene to estimate and "allocate" capacity. In practice, environmental capacity was only clearly being exceeded in one case study (lobster cages) - and this has already become an issue for government intervention with guidance solicited from the project researchers.

A question that arises out of this work is the need or otherwise for water quality sampling to support better production and environmental management in aquaculture in developing countries. A comprehensive sampling regime to understand variations in water quality is complex and expensive. Where water quality moves outside of acceptable bands there are usually clear indicators – either well known to scientists or well known to farmers or both. If these indicator sets can be jointly developed and agreed, water quality can be monitored simply, regularly and routinely. If management interventions are also recorded, then relationships can be established, and responses agreed. This understanding can then be enhanced through assessments and discussion of mass balance – put simply, where are the nutrients going. *Full blown laboratory sampling is rarely if ever needed.*

Conclusions

1. None of the shrimp production systems studied posed any significant threat to the wider environment. Roughly 30% of nitrogen and 10% of phosphorus were recovered in harvested animals. Only around 10% of both phosphorus and nitrogen was flushed to the wider environment, with the bulk residing in the system. This does imply however the need for much more action to deal with the accumulation of nutrients within the systems in order to maintain water quality for shrimp production itself

2. In Bangladesh nutrient concentrations were very high in the wider environment, and this may well be linked to sudden drops in oxygen concentration and/or nitrite spikes at times of water exchange.

3. Production in Bangladesh is not nutrient limited; it is probably limited by mortality associated with poor water quality, in turn associated with poor supply water quality and shallow ponds subject to extremes of salinity and temperature. Rotting stubble may also be a problem in some ponds.

4. Freshwater multi-user ponds in Bangladesh often contain plenty of nutrients. The practice of applying significant quantities of additional fertiliser in the form of urea and TSP according to local tradition or standard guidelines needs to be re-assessed. Any guidance offered by extension services needs to take account of existing inputs and nutrient status.

5. Development of marine cage culture in Vietnam is already in excess of environmental capacity in some locations. Simple mass balance and flushing models appear to offer reasonable prediction of environmental capacity and can be used to identify – and pre-empt problems – so long as management institutions exist to implement solutions.

6. There are many factors now driving greater farmer organisation - the need for traceability; efficiencies in marketing; increasing competition and economies of scale; the need for cooperative environmental management; exchange of knowledge. This project has shown that farmers are ready and willing to organise, and that developing a simple nutrient budget can be the first step in strengthening collaborative environmental management

7. Government infrastructure initiatives work. The new water system in Dosun has resulted in significant improvement in water quality. However, these gains may be lost if mechanisms are not put in place to manage nutrient accumulation within the canals.

8. In the case of Dosun, seaweed removed some 13% of waste nitrogen and 4% of waste phosphorus. While this is significant, it does not and cannot address the overall problem of system nutrient accumulation.

9. In terms of nutrient loadings there is little difference between extensive systems based primarily on fertilisation and semi-intensive systems based primarily on the use of pelleted feed. Clearly this will change as stocking densities and feeding rates are increased.

10. Significant quantities of phosphorus accumulate in aquatic production systems – even those which are conventionally termed extensive.

7 Contribution of outputs to development impact

This project was concerned with enhancing the quality and sustainability of existing development rather than generating development impact in its own right.

This is addressed in relation to each of the project outputs as set out in the logical framework.

1. *Enhanced understanding amongst collaborators, other scientists, and regional professionals of the applicability of simple environmental capacity models and/or adaptive management approaches in providing effective environmental management of key tropical aquaculture systems.*

Scientists from several key regional institutions have worked directly with local government and NGOs to develop and assess the utility of various approaches to environmental management. In several cases this has brought the scientists and professionals down to earth, forcing them to adapt and simplify their approaches to ensure practical relevance to a rapidly changing industry. The Tropeca approach has now been institutionalised in the teaching of the University of Fisheries in Vietnam and become a significant component in the suite of tools now used by aquaculture planners in Vietnam, including the Vietnam Institute for Fisheries Economics and planning, the official aquaculture planning institute.

2. *Identification and review of strengths and weaknesses of alternative biological and physical environmental indicators and their potential role in the development of practical environmental quality standards for a range of tropical habitat types associated with aquaculture.*

Farmers and scientists at all case study sites have shared their knowledge and understanding of environmental indicators and their management implications

3. *Enhanced understanding amongst collaborators, other scientists and regional professionals of the applicability of alternate planning instruments to allocate environmental capacity and control development for aquaculture in tropical developing countries.*

Aquaculture development planning in Vietnam now explicitly considers environmental capacity (it has become part of official guidance in the last few months) and the need to consider upper limits on development in some areas. This has not been achieved in Bangladesh because of weaker planning mechanisms.

4. *Practical strategies and management plans for promoting aquaculture equitably within environmental capacity for two or more case studies.*

This has been achieved in three case studies: Dosun (mainly government driven); Xuan Tu (farmer and local government driven) and Khulna (farmer association driven). In the case of Xuan Tu the main management response has been to move cages into deeper better flushed water, and disease now appears to be in decline.

5. *Enhanced capacity to plan and manage tropical aquaculture equitably within environmental capacity on the part of key government departments and agencies regionally, nationally and internationally.*

1 to 4 are all relevant to this. Under the follow-on TROPECA dissemination project we are actively working with government and agencies to strengthen this output, and to develop regional guidelines

Annex 1: Project logical framework

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal] Productive benefits of aquatic resources for poor people sustained and increased through improved knowledge of aquaculture processes and their management			
Purpose To increase the sustainability of aquaculture development in tropical developing countries	Crop failure rate lower in areas where guidelines applied; Long term productivity higher in areas where guidelines applied; water and soil quality maintained or enhanced in areas where guidelines applied; Environmental indicators before and after implementation of guidelines	Provincial statistics; Follow up case studies;	Environmental capacity is a constraint to sustainable development of aquaculture
Outputs Enhanced understanding amongst collaborators, other scientists, and regional professionals of the applicability of simple environmental capacity models and adaptive management approaches in providing effective environmental management of key tropical aquaculture system. Identification and review of strengths and weaknesses of alternative biological and physical environmental indicators and their potential role in the development of practical environmental quality standards for a range of tropical habitat types associated with aquaculture. Enhanced understanding amongst collaborators, other scientists and regional professionals of the applicability of alternate planning instruments to allocate environmental capacity and control development for aquaculture in tropical developing countries. Collaborative case-study based practical strategies for promoting aquaculture equitably within environmental capacity developed. Enhanced capacity to plan and manage tropical aquaculture equitably within environmental capacity on the part of key government departments and agencies regionally, nationally and internationally.	Comprehensive review developed with collaborators and submitted for publication in international journal by the end of year 1, and a summary published in the form of a trade journal article by the end of year three. Comprehensive review developed with collaborators and submitted to international journal by end of yr 1; summary published as trade journal article by end of yr 3. Comprehensive review developed with collaborators and submitted to international journal by end of yr 2; summary published as trade journal article by end of yr 3. Strategies in at least 1case study area in each of Vietnam (with SUMA) and Bangladesh (with CARE Bangladesh) developed, adopted and implemented by end of project. Guidelines adopted and promoted nationally by (at least) SUMA and CARE; Guidelines referred to in national and regional publications and project documents; Lessons learned and approaches developed applied in local sustainable aquaculture	peer review and semi popular articles peer review and semi popular/trade articles peer review and semi popular/trade articles CARE and SUMA progress reports CARE and SUMA progress reports and policy statements; National guideline documents;	Political support; agreement between stakeholders Effective strategy implementation may require changes in regulatory institutional frameworks which may not be possible within

	development plans and projects in at least Vietnam and Bangladesh Guidelines used in teaching/training at AIT and in support of other regional training initiatives NACA, SEAFDEC	TROPECA Project reports; Other project/programme reports and publications	project life

Activities

Output 1

Literature review and critical analysis of environmental capacity models and monitoring-adaptive management approaches;
Publish peer review and trade articles

Output 2

Literature review on environmental quality indicators and environmental quality standards in developing countries;
Publish peer review and trade articles

