Prepared for the Secretariat for East Africa Coastal Area Management (SEACAM)

Composite Guidelines for the Environmental Assessment of Coastal Aquaculture Development

Volume 2: Appendices

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August 1999

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Case Study 1

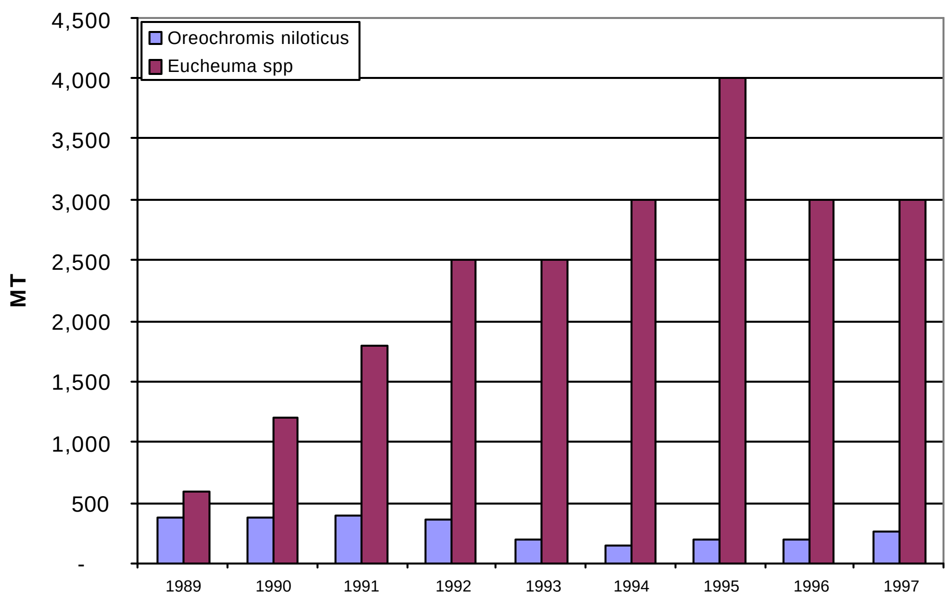
Environmental assessment and shrimp farming in Tanzania

This case study is based on several reports and other documents (listed at the end of the case study) as well as discussions held during the training course held in Dar Es Salaam, June 1999

Status and potential of aquaculture in Tanzania

Figure A1.1

Aquaculture production trends in Tanzania



Data FAO

A few tonnes of Tilapia (*Oreochromis niloticus*) have been produced in Tanzania for many years, and reached more than 300 tonnes in 1989. Since then production has been low and erratic.

The farming of seaweed (*Euchema* spp.) began in the late 80's, stimulated by government promotion and the active involvement of international corporations in promoting small-scale production. The industry grew rapidly in the early 90's reaching 4,000 tonnes in 1995, but has since declined, related partly to marketing difficulties.

There has been significant interest in shrimp farming for several years. Tanzania has good international trade routes, suitable climate, and a long coastline well suited to brackish-water pond production. To date the main interest has been in medium to large-scale projects with significant foreign interests. Environmental assessments have been carried out in respect of at least two proposed shrimp farm developments. The procedures and outcomes have been unsatisfactory in several respects, and it is instructive to consider what has happened, what lessons can be learned, and how procedures might be improved.

Legal and institutional framework

Government responsibility for aquaculture lies with the Ministry of Natural Resources and Tourism, Division of Fisheries (Fisheries Development and Resource Utilization). There are aquaculture advisory and extension services, but the main focus of activities is in freshwater aquaculture. There is limited activity with respect to coastal aquaculture, and there are no District staff, although District councils may have fishery officers under Technical Support and Extension services. The role and responsibilities of the Division of Fisheries is summarized in Box A1.1

Box A1.1 Role and Responsibilities of the Division of Fisheries with respect to mariculture:

- development planning, budgeting and submission of projects for government approval and financing;
- disbursement of funds for approved projects and projects supervision;
- procurement and allocation of necessary project resources;
- initial approval of mariculture project proposals;
- establishment of development guidelines;
- authority over issuing of permits and licenses;
- policy formulation and implementation;
- formulation of legislation and legal enforcement; and
- extension.

source: TCMP 1998

Approval procedure for commercial mariculture

The procedure for the approval of commercial mariculture projects is summarized in figure A1.1. This is based on the National Environmental Management Council (NEMC) Environmental Assessment Guidelines, presentations at the Dar Es Salaam Training Course, and TCMP (1998).