Output 3

Review relevant management, control and allocation instruments;
Publish peer review and trade articles

Output 4

Convene research (case study) planning workshops in Bangladesh and Vietnam;
Identify and initiate case studies in Bangladesh and Vietnam
Collaborative review and assessment of alternative approaches to the estimation of environmental capacity (local technical workshops in case study districts; meetings; circulation of discussion notes).
Identification and execution of necessary and feasible supporting biological and physical research in case study areas.
Collaborative management systems research and capacity building in case study districts (local technical workshops and capacity building; local stakeholder workshops and awareness raising);
Development of agreed management strategy in one or more case study districts in each country (stakeholder workshops supported by drafting team/secretariat)

Output 5

Convene final workshop for regional agencies (NACA, ADB, AIT, ICLARM, SEAFDEC); representatives of national fisheries, agriculture, rural development, and planning departments; regional and national coastal management and aquaculture development projects and programmes.
Engage in dialogue with government and non-government specialists and policy makers (in addition to SUMA and CARE) to further develop and promote policy guidelines;
Synthesise experience and learning in practical guidelines and case studies; translate guidelines to Vietnamese and Bangla;
Distribute guidelines to regional agencies (NACA, ADB, AIT, ICLARM, SEAFDEC); representatives of national fisheries, agriculture, rural development, and planning departments; regional and national coastal management and aquaculture development projects and programmes.
Disseminate and promote guidelines, workshop proceedings, and project papers nationally, regionally and internationally through direct mail and website.

Annex 2: project proposal

RD1
(12/96)

DEPARTMENT FOR INTERNATIONAL DEVELOPMENT

STRATEGY FOR RESEARCH ON RENEWABLE NATURAL RESOURCES

DFID *Project Number (to be completed by RLD)*

File Number

Project Title

Practical guidance for the estimation and allocation of environmental capacity for aquaculture in tropical developing countries (TROPECA)

7.1 RESEARCH AND DEVELOPMENT

FUNDING APPLICATION

AND

PROJECT MEMORANDUM FORM

Note: THE FORM MUST BE COMPLETED TAKING INTO ACCOUNT THE <u>NOTES ON COMPLETION OF DFID PROJECT MEMORANDUM FORMS</u>.

PROJECT HEADER SHEET

COUNTRY: Bangladesh; Vietnam FILE REF:

PROJ. TITLE (MAX 60 CHARS): Environmental capacity for tropical aquaculture (TROPECA)

PROJECT DESCRIPTION - WHAT PROJECT IS DESIGNED TO ACHIEVE (MAX 3 LINES):

The project will increase the capacity of fishery and planning professionals in tropical developing countries to develop management systems that will reduce the likelihood of aquaculture development exceeding environmental capacity.

---------- COMMITMENT (£) 164,241

	MIS CODE	TOTAL COSTS	LOCAL COSTS
DFID FINANCIAL AID:		164,241	59,471 (Bangladesh and Vietnam)
DFID TC:			

IS PROJECT COFINANCED WITH OTHER DONORS? (Y OR N):N

IF YES, ENTER TOTAL PROJECT VALUE:

PERIOD OF DFID FUNDING FROM: September 2001 TO:August 2004
ECON SECTOR CODE: ESC DESCRIPTION:

POLICY MARKERS (mandatory for projects over £100,000)

Priority Objectives

01 ECONOMIC REFORM :
02 ENHANCING PRODUCTIVE CAPACITY :
03 GOOD GOVERNMENT *
04 DIRECT ASSISTANCE TO POOR PEOPLE :
05 HUMAN DEVELOPMENT - EDUCATION *
06 HUMAN DEVELOPMENT - HEALTH :
07 HUMAN DEVELOPMENT - CHILDREN BY CHOICE :
08 WOMEN IN DEVELOPMENT :
09 ENVIRONMENT *

Other Markers

10 COMBATING ILLICIT DRUGS :
11 HIV/AIDS :
12 URBAN DEVELOPMENT :
13 PRIVATE SECTOR DEVELOPMENT :
14 TECHNOLOGY DEVELOPMENT & RESEARCH

Rio Markers

15 ENERGY EFFICIENCY
16 SUSTAINABLE FOREST M'GMENT
17 BIODIVERSITY *
18 SUSTAINABLE AGRICULTURE *

ASSOCIATES (mandatory for food aid, disaster & refugee relief, JFS)

MANAGING AGENT(S) :
PROCUREMENT AGENT(S) :
COFINANCIER(S) :
NGO(S) JOINTLY FUNDED :
EDUCATION LINK/PARTNER *

TYPE OF ENVIRONMENTAL ASSESSMENT (IS, EA, EIA) : none
DATE ENVIRONMENTAL ASSESSMENT COMPLETED:

APPROVAL DATE: APPROVAL LEVEL:

DATE PROJECT DOCUMENTS SIGNED:

I approve this project as described in this document and confirm that the commitment, economic sector, policy markers and associates have been checked for accuracy in line with the PIMS guidance.

Signed ______________________________ Name ______________________________ Date __________________

SECTION A: KEY INFORMATION

1. Project Title

Practical guidance for the estimation and allocation of environmental capacity for aquaculture in tropical developing countries (TROPECA)

Abbreviated Title:

Environmental capacity for tropical aquaculture (TROPECA)

5. **Is the research strategic/adaptive?** (delete as appropriate)

Adaptive with strategic elements

3. **Project Summary** (maximum 100 words)

The expansion of aquaculture in developing countries poses risks in exceeding environmental capacity. The possible need to control use of suitable sites has implications for allocation and access. A collaborating team of UK and national scientists, working closely with an NGO and an aid funded project, will review existing approaches to the estimation of environmental capacity and associated environmental management systems. We will explore their application to a range of tropical aquatic systems in Bangladesh and Vietnam which are likely to see increased pressure from aquaculture development. We will develop and adapt these approaches to generate practical guidance for planners and aquatic sector professionals in tropical developing countries in order to increase the sustainability of aquaculture development.

4. **Keywords** (including subject, species, countries etc.)

Environmental capacity; aquaculture; environmental management; rights allocation; assimilative capacity;Vietnam; Bangladesh

5. **RNRRS Programme**

Aquaculture and Fish Genetics Research Programme

6. **RNRRS Production System**

Land-water Interface

7. **Project Goal** (include RNRRS Programme Purpose where appropriate)

Productive benefits of aquatic resources for poor people sustained and increased through improved knowledge of aquaculture processes and their management

8. **Geographic Focus**

Bangladesh; Vietnam

9. **Commodity Base**

fish

SECTION A: KEY INFORMATION Continued

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12. **Project Location**

Most of the theoretical review/desk research will be undertaken in the UK. Field work and workshops will be held at a variety of case study sites in Vietnam and Bangladesh. Writing and reporting related to field work and workshops will take place initially in Vietnam and Bangladesh, with editing and finalisation in the UK.

13. **If the project is located overseas or if there is an overseas collaborator, has the approval of the overseas government been obtained? If so, provide details**.

MoUs and agreements currently being exchanged

14. **Starting and finishing dates**

January 2002	December 2004

ATTACH THE PROJECT LOGICAL FRAMEWORK (see Annex 1)

SECTION B: DEMAND, UPTAKE AND GEOGRAPHICAL FOCUS

15a. **What is the project's purpose** (maximum 50 words)?

The purpose of the project is:
to increase the sustainability of aquaculture development in tropical developing countries

This will be achieved through enhanced capacity of national professionals to understand and estimate environmental capacity, and to use this information to inform development plans and management regimes.

15b. **What developmental problems or needs is the project aimed at?**

There is a widespread tendency for successful aquaculture development (irrespective of scale) to exceed environmental capacity in developing countries. This negatively impacts the sustainability of aquaculture itself, through poor productivity and disease, and may negatively impact other users of the shared natural resource system.

The consequences can be severe in social and economic terms. In the case of small scale shrimp farming which has developed very rapidly in Vietnam in recent years, crop failure rate, in extensive as well as more intensive systems, is commonly more than 50%, corresponding to significant financial loss, and in many cases debt and worsening poverty. This contrasts sharply with the tremendous benefits successful aquaculture can bring. Failure rate is at least partly related to the very high concentration of development, declining water quality, and environmental capacity issues.

Cage culture is now developing rapidly with strong government backing, and can be highly profitable. In the absence of a precautionary approach it is also likely to exceed environmental capacity, at least locally.

In Bangladesh the development of aquaculture has not been as rapid as in Vietnam. However, the relatively high local price of fish, and the correspondingly attractive financial returns means that rapid development is likely, at least in some locations. Small scale cage culture (as promoted by CARE) may come up against environmental capacity limits quite quickly in small enclosed water bodies and ponds. In coastal areas there are already concerns related to the possible negative impacts of shrimp culture on biodiversity in the Sundarbans Forest Reserve and in other areas. There are also important issues of site allocation for aquaculture, and in particular access to sites by the poor, and conflicts over resource use.

15c. **What is the evidence for the demand for the research?**

Sustainable development is central to DFID's development approach, and is a key element in the National Development Plans of Bangladesh and Vietnam, as well as other countries in Asia. A key element in many definitions of sustainable development is to stay within the "carrying capacity" of the environment. Most environmental assessment guidelines require analysis of the relationship between new developments or development programmes and environmental capacity[3]. Codes of conduct and codes of practice refer to environmental capacity either explicitly or implicitly.

There is widespread demand in Asian countries from government, scientists and NGOs for guidance on the estimation of environmental capacity. The issue is raised regularly at national and international meetings. Where the industry has already grown rapidly and is suffering from environmental degradation, there is also demand from farmers themselves.

"Allocation" of environmental capacity implies some limit to entry, or to output, or some influence over management and technology. This cuts across the key issues of access and use rights, equity and poverty. Addressing these issues is a priority for DFID and many other development agencies.

[3] By *environmental capacity* we mean the capacity of the environment to assimilate/disperse waste. This may for example correspond to the total quantity of N which can be loaded into a lagoon before an environmental quality standard is breached. *Carrying capacity* refers to the level of activity (e.g. tonnes of aquaculture production) which would generate this quantity of waste.

Specific requests for assistance in the development of approaches to environmental capacity estimation, and corresponding management systems, were made by local government officials and scientists at the final workshops of the CAGES 2 project in both Vietnam and Bangladesh

15d. **What will the project contribute to resolving these problems or needs and over what time-scale?**

By the end of the project (3 years) practical guidelines for the estimation of environmental capacity, and for the management of aquaculture to stay within environmental capacity will have been developed. In addition significant professional capacity will have been developed within national research institutions commonly called on to advise government in these issues. Capacity will also have been developed within a major aid funded programme for sustainable aquaculture development in Vietnam, and within a major NGO involved in aquaculture in Bangladesh.

If the use of the guidelines, and the increased professional capacity results in aquaculture in one Province of Vietnam enjoying more sustained and higher yields and (say) 10% less crop failure, the economic benefits will be of the order of hundreds of thousands of dollars, and the social benefits will be greater income security and reduced likelihood of debt for hundreds of farmers. If the guidelines are used widely and have significant impact throughout the region, the financial and social returns will be enormous.

15e. **What is the geographical focus of the project?**

The project will be focused on case study locations in Bangladesh and Vietnam. However, it is anticipated that the guidelines will be broadly applicable to aquaculture development in tropical and sub-tropical developing countries.

15f. **Which are the identified target institutions?**

University of Fisheries, Vietnam and Khulna University, Bangladesh; CARE Bangladesh; DANIDA Fisheries Support Programme, Vietnam – Support for Marine and Brackishwater Aquaculture (SUMA-planning component)

Provincial planning and fishery departments in Vietnam agreed the importance of the objectives at a training workshop held by SUMA.

As noted elsewhere however, there is near universal demand for improved guidance on environmental capacity issues from relevant government agencies and departments throughout the region.

15g. **What are the proposed promotion pathways for the uptake of the project outputs?**

i) Market studies carried out for project outputs:
We will be working directly with two important “clients” for the product – a major NGO in Bangladesh, and a major aquaculture development planning programme in Vietnam. The research products will be developed and refined largely in direct response to the needs of these clients. In addition, we will engage with other agencies and NGOs involved with aquaculture development in the target countries and elsewhere in the region to gauge both the need and demand for different kinds of product associated with the research outputs, and to promote these products. The research process itself will be adaptive, with focus steadily refined according to both technical feasibility and demand.

ii) How outputs will be made available to intended users:

11. Outputs will be developed with local collaborators, ensuring that they are an integral part of a broader capacity building process. The collaborators themselves will thus have a stake in using and promoting the outputs.
12. A wide range of technical specialists, government officials, farmers and other stakeholders will be engaged in local workshops designed to explore the feasibility and suitability of different approaches to the assessment and allocation of environmental capacity. Awareness raising, capacity building, and promotion of project outputs will be an on-going and integral part of the project case studies.
13. Project outputs and findings will be tested and used directly by SUMA(Vietnam) and CARE Bangladesh towards the end of the project. SUMA (a collaboration between Danida and the Government of Vietnam) is currently running 5 pilot projects on sustainable aquaculture development planning in different Provinces of Vietnam. These will be used

as a practical testing ground for the approaches developed, and for the quality of the guidelines and other materials produced. It is the intention of the Government of Vietnam to apply the lessons learned from the SUMA pilot projects throughout the country. The approaches developed and lessons learned from the TROPECA project will therefore feed directly into an on-going government led capacity building process for improved aquaculture development planning and management. In Bangladesh CARE is currently a major player in the promotion of small-scale aquaculture, with significant influence on government and national NGO thinking. The lessons learned with TROPECA will be promoted directly in all CARE interventions in aquaculture development, and the CARE organisation on the ground will facilitate dissemination throughout local government planning and extension services, as well as through the highly developed NGO network.

14. There may be significant institutional and political constraints to the implementation of the approaches developed. Efforts will be made, through collaborating programmes and institutions, to promote changes in national level policy and legislation where this is considered to be a constraint to implementation.
15. Findings will be discussed with a range of other government and non-government policy makers and advisors with a view to developing and promoting national/provincial policy guidelines;
16. A regional workshop will be convened toward the end of the research to present the main findings to representatives of relevant national and regional institutions, and discuss their application more widely in the region and in other tropical developing countries. Participants will include representatives of government fisheries, agriculture, rural development and planning departments, extension services, training and education establishments, regional agencies (ADB, NACA, ICLARM, SEAFDEC, AIT) and international agencies (FAO, World Bank)
17. On the basis of the research findings and the dialogue described above, a set of guidelines will be developed for dissemination nationally, throughout the region, and if appropriate globally. These guidelines will be translated into Vietnamese and Bangla and will be concise and accessible.
18. The guidelines will be sent to other major regional institutions (SEAFDEC, ICLARM, NACA, AIT, SEAFDEC) and distributed through the NACA network of national government institutions.
19. A web site will be set up and kept updated during the project and for 2 years after project completion. All publications (including working papers) will be made available as downloads from the site. This will ensure regional and global dissemination of project outputs to key professionals and researchers, and will also strengthen the awareness raising component of the work. Many government research and advisory institutions in Southeast Asia now access a large part of their material from web sites since the costs of access to none electronic media are high.
20. Semi-popular papers will be published in regional and international aquaculture and development magazines with a broad professional readership.
21. At least two papers will be published in professional journals to ensure that future research builds upon our findings.
22. The findings will be incorporated within a regional training course on “planning for sustainable aquaculture development” delivered annually at the Asian Institute of Technology, Thailand.

iii) Further stages needed to develop outputs:
We will seek on-going funding to maintain a web-site dedicated to aquaculture and environmental capacity issues;
Depending on research findings we may seek funding for on-going research and/or capacity building

iv) How will further stages be carried out and paid for?
This will depend on what is required (e.g. further research and/or dissemination and capacity building)

v) Dissemination mechanisms:
see ii above.
In addition, the results will be promoted through professional personal contacts (e.g. through GESAMP; through international meetings and workshops etc).