The acquisition of land is a key issue in this process. Usually the investor acquires land first. Community consultation is required in order to do this, and a certificate may then be issued for industrial, agricultural or residential use, with few conditions. Once the land is obtained however, it may be leased to other users without further community consultation.

If land acquisition is the first stage in the process, a major principle of environmental assessment – the examination and comparison of alternative sites - is immediately undermined. Environmental assessment becomes more regulatory (yes or no to a development) rather than a planning tool (yes, but at site A rather than site B)

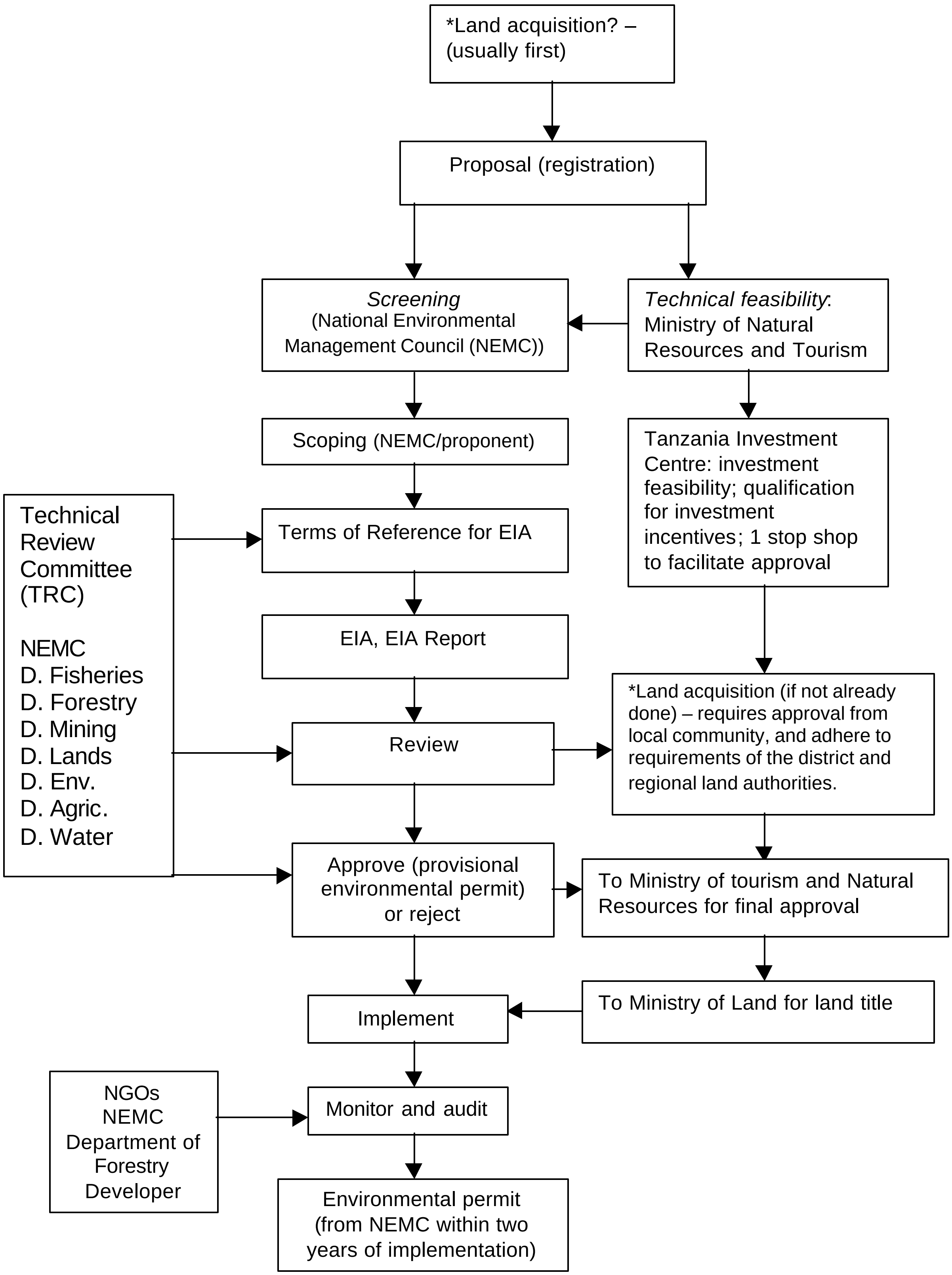
Box A1.2. Screening criteria

- Location and scale
- Technology
- Concern of the public
- Land use considerations
- Environmental impacts
- Any other relevant factors

(source NEMC)

A proposal, using standard application forms, is submitted to the Ministry of Natural Resources and Tourism for technical feasibility appraisal, and to the National Environmental Management Council (NEMC) for environmental assessment screening (see box A1.2). NEMC may require no EIA, a preliminary assessment, or a full EIA. In practice however, EIA is mandatory for “artificial fisheries (aquaculture for fish, algae, crustaceans, shrimps, lobsters or crabs)” (NEMC). If the NEMC decides that EIA is required (as would be the case with aquaculture) then a public scoping exercise is undertaken by the proponent in consultation with NEMC, and draft TOR are developed. These must address any public concerns expressed during the scoping exercise. TOR are then reviewed and further developed by NEMC in consultation with a cross-sectoral Technical Review Committee (TRC) comprising a range of relevant government departments. This committee also reviews the EIA

Figure A1.1: Framework for environmental assessment and project approval in Tanzania



report. If there is strong public concern, and impacts are extensive and far reaching, NEMC organizes a public hearing as part of this review process. NEMC may then issue or refuse a provisional environmental permit, or require improvements to the EIA report. If a provisional permit is issued and the project goes ahead, monitoring is the responsibility of the proponent, but with auditing by NEMC. A full environmental permit is issued within two years subject to satisfactory performance, adequate reporting, and compliance with mitigation measures and permitting/approval conditions.

Throughout this process the Tanzania Investment Centre (TIC, previously the Investment Promotion Centre) plays a key role in coordinating and facilitating the approval process, serving as a "1 stop shop" to potential investors. However, TIC does not serve on the EIA Technical Review Committee.

Examples of the application of EA procedures to aquaculture

EA procedures have been applied to two shrimp farm projects in Tanzania in recent years. The first was an Initial EA, undertaken for a potential sponsor (NORAD) relating to a medium scale (160ha) shrimp farm on the Ruvu river near Bagamoyo. The second related to a large shrimp farm in the Rufiji Delta

Initial environmental impact assessment (IEIA) of a shrimp farm near Bagamoyo

In 1994 a private company sought assistance from NORAD (Norwegian Development Aid Agency) for the establishment of a shrimp farm on a 600 ha site on the south side of the Ruvu river, about 5km from the sea, near Bagamoyo. Initially 160 ha of ponds were to be developed, with an estimated production of around 500mt per year. The farm site was set adjacent to the mangroves of the Ruvu River, the largest single expanse of mangrove in Bagamoyo District

NORAD commissioned an initial EIA, which was undertaken over a period of 1 month (10 days in the field) by a small team of international consultants from Thailand (AIT 1995) in collaboration with a local consultant, using the NORAD (1992) Guidelines.

Box A1.3. Major impacts identified and discussed in the IEIA report, and level of analysis

- Impact of **habitat conversion** (pond construction) on biodiversity and other resource users (quantified in physical terms (land/habitat area affected, relative to the totals for the district and country) and discussed in terms of ecological and socio-economic impact);
- Impact of **high salinity effluent** on river/estuary system (quantified in physical terms; discussed in ecological and socio-economic terms);
- Impact of **nutrients (P and N)** in effluent on river/estuary system (quantified in physical terms; discussed in ecological and socio-economic terms);
- Impact of **sediments** on river/estuary and adjacent coastal waters (discussed in physical and ecological terms)

Some difficulty was experienced in presenting and discussing the possible environmental impacts because of the limited baseline information, understanding of the physical and ecological systems, and lack of local environmental standards or development objectives. The "significance ratings" were therefore subjective and based on the experience of the (mainly foreign) consultants.

There was very little public

involvement because of limited time, and the difficulty of operating outside official representative channels on a short visit.

The consultants were unable to discuss alternative sites, since site selection had already taken place.