15h. **Who will the beneficiaries be and are there any groups who will be disadvantaged by the application of the research findings?**

The beneficiaries will include:

23. Future aquaculturists who will be operating within a high quality rather than degraded environment. This should result in higher and more consistent production and lower risk of disease, crop loss, and debt.
24. Other persons dependent upon the quality of the natural environment, such as fishermen and farmers. A high quality environment should ensure that the natural resources upon which they depend remain productive.

During research under the CAGES II project, poor local people in Khanh Hoa Province, Vietnam identified environmental degradation and shrimp disease as significant underlying causes of poverty and constraints to development.

16. **Is this proposal a continuation or extension of work already funded by DFID?**

Environmental capacity was addressed as part of broader environmental considerations in CAGES 2 project (Reference No: R7100; Title: The improved management of small scale cage culture in Asia). It became clear in that project that although environmental capacity was not an immediate problem for the aquaculture systems being researched, it was likely to become a significant issue as levels of activity increase. Since the issue is complex, and important for aquaculture development more generally, it was concluded that a dedicated research project would be required to address the issues adequately.

SECTION C: SCIENTIFIC BACKGROUND

17. **What work has previously been done or is currently being pursued towards the purpose, outputs and activities of the project? (A review of literature should be attached)**

The potential of cage culture for poverty alleviation has recently been assessed and, in small-scale freshwater cage operations in Bangladesh, and medium-scale sea water cage operations in Vietnam, was found to rate highly against most criteria[1,2]. Community based aquaculture in India is regarded as an important tool for both poverty alleviation and community development [3].

Unfortunately, aquaculture in ponds and cages can cause organic and chemical pollution, these problems tending to increase with intensity of production. Powerful financial and economic forces encourage intensification irrespective of scale of activity, or the nature of the feed or fertilisation regime. Furthermore, a range of physical, social and management factors tend to promote aggregation and crowding of aquaculture development, irrespective of scale or intensity. Cultured organisms become stressed as water quality decreases. This may increase both susceptibility to disease, and the density of pathogens in culture water. A vicious spiral of declining water quality and increasing abundance of pathogens may ultimately result in decline or collapse in production over large areas. This has already happened in the case of shrimp culture in most countries in Southeast Asia, and as the extent, density and intensity of cage culture increase, similar problems are likely to arise. Secondary impacts on other resource users, habitat quality, and biodiversity are also likely. In Southeast Asia, where population density is high, this is not just a problem for large scale and intensive systems, but also for small scale systems. When this decline takes place, it is common to suggest that the *carrying capacity* of the environment, or *environmental capacity* has been exceeded.

The social and financial costs of exceeding environmental capacity is huge. For example, our own research[3] suggests average crop failure rate between 40 and 60% in the case of smallholder shrimp farms in parts of Vietnam. Up to 50% of farmers may be losing money, with serious social and economic consequences. While many factors contribute to disease, there is little doubt that the incidence and severity of disease outbreak, and the growth performance of cultured organisms, are closely related to environmental capacity.

It is important to clarify the terminology relating to environmental capacity and the various components associated with it. *Carrying capacity* is the number of organisms, or number of enterprises, or total production, which can be supported by a defined area, ecosystem or coastline. *Environmental capacity* is sometimes confused with carrying capacity and has been subject to a range of interpretations and definitions. According to GESAMP[4] environmental capacity is "a property of the environment and its ability to accommodate a particular activity or rate of an activity...without unacceptable impact". The key point here is that environmental capacity is a property of the environment (for example, the rate at which nitrogen can be assimilated, or the rate of production of planktonic food), while carrying capacity depends on both environmental capacity and (e.g.) the rate of waste output from aquaculture, or (in the case of bivalve molluscs) the rate of consumption of plankton food[5,6]. The rate of waste production from different forms of aquaculture, and the rate of food consumption of bivalve molluscs, are relatively well established. The environmental capacity of different tropical aquatic systems is not well established, and is likely to vary significantly according to local physical-chemical and ecological conditions. This will therefore the main focus of this study.

In practice several sub-components must be addressed in order to gain an improved understanding of environmental capacity for different aquatic systems:

25. The dispersal of nutrients (or other substances) in receiving water;
26. The dilution of these substances in the receiving water
27. The degradation or breakdown of these substances in the water column or sediments;
28. The assimilation of these substances by aquatic organisms;
29. The adsorption of these substances by sediments;
30. The effects that the absolute concentrations of these materials, and their assimilation, have on resources or ecosystem integrity and functioning;
31. Comparison of these concentrations, or their effects, with environmental quality standards reflecting acceptable levels of change

In other words, for the concept of environmental capacity to be practically useful we need to model, in a simple and cost-effective way, the processes of dilution, dispersal and assimilation, and define acceptable limits to change and/or environmental quality standards. These standards should reflect acceptable levels of risk to aquaculture itself, and broader environmental and social considerations[7].

A variety of mass balance, steady state and dynamic dilution and dispersal models have been developed for the estimation of environmental capacity in respect of organic matter and nutrient loads, based mainly on temperate conditions and semi-closed water bodies[6-13]. Some approaches go further, and seek to model the impact on phytoplankton dynamics, with a view to predicting more subtle impacts associated with nutrient loads, or the impact of shellfish farming on plankton density and composition[14-15]. A few studies have been undertaken in respect of tropical developing countries[8,16,17]. Unfortunately, simple mass balance models such as those applied to Kung Krabaen Bay (lagoon) in Thailand[16] tend to be highly inaccurate (and optimistic) when applied to complex lagoon systems, and are difficult to apply to estuarine and delta systems. On the other hand, the research required to provide data for the more sophisticated hydraulic models such as those developed in respect of Norwegian Fjiords[14] and for the estuarine systems of the Gulf of Fonseca in Honduras[17] is likely to be beyond the means of local government or the capacity of small-scale farmers in developing countries. Furthermore, the rate processes and environmental quality standards required to estimate environmental capacity are poorly specified for tropical aquatic systems, as are biological indicators.

Rather more attention has been paid to the simpler issue of the accumulation of sediments below cages or in pond effluents, and various estimates for the maximum rates of input of organic matter have been estimated on theoretical grounds or based on empirical studies[18-23]. However, few theoretical or empirical studies have been undertaken relating to tropical or sub-tropical conditions[9].

A variety of studies have looked at or are looking at broader brush approaches to environmental capacity issues. The Norwegian LENKA project used mixed theoretical-empirical modelling to assess environmental capacity of different coastal systems in relation to aquaculture[24]. The UNEP GEF funded Land Ocean Interactions in the Coastal Zone (LOICZ)[25] is developing a *coastal typology* with a view to making broad estimates of associated physical-biological processes and environmental capacity. A major research programme is currently examining aquaculture and carrying capacity issues in Xincun Bay, Hainan Province, China using ecosystem modelling and remote sensing approaches[26]. Sophisticated software such as SIMCOAST is also becoming available to support these approaches.

Almost all of the discussions on environmental capacity in developed and developing countries focus on its calculation or estimation. In practice, of at least equal importance is the issue of how to ensure that it is not exceeded – or how to manage or allocate it once it has been estimated. Even where this is a specific objective (such as in the case of MOM - monitoring, on-growing fish farms, modelling - in Norway[27]; EIA procedures in the UK and other developed countries; the TMDL approach used by the EPA in the US), the emphasis is on monitoring and modelling, rather than allocation, compliance, and response procedures. While such approaches may be appropriate in a relatively centralised industry with large individual farms and strong regulatory regimes, they are unlikely to be effective in developing countries where small scale aquaculture is expanding rapidly, and in many cases already *over-shooting* environmental capacity. Clear (*pre-emptive*) allocation procedures, and/or response procedures, and approaches which promote compliance, are required if the industry is to develop sustainably. Furthermore, these approaches must take account of other resource users, both in terms of their contribution to the problem (e.g nutrient and organic wastes) or their susceptibility to it. In Hong Kong, a study of environmental quality related to cage culture development resulted in a zoning initiative, and the relocation of cage culture to ensure that water quality was adequate[28].