Despite these limitations, the consultants were able to identify and discuss the main impacts (summarized in Box A1.3), and present clear and simple recommendations for mitigation, in terms of both design and operation (summarized in Box A1.4).

The overall tone of the assessment was positive, and the final paragraph of the executive summary stated:

> *"We believe that if such (mitigation) procedures are followed, the proposed project might become a model for the development of sustainable shrimp culture throughout the world, and in this sense offers a unique opportunity for realizing the undoubted and substantial potential benefits offered by well planned and managed farms".*

However, it had already cautioned:

> *"If appropriately designed and managed, **and if considered in isolation**, this farm is unlikely to have a significant impact on the environment. However, in many other parts of the world successful farms have attracted uncontrolled smaller scale satellite developments which in places have had a serious cumulative impact on the environment and the sustainability of shrimp farming itself……. It is essential that this and future developments take place within a planning and regulatory framework which will prevent uncontrolled development and ensure on-going responsible management practices. …Without such a framework, this development may simply become a small part of a wider development problem"*

Box A1.4 Summary of mitigation measures

Discussed:

- possible use of mangrove as nutrient sink and sediment trap (quantified + discussion of associated risks);

Recommended:

- reduction in water (sea and freshwater) exchange rate to a maximum of 5% per day overall;
- use of settling ponds/reservoirs comprising 10-20% of total pond area to treat routine pond effluent;
- partial recycling of water from these settling ponds/reservoirs if required;
- use of separate smaller settling/sludge ponds to treat effluents discharged during final stages of harvest and pond emptying;
- removal of sediment/sludge from grow-out and settling ponds to landfill site, or processed/desalinated for use as agricultural fertilizer;
- establishment of a set of protocols for the use and handling of chemicals ;
- adherence to best management practice guidelines (draft appended to the report)

It would appear that this caution, and the evident lack of any wider environmental management framework, was taken seriously, and funding for the project was rejected.

Lessons learned

This example illustrates the difficulty of using EIA as a positive planning or management tool in the absence of a broader environmental management framework:

- it will either allow or restrict development, on a relatively ad hoc basis, dependent largely on the knowledge or bias of the EIA consultant and the decision maker;
- it will be based on no broadly accepted decision criteria;
- if mitigation measures are recommended, there will be little chance of them being implemented, especially if they are associated with additional costs;
- although it can identify possible cumulative impacts from other large developments or smaller "satellite" developments, it is unlikely to be able to identify an appropriate mitigation strategy, since this requires action at the sector, rather than the farm level.

Large scale shrimp farm on the Rufiji Delta

Following a proposal in mid 1995 for a large shrimp farming project to be sited in the Rufiji Delta, the District Commissioner requested that the proposer (African Fishing Company) collaborate with a consultant to write an initial environmental impact statement (EIS). The EIS was produced and submitted to relevant ministries for review in May 1996. Before an official answer was received the environmental community in Dar Es Salaam pressured the government to have a public debate on the proposal. AFC also increased the scope of their consultation to a range of government agencies, ministries and academic institutions. The National Environment Management Council then convened a forum of interested parties at a large Hotel in Dar Es Salaam, which was attended by more than 70 participants, mostly from government, regional authorities, aid assisted projects or programs, NGOs and journalists, embassies, and commercial companies. Some local people from the Rufiji delta also attended. AFC and various technical experts described the project, and a range of academics made comments.

The forum cleared up a good deal of misunderstanding about the project which had already grown up, and it was agreed that a comprehensive EIA was required. The forum offered some guidance on content.

A large team of local and international consultants was appointed, including aquaculture specialists, fisheries specialists, ecologists and sociologists. This team sought not only to assess the project, but also to further develop and design the project to take full account of environmental concerns – in other words to include mitigation measures in the design from the outset. A prominent international expert was appointed to the team to ensure that this was done to the highest international standards.

The first contact with the villagers was by the fishery specialists. They observed that the villagers had many serious concerns, and some significant misconceptions as to the nature of the project. As a result they "advised that a high ranking governmental delegation be sent to the area to inform the people of the pro's and cons of the project, and *the benefits that such a project would bring to them" .* The suggestion was immediately implemented. Other teams also visited the villages and found that the inhabitants did not have accurate facts. As a result a critical report was produced by the sociologist team reflecting the (possibly erroneous) fears of the villagers. As a result a more technical team, a fisheries specialist, a sociologist, and a representative of AFC was sent to the villages to explain the nature of the project and the socio-economic benefits it would bring. After the visit " a good number of villages now accepted the project and were eager to see it implemented immediately".

A final survey was then made by a new team in order to assess "whether or not the people are now aware of the project, and have accepted or rejected it, especially after the several visits to the area by senior government officials and experts. The survey identified the nature of local economic activities, as well as a range of local concerns about health, education and transportation, and explored ways in which the project might contribute to their alleviation. They also reviewed both the positive and negative views of the project. Concerns included mangrove cutting, impacts on fisheries, impacts on local markets, pollution and chemicals, fears that they would be prevented from fishing. A larger number of positive impacts were identified related to transportation, marketing employment. Overall about 82% of interviewees and members of focus groups accepted that the project would beneficial, while only 18% opposed it. A series of suggestions were also reported for more local participation in the development of the project.

Subsequently, this project became the subject of intense debate over the appropriateness of a major aquaculture development proposal. At the local level there was a polarization of opinion with fisheries specialists generally in favour, and forestry specialists and NGOs strongly opposed. The local media became heavily involved and generally negative. The local people were pulled in different directions according to their exposure to different specialist interests and the media. This debate became the subject of international comment on email discussion groups related to sustainable aquaculture and mangrove conservation with heavy involvement of international environmental NGOs. This debate was highly polarized (for or against) and generally rather poorly informed.

The output of the EIA process was two detailed volumes amounting to more than 450 pages entitled *"Environmental Impact Assessment for an environmentally responsible prawn farming project in the Rufiji Delta, Tanzania".* The assessment was technically thorough, analyzing in detail possible impacts on the physical and ecological system of the Rufiji Delta, as well as socio-economic impact. The overall tone was however necessarily positive, since it had already "designed in" a range of mitigation measures identified by the team.

After much further delay and debate, the project was finally approved, amid much bitterness and controversy. However, the project has not been implemented to date, and, given the legacy of bitterness and conflict, there are doubts that it ever will be.

Lessons learned

The EIA has been strongly criticized by some (e.g. Hughes 1996) as being seriously biased. There are several reasons for this. The first is obvious in the title of the EIA, which pre-judges the outcome of the assessment, and this language is repeated throughout the report. While understandable – since the proponent had sought expert advice and designed mitigation into the project – this undermined the neutrality and credibility of the whole document. This is particularly unfortunate, since integrating environmental assessment with project design is an example of best practice EIA.

The second was the nature of public consultation. This appeared to be based on the need to inform local people of the benefits of the project, rather than to provide them with an unbiased presentation of costs and benefits, solicit their views on the proposal, and tap their knowledge of local conditions and resources. The location of the public hearing – at an international Hotel in Dar Es Salaam – was also criticized by some as being inappropriate in both location and style for a project based in Rufiji.

The lack of agreement between different government interests (such as forestry and fisheries) probably also contributed to the polarization of the debate. Although a forestry management plan existed for the area, there was no cross sectoral agreement in the form of an integrated coastal management plan or strategy, and no obvious forum for the development of such a plan or strategy. This meant that there were no clear or agreed criteria for reviewing the EIA and assessing the significance of impacts. Indeed, it is probable that the EIA, which highlighted many different practical resource use issues, inflamed latent inter-departmental conflict.

In retrospect, the company itself, and the project designers, could have engaged the local people at an earlier stage to explain, discuss, and adapt project design, as well as take account of local concerns. In other words the public consultation exercise could have been more participatory, rather than promotional.

The EIA should then have been undertaken by a more independent team – although still working closely with the designer and proponent - to produce a more credible EA. Had conflict still arisen, conflict resolution techniques might have been used to develop a broader consensus.

However, the difficulties of appropriate public consultation, which have been highlighted in the main report of these guidelines – should not be under-estimated, especially when powerful interest groups – business on the one hand, and environmental pressure groups on the other – become involved.

Box A1.5: Public involvement in Rufiji EIA

Weaknesses:
- Did not involve local community from outset;
- Limited exchange of information relating to local resources, impacts and benefits;
- Limited feedback and response to local concerns;
- Inadequate attention to selection of representative groups for discussion/consultation;
- Location of public meeting at Sheraton Hotel? (better under a tree in Rufiji?)