Allocation depends critically on the nature of ownership and/or access rights as well as other broader legal, institutional, and socio-political circumstances. It is unlikely that there will be a single optimal approach to allocation, but rather a suite of alternative approaches with different strengths and weaknesses according to different circumstances. Allocation issues are therefore best addressed through a case study approach, covering a range of socio-political systems.

There is now a substantial literature and increasing international experience on resource allocation issues, especially the use of economic measures and/or participatory/co-management regimes[29-31]. There is also a steadily increasing body of experience relating to the regulation and monitoring of aquaculture development in developed countries[32]. Despite a clear need, the practical application and possible adaptation of this increasing body of knowledge and experience to the management of aquaculture in a developing country context has hardly been addressed[9].

The time is therefore right to apply and bring together the substantial research that has been undertaken on the estimation of environmental capacity, and on effective approaches to natural resource management, with a focus on the particular needs of sustainable aquaculture development in tropical developing countries. Any approaches developed must take into account the high levels of variation and uncertainty associated with estimates of environmental capacity, the costs of research and monitoring, and the capacity of local farmers and regulatory institutions to use scientific information effectively within a planning and management process for aquaculture.

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SECTION D: OUTPUTS AND ACTIVITIES

18a. **What are the outputs of the project?**

1. Enhanced understanding amongst collaborators, other scientists, and regional professionals of the applicability of simple environmental capacity models and adaptive management approaches in providing effective environmental management of key tropical aquaculture system.

1. Identification and review of strengths and weaknesses of alternative biological and physical environmental indicators and their potential role in the development of practical environmental quality standards for a range of tropical habitat types associated with aquaculture.

2. Enhanced understanding amongst collaborators, other scientists and regional professionals of the applicability of alternate planning instruments to allocate environmental capacity and control development for aquaculture in tropical developing countries.

3. Collaborative case-study based practical strategies for promoting aquaculture equitably within environmental capacity developed.

4. Enhanced capacity to plan and manage tropical aquaculture equitably within environmental capacity on the part of key government departments and agencies regionally, nationally and internationally

One peer reviewed article will be published in relation to outputs 1-2 above, and a second will be published in relation to output 3. A final comprehensive journal article will present the main findings of the research.

One or two broad ranging semi-popular articles will be written to synthesise the findings and promote and raise awareness of the existence of the guidelines.

Output 4 will be developed “on the ground” in close collaboration with CARE Bangladesh and SUMA (support to brackishwater and marine aquaculture – planning component) in Vietnam. This will ensure that the approaches are practical, rigorously tested in the context of national policy, and institutionalised within longer term capacity building programmes.

Guidelines associated with output 5 will be developed and adapted based on the practical experience of implementation in Vietnam and Bangladesh, and dialogue with relevant government departments and agencies. They will be designed for wider dissemination to national research institutions and consultants; local and national government; environmental agencies; NGOs engaged in aquaculture development and/or natural resource management throughout the region.

18b. **What are the objective verifiable indicators for the outputs?**

OVI Outputs 1-2:
Review of environmental capacity models, indicators, standards and management approaches, submitted for publication in international journal by the end of year 1, and a summary published in the form of a semi-popular journal article by the end of year three.

7.1.1 OVI Output 3

A review and analysis of the applicability of the various instruments which might be used to allocate environmental capacity and/or limit development so as to stay within it for tropical developing countries submitted for publication in international journal by the end of year 2, and a summary published in the form of a semi-popular journal article by the end of year three

7.1.2 OVI Output 4

Strategies in at least 1case study area in each of Vietnam (with SUMA) and Bangladesh (with CARE Bangladesh) developed, adopted and implemented by end of project.

7.1.3 OVI Output 5

32. Guidelines adopted and promoted nationally by (at least) SUMA and CARE.
33. Guidelines referred to in national and regional publications and project documents.
34. Lessons learned and approaches developed applied in local sustainable aquaculture development plans and projects in at least Vietnam and Bangladesh
35. Guidelines used in teaching/training at AIT and in support of other regional training initiatives NACA, SEAFDEC

18c. **What are the means of verification of the outputs?**

Means of verification are:

36. project reports (all outputs); peer review and semi popular articles (outputs 1-3).;
37. locally published plan or strategy, incorporating detailed implementation plan and schedule; CARE and SUMA progress reports (output 4).
38. CARE and SUMA progress reports and policy statements; national guideline documents; TROPECA Project reports, and other project/programme reports and publications (output 5).

18d. **What are the expected environmental impacts? (beneficial, harmful, neutral)**

i) Direct

Not relevant since the whole project is focused on delivering reduced environmental impacts

ii) Indirect

Not relevant since the whole project is focused on delivering reduced environmental impacts

19a**. Describe the project activities**

General approach

Three key requirements have been taken into account in developing the initial methodology, and will further inform methodology development as the project evolves:

39. The need to develop *cost effective and practical* methodologies suited to developing countries;
40. The need to take account of *the variation between different socio-economic and political-institutional systems*;
41. The need to take account of the enormous *differences between types of aquatic system* (ranging from open bays to closed lakes and wetlands);

We will undertake the study in two very different tropical developing countries. Bangladesh is characterised by relatively informal and decentralised (but nonetheless powerful) social, political and religious institutions. Vietnam is secular and highly politically organised at both local and national levels. In terms of resource allocation issues these countries therefore represent opposite ends of a political spectrum.

We will select case study locations representing a range of major habitat/ecosystem types under greatest pressure from aquaculture development. This will allow us to asses the strengths and weaknesses of alternate approaches to both environmental capacity estimation and allocation under widely different ecological regimes.

We will delay detailed technical research on the estimation of environmental capacity until we have a sufficient understanding of local physical-ecological and social-institutional systems to make an informed assessment of the relative value of such research. In other words, the research will be adaptive, steadily focusing on key researchable constraints as we increase our understanding of local systems, and the potential of alternative allocation/management procedures.

Project structure

The project will take place in three phases. The first phase, based mainly on literature review and workshops, will result in a comprehensive overview of the cost, utility, adaptability and applicability (to tropical developing countries) of existing models and approaches to the estimation of environmental capacity, and the use of these estimates to improve the environmental management of aquaculture. This phase will culminate with the identification of case study locations and development of a detailed research plan.

The second phase will comprise case studies designed to examine in more detail the practical application and adaptation of promising approaches to addressing environmental capacity issues. The case studies will be selected on the basis of need – i.e. the existence or likelihood of significant aquaculture development; and as representative of important habitat/aquatic system types. Using these cases from two countries with very different resource allocation systems, we will be able to assess the need or otherwise for 1 or more approaches, according to habitat/system and political/resource allocation systems.

Phase 3 will comprise gap filling technical research coupled with capacity building. The first two phases will have highlighted specific practical research (relating to technical and management parameters) needed to facilitate more realistic and effective approaches to environmental capacity assessment and allocation. Following on from a rigorous “value of information/value of research” analysis, and taking account of the limited time and resources available, we will focus on key identified researchable constraints. These are likely to be relatively simple “gap filling” studies. This final phase will also see comprehensive analysis of institutions and decision making systems and their capacity for delivering improved management. Alternative approaches to the allocation and management of environmental capacity will be evaluated in relation to each case study area/system. This evaluation will be both technical and participatory with a view to developing a shared and agreed management strategy for aquaculture in the case study areas.

Specific activities are presented below.

Phase 1: review, scoping and classifying

Desk studies

a) A critical review of existing models and rules of thumb for the estimation of environmental capacity, and a comparison with alternative monitoring-adaptive management approaches, including analysis of their application to tropical developing countries (in terms of the model framework, the parameters and data requirements, the costs, and the institutional capacity for their utilisation). This review will draw on published material and discussion with other international specialists, and other members of the project team.
b) A critical review and summary of actual and possible biological and physical indicators of environmental quality for major tropical habitat types. This will again draw on published information, discussion with other regional and international specialists, and other members of the project team. This review and analysis will be closely linked to:
c) A critical review and discussion of existing environmental quality standards appropriate to a range of tropical habitat types. This review and those relating to a) and b) above will be written up in a single comprehensive review which will serve as the first major project output. A summary version of this will also serve as a key resource document for the workshops.
d) A critical review of the management tools and instruments which might be used to allocate environmental capacity, and/or prevent it being exceeded. This review will cover the full spectrum of approaches including regulatory, economic, and participatory instruments. It will draw on both developed and developing country experience, but with emphasis on applicability in a developing country/developing industry context. This review will be written for journal publication, but with an accessible summary suitable for use as a resource document for in-country workshops.

Research planning workshops

Two research planning workshops will be held – one in Bangladesh and one in Vietnam. The objectives of the workshops will be:

- *To introduce the research team (Nautilus, Stirling, Khulna, UoF, CaF) and collaborating organisations (CARE Bangladesh and SUMA Vietnam);*
- *To identify key aquatic systems and locations already affected by, or likely to be affected by, significant levels of aquaculture development;*
- *To examine in detail the applicability of existing environmental capacity models.* Partner researchers will be briefed to bring relevant existing information (detailed maps and charts of possible case study areas; sources and quantities of pollution, including from aquaculture; climatic and hydrographic information; sediment and habitat type and distribution). Rough assessments of capacity will be made using mass balance/water exchange and physical/biological assimilation models. The accuracy and utility of these models, and the need or otherwise for more detailed information, and/or more sophisticated models will be discussed.
- *To examine the potential of monitoring/adaptive management procedures as an alternative to, or supplement to, modelling environmental capacity.* Discussion would focus on both technical and institutional issues.
- *To make a preliminary exploration, and raise awareness, of implementation and management issues.* Ways in which aquaculture development can be restrained within the limits of environmental capacity (however estimated) will be discussed, and the implications of this for the focus of effort in the research.
- *To review the utility of existing agro-ecosystem/habitat classifications as a framework for applying different approaches/rules of thumb to environmental capacity issues, and as a criterion for the selection of case studies;*
- *develop a research plan, including case study locations, detailed outputs, schedule of activities, and responsibility for outputs.*

Phase 2 : mining and reformulating

Case studies

Case study locations will be chosen in the workshop on the basis of both demand and feasibility. We anticipate between 2 and 3 case studies in each country, selected from the following major aquatic system types:

42. freshwater floodplain;

43. freshwater reservoir
44. mangrove forest/delta
45. estuary
46. coastal lagoon
47. restricted coastal bay

The case studies will generate:

1. A more detailed assessment of the application and utility of existing models and rules of thumb, building on the conclusions drawn in the workshop, and collecting readily available data as required to test the feasibility and accuracy of the various approaches;
2. A detailed evaluation and feasibility study of the way in which the models/rules of thumb might be used to inform a planning and management framework to ensure that environmental capacity is not exceeded;
3. Adaptation/reformulation of these approaches in line with local conditions, capacities (physical, biological and institutional) and the nature of any evolving management framework;
4. Identification of critical information requirements (such as key rate processes) to allow for realistic and practical application of these approaches

The case studies will be undertaken mainly by the local scientific teams, drawing on technical expertise from Nautilus and Stirling as required. In addition to the review and assimilation of existing information, and its use in testing the various models/approaches, the team will begin the process of stakeholder involvement through local workshops, drawing on their experience and knowledge, raising awareness, involving them as far as possible in the project, and ensuring that science and practical considerations are integrated from the outset.

Phase 3: Technical research and capacity building

1. Biological and physical research

The case studies are likely to generate a clear assessment of the need – if any – for detailed technical research. Such research might, for example, address the following:

- Survey of water quality, sediment quality and the presence/absence/abundance of potential indicator species in selected locations within case study areas. Association analysis might be used to analyse the data.
- Sampling of key water and soil quality parameters in the case study locations, covering a range from pristine to degraded, and supporting a range of economic activities, with a view to providing the basis for the development of locally appropriate environmental quality standards, and allowing for enhanced understanding or estimation of waste assimilation rates from aquaculture and other activities;
- Assessment of process rates for the assimilation of organic matter in sediments, and for the assimilation of nutrients in the aquatic system as a whole, based on the above and/or on specific experimental studies.

Clearly some of these issues will be complex and difficult, and the feasibility of delivering useful analysis within the resources and time frame of the project will be a key consideration in the prioritisation and planning of such research.

***2**. Management research and capacity building*

Alternative approaches to the allocation and management of environmental capacity will be evaluated in relation to each case study area/system. Approaches considered might include:

- Estimation and allocation of capacity, in terms of acceptable loadings, corresponding production rates, corresponding input and conversion rate – to individuals, groups of farmers, or to the sector as a whole;
- Monitoring and response mechanisms – environmental monitoring coupled with procedures to restrict production and/or waste generation should precautionary environmental reference points be reached;
- Pre-emptive mechanisms – targeting input quality, conversion efficiency (skills, technology), waste management (on farm/off farm), on the assumption that these, coupled with market constraints on production, will effectively prevent environmental capacity being exceeded;
- Sets of incentives and/or constraints to implement the above alternatives in practice (e.g. licensing, regulations, policing, economic and market instruments, infrastructure and services, skills and awareness).

The evaluation will take into account the cost/accuracy/uncertainty of environmental capacity assessments, the capacity of the farmers and/or local government and/or fisheries department to implement associated management measures; and the seriousness of potential environmental impact.

This evaluation will be both technical (i.e. drawing on an analysis of institutions, stakeholders, policy and procedures) and participatory (joint meetings and workshops to discuss the need for management, and the strengths and weaknesses of alternative approaches) with a view to developing a shared and agreed management strategy and management system for aquaculture in the case study areas. The process will also result in significantly increased awareness and understanding of the concept of environmental capacity amongst farmers and decision makers. The practical applicability of these approaches will be tested within the framework of the DANIDA *Suma* aquaculture development planning initiative in Vietnam (at Provincial and District levels), and the CARE CAGES project in Bangladesh (at village and possibly district level).

3. Ground-truthing

Rough estimates of environmental capacity – with an indication of uncertainty – will be generated in relation to all, or specific parts of, each case study area. If the models used are simple (e.g. a rough value for nitrogen assimilation rate per hectare of a particular habitat; or organic matter assimilation per m^2 of a type of sediment/system) then we can apply and test them in other locations – and specifically in situations where it appears that environmental capacity may have been exceeded. If/where more complex measurements and calculations appear to offer a more satisfactory approach, ground truthing will be difficult, and we may have to fall back on ensuring that effective monitoring mechanisms are set in place to allow national scientists to test the accuracy of any predictions in situ.

4. Scale issues

By definition, environmental capacity estimates must apply to a specified defined area or system. Ideally the case study systems chosen will correspond roughly to a practical management unit (a lagoon; estuary etc) but especially for delta and inland systems, “natural” boundaries may be hard to define and “administrative” boundaries may be unsuitable. This is one important reason for integrating management systems research with more technical-biological research in this project. The interplay between the two research strands should help to define the level at which environmental capacity can be reasonably estimated and effectively used.

Roles

1. Partner research institutions in Vietnam and Bangladesh will contribute detailed local understanding of both ecological systems and management issues. They will undertake the bulk of the case study research, supported as required by Stirling Institute of Aquaculture and Nautilus. They will contribute to all publications and will make a significant contribution to the preparation of the guidelines. Specifically they will:
2. Assimilate background secondary information on potential case study sites, and present this information to the research planning workshops. Key sections of local documents will be translated into English as required
3. Organise national workshops, with inputs from other partners
4. Take a full and active part in research planning
5. Manage and implement the technical biological and management systems fieldwork on a day to day basis, following research plans agreed with Stirling and Nautilus.
6. Contribute to the drafting of all significant reports and publications, and translate these into national language where appropriate.
7. *The local laboratory facilities* at the collaborating Universities will be drawn on to facilitate field work, supplemented with equipment supplied by the Institute of Aquaculture if necessary, and some limited additional equipment purchased under the project.
8. *The Institute of Aquaculture* will provide expertise on technical and biological aspects of environmental capacity and monitoring. They will take a lead role in developing research plans in respect of technical/biological aspects of environmental capacity and water quality issues. They will have primary responsibility for final delivery of the first journal paper relating mainly to the technical outputs, although they will be supported by Nautilus in the preparation of this review. They will make a significant contribution to the second journal paper and the semi-popular papers and guidelines.
9. *Nautilus* will manage the project, ensure delivery of all outputs, and provide expertise related to institutional issues, and the uses of economic, planning and regulatory instruments and/or local management regimes in the application of the concept of environmental capacity. They will have primary responsibility for the background research and literature review, and for preparation of the second journal article, the semi-popular articles, and the guidelines.
10. *SUMA* (Vietnam) and CARE (Bangladesh) will take an active part in research workshops, and in reviewing written materials generated by the project. They will assist in the selection of case study areas, offer advice throughout the project, and seek to apply, test and where appropriate institutionalise research findings in the practical context of their programmes.