Alternative approaches
- Identify current land/water use activities;
- Gain understanding of land tenure system;
- Meet with village council to outline nature of project;
- Follow up meetings to address in more detail:
  - Positive and negative impacts;
  - Alternative activities;
  - Selection of best options;
  - Mitigation measures for best options
  - Reach consensus
- Monitoring and impact management

Problems
- Who are the stakeholders, and how should their views be weighted?:
  - pastoralists, agriculturalists, experts
- Communications
  - Language (English at public meeting not accessible to all);
  - Technical level and understanding
- When should consultation take place?
  - Timing of community activities must be taken into account

Solutions/recommendations
- Information about the project and associated positive and negative effects must be communicated at a range of levels from scientific technical, to practical and local, using appropriate communication techniques, at the earliest opportunity;
- There should be written backup of information presented at these different levels, whatever the medium of communication used on the ground.

Source: output of working group exercise, SEACAM mariculture EA training course, Dar Es Salaam, June 1999

Strengths and weaknesses of Tanzania EIA procedures

Mwalyosi and Hughes (1998) have reviewed the application of EA in Tanzania. They conclude that EA has had little impact on decision making. They summarize the weaknesses as follows:

- usually started late in project development;
- under-resourced;
- limited stakeholder involvement;
- output, rather than process orientated;
- limited input to design or location issues;
- limited identification, costing and integration of environmental management into project design;
- poor definition of compliance responsibilities;
- EIA seen as an impediment to development; and
- limited monitoring or audit.

The procedures were also reviewed at the SEACAM EA Training Course in Dar es Salaam in June 1999 specifically in relation to aquaculture. The following limitations and weaknesses were identified:

- the Tanzania Investment Centre are not on the Technical Review Committee (TRC);
- drafting of TOR tends to be sectoral (i.e. specific sectoral requirements from different TRC members);
- many sectors and interests are involved, leading to lengthy procedures and extended discussion of contradictory interests;
- the legal framework is weak;.
- enforcement, monitoring and auditing are ineffective.

The Tanzania Coastal Management Partnership (TCMP 1998) identified several shortcomings in the existing procedures for EIA relating to mariculture. In particular, the document notes that:

> *"Local communities play an important role in regulating mariculture development because site allocations should be decided at local level. In practice, most decisions on investment projects are made outside of the local community, which often leads to conflicts. On the other hand, consultation at the local level is time consuming, and approval by district and regional authorities can be frustrating due to contradictory and overlapping policies, regulations and legislation".*

The document also points out the lack of transparency relating to land rights. In order to address many of these difficulties the Tanzania Investment Centre is delegated responsibility for facilitating and coordinating decision-making – a "one stop shop". Unfortunately, while such an approach should facilitate investment, it is unpredictable and ad hoc, lacks transparency, and does not meet the principle of local participation in decision making.

The following weaknesses were also identified:

- permitting procedures unclear to potential investors;
- land acquisition procedures not clear, especially to local poor people;
- many overlapping and contradictory policies regulations and legislation;
- local level approval either time consuming, or by-passed;
- TIC may facilitate more rapid approval (in accordance with the Investment Act) (good and bad);
- lack of communication and coordination between all stakeholders;

- lack of integration: lack of an inter-sectoral approach; sectoral fragmentation; lack of coordination and planning; territoriality in jurisdiction; no forum for expressing shared interests;
- lack of oversight and accountability;
- no licensing for mariculture except for product export.

TCMP identified the following *needs* in terms of policy development :

"The various sectoral policies relating to mariculture must be harmonized and integrated into a single statement. There are gaps in the various sectoral policies and regulations where concerns related to mariculture are not addressed. New policies and regulations are needed to cover these areas. Priority areas are:

- permitting procedures;
- procedures governing access to land and water tenure;
- water use regulations;
- water quality control and standards;
- monitoring guidelines and procedures;
- licenses addressing operational issues that affect environmental quality;
- strict enforcement of existing laws and regulations;
- provision of oversight for the permitting process

General conclusions

The existing policy framework for the EA of mariculture has many general limitations as discussed above. Some of these have been highlighted in the examples of EA as applied to shrimp farming. It is clear that a more strategic approach is required to the environmental assessment of aquaculture in Tanzania.