19b. **What factors could prevent the attainment of:**

i) Planned activities

The participatory aspects of the case study management research component may come up against local vested interests and political problems. While this may cause difficulty in the formulation of an agreed strategy to address environmental capacity issues, it would not undermine the value of attempting to do this. Furthermore, these difficulties are to be expected, and will generate important lessons regarding the feasibility of different approaches.

ii) Outputs

Related to i) above, difficulty may be encountered generating agreed strategies to address environmental capacity issues.

The complexity of natural ecosystems and assimilation processes are such that it may be difficult to provide adequate scientific underpinning to support effective management strategies. While this may demonstrate the limitations of science (at least in the short term), it in no way undermines the rationale and demand for the research, and will in itself be an important finding with clear policy development implications.

There may also be conflicts reconciling local sustainable development needs and targets with national level development targets. This may delay implementation of strategies developed, or in the worst case prevent them. Dialogue with government at all levels will be a significant on-going activity to try to prevent such an outcome

iii) Project Purpose

1. Other constraints may make aquaculture unsustainable before environmental capacity problems arise - for example market constraints or disease (although the latter is related to environmental capacity).

2. Managing aquaculture within the limits set by environmental capacity will be difficult, especially for the more financially rewarding forms of aquaculture. Success will depend upon a combination of awareness, technical capacity, political will, effective institutions and decision making processes. This project will only address some of these issues. The project's role in institution and management capacity building will be limited to the case study sub-components. It is important that this work is taken forward and built on elsewhere in projects with a stronger institutional/planning focus.

iv) Project Goal

Goal: *Productive benefits of aquatic resources for poor people sustained and increased through improved knowledge of aquaculture processes and their management*

The goal depends upon relevant knowledge being disseminated and applied. Since dissemination and stakeholder participation is a key component of this project, we see no reason why this goal should not be achieved.

20. **Complete a bar chart or attach milestone charts over the life of the project.**

	2002												2003												2004											
	j	f	m	a	m	j	j	a	s	o	n	d	j	f	m	a	m	j	j	a	s	o	n	d	j	f	m	a	m	j	j	a	s	o	n	d
review of environmental capacity models	■	■	■	■																																
comparison with monitoring-adaptive management			■	■	■																															
Review environmental quality indicators		■	■	■	■	■																														
Review environmental quality standards			■	■	■	■																														
Research planning workshop Bangladesh					■	■																														
Research planning workshop Vietnam					■	■																														
Case studies Bangladesh (review and application)							■	■	■	■	■	■	■																							
Case studies Vietnam (review and application)							■	■	■	■	■	■	■																							
Case studies Bangladesh (biological and physical research)												■	■	■	■	■	■	■	■	■	■	■	■													
Case studies Vietnam (biological and physical research)												■	■	■	■	■	■	■	■	■	■	■	■													
Case studies Bangl. (management research and capacity building)																	■	■	■	■	■	■	■	■	■	■	■									
Case studies Vietnam (management research and capacity building)																	■	■	■	■	■	■	■	■	■	■	■									
Semi popular articles																										■	■	■	■	■	■	■	■			
Final project report																														■	■	■	■	■	■	■

SECTION E: FINANCIAL INFORMATION

21a. **Total funding requested from DFID**

£164,241

21b. **Summary of funding (£) requested from DFID to be shown by DFID financial years 1 April to 31 March** (also complete Section 22)

YEAR	2001/2	2002/3	2003/4	2004/5	***project total***
Staff Costs	7,271	30,350	30,350	25,080	***93,051***
Overheads	3,132	9,844	9,844	7,877	***30,697***
Equipment	4,000	2,000	-	-	***6,000***
Overseas Travel	1,180	4,720	2,360	4,400	***12,660***
Miscellaneous	800	4,200	4,700	3,150	***12,850***
VAT	1,197	2,790	2,790	2,206	***8,983***
TOTAL COSTS	***17,580***	***53,904***	***50,044***	***42,713***	**164,241**

21c. **Will your organisation charge DFID Value Added Tax?** Yes

VAT registration number

502268672

21d. **Contributions from other organisations towards the costs of the project**

Contributions in kind from CARE Bangladesh and Danida SUMA, Vietnam (misc. transport, time input to meetings etc)

21e. **If this proposal is being submitted elsewhere for funding state the organisation and when a decision is expected**

no

SECTION E: FINANCIAL INFORMATION Continued

22a. **Staff Costs**

SALARY COSTS: (Salary, National Insurance, and Superannuation contributions should be shown separately for each person). **All likely salary increases and inflation must be allowed for**. If staff are on incremental scales, give incremental date for each staff category.

Name and percentage of time charged for	grade	2001/2		2002/3		2003/4			2004/5
		% time	cost	% time	cost	% time	cost	% time	cost
John Hambrey	Director	25%	1,750	10%	4,200	10%	4,200	10%	3,150
Rod Cappel	technical advisor	75%	4,000	25%	8,000	25%	8,000	25%	6,000
Trevor Telfer	consultant	10%	700	5%	2,100	5%	2,100	7%	2,205
Myriam Baete	administrator	5%	200	5%	1,200	5%	1,200	5%	900
Bangladesh national project officer	scientist	25%	113	100%	2,700	100%	2,700	100%	2,025
Bangladesh local research manager 1 (marine)	scientist	15%	68	25%	675	25%	675	25%	506
Bangladesh local research manager 2 (FW)	scientist	15%	68	25%	675	25%	675	25%	506
BD research assistants and local consultants			63		3,375		3,375		3,375
Vietnam national project officer	scientist	25%	113	100%	2,700	100%	2,700	100%	2,025
Vietnam local research manager 1	scientist	15%	68	25%	675	25%	675	25%	506
Vietnam local research manager 2	scientist	15%	68	25%	675	25%	675	25%	506
VN research assistants and local consultants			63		3,375		3,375		3,375
sub totals			*7,271*		*30,350*		*30,350*		*25,080*
VAT (UK staff only)	18%		1,197		2,790		2,790		2,206
Totals			***8,468***		***33,140***		***33,140***		***27,286***

22b. **Overheads**

This section must include any overheads stating method of calculation.

Overheads	rate	2001/2	2002/3	2003/4	2004/5	project total

Overhead on UK salaries	45%	2,993	6,975	6,975	5,515	22,457
Overhead on overseas salaries	25%	140	2,869	2,869	2,363	8,240
total		***3,132***	***9,844***	***9,844***	***7,877***	***30,697***

SECTION E: FINANCIAL INFORMATION Continued

22c. Capital Equipment

Is it assumed that the laboratory where the work is to be done is adequately equipped with the basic tools to undertake the work. In the event of additional equipment being required, it must be project-specific and full justification must be given for its purchase. Equipment purchased from DFID funds should be of UK manufacture. If non-UK goods are required, RLD must be consulted.

All non-expendable items which cost £500 or more to purchase (excluding VAT) remain the property of the Department for International Development and must not be disposed of without the prior permission of RLD. No items must exceed £25,000.

Detailed specifications should be given for all items including details of suppliers and catalogue numbers where known and the financial year in which they will be required.