1. The various sectoral departments and agencies must develop a coherent and integrated policy relating to mariculture development, land acquisition and use, and coastal resource management in general. This implies at least a sector EA for aquaculture, and ideally a broader integrated coastal management initiative (this is currently beginning);

2. This broader process should involve extensive public consultation, and should generate clear guidelines for the project EIA process, including assessment and permitting criteria. This should reduce the time required to undertake individual assessments, reduce the likelihood of conflict in relation to specific projects, and provide clear guidance to potential investors as to what is or is not acceptable;

3. This process must also generate a strategy to deal with the environmental impact of multiple small scale projects, which are likely to arise once commercial aquaculture has been demonstrated.

It is notable the Tanzania Coastal management Partnership, and in particular the mariculture working group, is already working in this direction.

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Case Study 2

Environmental assessment of shrimp farming in Sri Lanka

The development of shrimp farming in Sri Lanka

The brackish water area in Sri Lanka is estimated to be 120,000 ha of which 80,000 ha are estuaries and large deep lagoons. The rest comprise shallow lagoons, tidal flats, and mangrove swamp.

Interest in shrimp farming developed in late 1970's with a small farm commencing operations in Batticaloa in 1977. Among the other influential factors, export demand and the export promotion policy of the government were major factors that led to the initiation of shrimp farming in Sri Lanka. The government has given various concessions and duty rebates to encourage the investors in this industry. Under the government investment promotion policy, a large area of suitable crown lands were rented to investors at a nominal rent. With these incentives, a large number of small scale entrepreneurs and a few large international companies have ventured into shrimp farming since 1982. They use local labor and in some cases expatriate technicians. Presently, the shrimp industry contributes over fifty percent of the total fisheries export sector with a total labor force exceeding 9,000 full time equivalent jobs.

More than 70 % of shrimp farm developments are located in the coastal areas around Dutch Canal and Mundel Lagoon ecosystems between Negambo and Puttalam. The low population density in the NW, and easy availability of suitable land in these areas facilitates large scale operations. In the Western Province on the other hand relatively high population density prevents operation of large scale farms. The high returns from shrimp farming has led farmers to utilize all possible land, and due to the insufficiency of low salinity areas, high salinity areas are also used for farming, using ground water drawn through tube wells.

By 1994 there were 250 authorized farms covering an area of 1,400ha. However, a survey undertaken by the Network of Aquaculture Centres in Asia (NACA) in 1994 estimated 740 intensive farms utilizing 1,875 ha and 80 extensive farms covering 400 ha. The actual number of shrimp farms is not known accurately due to the rapid development of unauthorized farms. Table A1.1 shows an estimate of the contribution of authorized and unauthorized farms developed on private and government lands.

Table A1.1: Distribution of farms on governmental and private land and its status

Category	Government lands		Private lands		Total lands	
	Projects	*Area (ha)*	*Projects*	*Area (ha)*	*Projects*	*Area (ha)*
Approved	177	1407	63	306	240	1713
Developed	172	1216	57	292	229	1508
Unauthorized	243	187	216	221	459	408
Abandoned	8	11	5	7	13	18

Source: Report on the Puttalam/Mudel Estuarine Systems and Associated Coastal Waters (1996)

Unpublished data from the Provincial Land Commissioners Dept indicates the presence of 705 unauthorized farms covering an area of 788 ha.

Environmental Issues

Shrimp farm effluents contain significant nutrient and suspended solid loadings. This has resulted in increased turbidity and BOD in some receiving waters, and in some lagoons and estuaries a significant increase in nitrite, sulphide and ammonia concentrations. The depth of the main water source (The Dutch Canal) has been reduced due to increased siltation.

The land use pattern has changed with agricultural land converted to shrimp farms. Significant areas of mangroves and salt marshes have been converted. Due to limited access to brackish or fresh water in the shrimp farming area, farmers are restricted to taking their source water from the same canal that they discharge their pond effluent into. Further due to unplanned development, inlet and outlet canals of adjoining farms are closely located. The result is intake of discharged water with sub-optimal water quality from one farm into an adjoining farm. This situation contributed to a recent disease outbreak (1996/7) that resulted in closure of more that 50% of shrimp farms, and has become a chronic on-going problem..