Note: At this stage it is impossible to estimate exactly the costs of equipment related to field work. The scope and detail of the physical/biological field work will only be defined toward the end of phase 2 of the project, and will be of a "gap filling" nature. Equipment may be loaned, hired or purchased as possible/necessary.

Capital equipment	2001/2	2002/3	2003/4	2004/5	project total
3 lap-top computers for international project officer and national project coordinators	3600				3600
printers for 2 national coordinators	400				400
associated software		1000			1000
6 water quality kits?			1000		1000
total	**4,000**	**1,000**	**1,000**	**-**	**6,000**

SECTION E: FINANCIAL INFORMATION Continued

22d. **Overseas Travel and Subsistence**

Please itemise airfares (economy class), subsistence, etc.

Overseas travel and subsistence	purpose	Route (economy air fare)	travel cost	nights away	Sub-sistence rate	Sub-sistence costs	total for trip	**total for year**

2001/2	project officer liaison	Edinburgh-Bangladesh-Vietnam-Edinburgh	1000	9	20	180	1180	**1,180**
2002/3	project officer liaison	Edinburgh-Bangladesh-Vietnam-Edinburgh	1000	9	20	180	1180	
	project officer workshop	Edinburgh-Bangladesh-Vietnam-Edinburgh	1000	9	20	180	1180	
	PI workshop	Edinburgh-Bangladesh-Vietnam-Edinburgh	1000	9	20	180	1180	
	technical advisor workshop	Edinburgh-Bangladesh-Vietnam-Edinburgh	1000	9	20	180	1180	**4,720**
2003/4	PI research planning	Edinburgh-Bangladesh-Vietnam-Edinburgh	1000	9	20	180	1180	
	project officer liaison	Edinburgh-Bangladesh-Vietnam-Edinburgh	1000	9	20	180	1180	**2,360**
2004/5	project officer liaison	Edinburgh-Bangladesh-Vietnam-Edinburgh	1000	9	20	180	1180	
	project officer liaison	Edinburgh-Bangladesh-Vietnam-Edinburgh	1000	9	20	180	1180	
	project officer workshop	Edinburgh-Bangkok-Edinburgh	600	4	20	80	680	
	PI workshop	Edinburgh-Bangkok-Edinburgh	600	4	20	80	680	
	technical advisor workshop	Edinburgh-Bangkok-Edinburgh	600	4	20	80	680	**4,400**
Project total								**12,660**

SECTION E: FINANCIAL INFORMATION Continued

22e. **Miscellaneous**

This section should include UK travel and all other costs not covered by 22a-22d.

Miscellaneous costs	2001/2	2002/3	2003/4	2004/5	project total
Research grant for AIT Masters student		1,000	1,000		***2,000***
Local travel and subsistence	300	1,000	1,000	800	***3,100***
consumables (office, paper, disks, cartridges etc)	200	1,000	1,000	300	***2,500***
Information resources - internet acces, electronic publications, papers etc	300	500	500	300	***1,600***
guideline and leaflet production and printing	-	-	500	750	***1,250***
workshop costs		700	700	1000	***2,400***
total	***800***	***4,200***	***4,700***	***3,150***	***12,850***

Annex 3 List of outputs

Engagement of farmers and aquaculture professionals during execution of research

Dissemination/participation (pre-dissemination phase)	Khulna	Putia	Dosun	Khanh Hoa	Can Gio
Numbers of farmers and other aquatic resource users/stakeholders attending Tropeca meetings and workshops	25	60	155	96	90
Numbers of government officials, fishery officers, extension agents etc attending Tropeca meetings and workshops	4	4	18	6	6
Number of farmers engaged in participatory research with Tropeca/collaborating with tropeca	60	10	40 (2004)	50	25
Numbers of meetings/workshops (not organised by Tropeca) where Tropeca approach discussed.	5	5	5	2	5
Any press or media coverage to date or imminent	Y	Y			
Students/trainees introduced to Tropeca approach	40			1041	
Leaflet, booklet, journal	Poster, leaflets		100 leaflets on disease and environmental management	leaflets	

Working papers and case reports

These are available on the web site (http://www.hambreyconsulting.co.uk/tropeca-research-outputs-g.asp) and hard copies can be obtained from the authors. They include:

- Working paper 1: Environmental capacity modelling in aquaculture development
- Working paper 2: Environmental indicators for sustainable aquaculture development
- Working paper 3: Environmental capacity in the management of aquaculture and its potential application in developing countries
- Working paper 4: The status of aquaculture and environmental management issues in Vietnam
- Working paper 5: Nutrient Cycling in Flooded Production Systems

- Case report 1: Xuan Tu Lobster village, Khanh Hoa, Vietnam
- Case report 2 Shrimp farming in Can Gio, Vietnam
- Case report 3 Shrimp and crab farming in Dosun, Vietnam
- Case report 4: Shrimp farming in Khulna, Bangladesh
- Case report 5: Multiple use ponds in Puttia village, Bangladesh

Presentations and conference papers

- Tuan, L, A., Hambrey, J.B. Cappell, R. 2004. Using Environmental Capacity in Tropical Aquaculture – The TROPECA approach. Paper presented to 7th Asian Fisheries Forum
- Rouf, M.A., Cappell, R and Hambrey J.B. 2004. Environmental Capacity and Management of Coastal Shrimp Aquaculture in Bangladesh. Paper presented to 7th Asian Fisheries Forum

- Telfer, T. 2005 .Aquaculture in SE Asia: the environmental capacity dilemma. Presentation to the Scottish Marine Group 27th October 2005
- Hambrey, J., Rouf, M.A., Tuan, L.A., Hien, N.T., Naser, A., Tu, N., Telfer T 2005. Using environmental capacity in tropical aquaculture: the Tropeca approach – main findings. Presentation to a seminar at the Asian Institute of Technology, Bangkok, February 2005.

Other related reports and publications

A report was produced for SUMA and the Hon Mun Marine Protected Area Authority which drew heavily on TROPECA research:

> Hambrey, J. 2004. Towards a plan for aquaculture development and management within the Hon Mun Marine Protected Area. Preliminary report to Hon Mun MPA project. 15th June 2004 (see www.hambreyconsulting.co.uk publications).

Poster and leaflet on group environmental management of aquaculture systems in Bangladesh language for NGOs an farmers groups in Bangladesh. 2005

Leaflets for farmers and local fishery officers on disease and environmental management in Vietnamese.

Currently in preparation

- Leaflets for farmers and fishery officers on environmental capacity and management of cage aquaculture in Vietnamese
- Regional guidelines for the assessment of environmental capacity for aquaculture

Annex 4 List of participating scientists and institutions

Dr John Hambrey, Hambrey Consulting, Strathpeffer, UK
Mr Le Anh Tuan, University of Fisheries, Nha Trang, Vietnam
Mr Mohammud Abdur Rouf, University of Khulna,Khulna, Bangladesh
Dr Vu Dung/Ms Hien, Research Institute for Aquaculture No 1 (Brackishwater Research Station), Dosun, Vietnam
Mr Nguyen van Tu, University of Agriculture and Forestry, Ho Chi Minh Cit, Vietnam
Dr Niamul Naser, University of Dhaka, Bangladesh
Dr Trevor Telfer, Institute of Aquaculture, University of Stirling, Scotland, UK

Annex 5: References and resources

Selected references

More comprehensive reference lists can be found in the case reports and working papers

Angel, D. L., Krost, P. and Gordin, H. 1995. Benthic implications of net cage aquaculture in the oligotrophic Gulf of Aqaba. In, H. 19. Rosenthal, B. Moav and H.

Aure, J. and Stigebrandt, A. 1990. Quantitative estimates of the eutrophication effects of fish farming on fjords. Aquaculture 90: 135-156.

Barg, U.C. 1992. Guidelines for the promotion of environmental management of coastal aquaculture development. FAO Fish. Tech. Pap (328) : 122pp

Bacher, C. 1999. The use of mathematical models to assess the carrying capacity of exploited ecosystems. J. Shellfish Res. Vol 18. No. 2 p 708

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