Environmental assessment and management of shrimp culture

Legal framework

The regulation and management of coastal aquaculture in Sri Lanka is complex, and takes place within a broad national policy and legislative framework including provision for coastal zone management and coastal zone planning.
The main legislation relevant to environmental management of aquaculture are presented in Table A1.2.

Table A1.2: Relevant legislation

Legislation	Scope
• Fisheries Ordinance	• Introduction of new species
• Draft Fisheries Act	• Licensing of fish farms
• Coast Conservation Act No. 57	• Permit procedure for any development activity in coastal zone
• Soil Conservation Act No. 25	• Control of soil degradation
• National Aquatic Resources	• Prohibition of discharges and emission of effluent to environment
• Research and Development Act-No. 54, 1981	
• Fauna and Flora Ordinance	• Development, management and conservation of aquatic resources
• National Wetland Heritage Bill	

Institutions

A large number of agencies and institutions are required to coordinate and collaborate with regard to aquaculture and coastal management issues (Box A1.6).

Specific roles and responsibilities in relation to aquaculture are as follows:

- National Aquatic Resources Agency - operation, planning and management;

- Land Commissioner – planning;
- Department of Irrigation – planning;
- Central Environmental Authority - planning and monitoring;
- Coast Conservation department - planning and monitoring,
- Irrigation Department - planning; and
- Land Reclamation and Development Board - planning and operation.

Institutions with a role in environmental management include:

- Central Environmental Authority – management;
- Ministry of Fisheries and Aquatic Resources - management;
- Department of Coastal Conservation (management);
- National Aquatic Resources Agency - research and management; and
- Universities of Sri Lanka - research and education.

Box A1.6: Institutions

There are more than 20 institutions with an interest in the development of the shrimp industry in Sri Lanka:

National Level Institutions

1. Ministry of Fisheries and Aquatic Resources (MFAR)
2. National Aquatic Resources Agency (NARA
3. Department of Coastal Conservation (CCD)
4. Central Environmental Authority (CEA)
5. Land Commissioner (LC)
6. Department of Irrigation (DI)
7. Department of Wildlife Conservation (WLCD)
8. Department of Forest Conservation (FD)
9. Land Reclamation & Development Board (LRDB)
10. Coconut Cultivation Board (CCB)
11. Board of Investment-Sri Lanka (BOI)
12. Sri Lanka Export Development Board (EDB)
13. Divisional Secretaries of Respective Areas (DS)

Provincial Level Institutions

14. Provincial Ministry of Fisheries (PMF)
15. Provincial Environmental Authority (PEA)
16. Provincial Land Commissioner (PLC)
17. Wayamba Development Authority (WDA)
18. Industrial Services Bureau (ISB)

International Agencies

19. Agro-Enterprises Development Project (Ag-Ent)
20. United States- Asia Environmental Partnership (USAEP)

Procedures for environmental assessment

Sri Lanka has a well-developed system for environmental management of shrimp culture. In theory, this system should allow for the control of the density and location of shrimp farms in order to mitigate environmental impacts. The procedures are summarised in Figure A1.3.

All potential developers of aquaculture farms should forward an application with an initial environmental examination (IEE) to MFAR. MFAR will forward the application to its project approving agency called *Inter-Ministerial Scoping Committee* to examine the proposed project. The committee consists of MFAR, NARA, CEA, CCD, PMF and Department of Irrigation (see box A1.6 for acronyms). In addition, representation from Coconut Development Authority and LRDB is invited whenever necessary. The committee can recommend the allocation of state land, and approval of the committee is important for obtaining financial assistance. Normally, Committee meetings are scheduled once a month.

The IEE provides details on the specific location, investment, soil quality, water quality, pond plans, water requirements, water discharge, basic sociological and environmental aspects. The IEE provides sufficient information to assess most of the small-scale projects in less environmentally sensitive areas. If the project is above 5 ha and appears to be located in an environmentally sensitive area, an EIA is required and official TOR are provided. Projects are usually approved with a set of general conditions and mitigation requirements (which includes requirements for effluent treatment), as well as conditions specific to the project. Once a development has been approved, an environmental protection licence is also required for the use of lakes, rivers, streams and coastal areas (including mangroves) for aquaculture. This licence has to be renewed annually.

Table A1.3 Tolerance limits for aquaculture wastewaters discharged into inland surface or marine coastal water in Sri Lanka.

Parameter	Values (not to exceed)	
	Inland Surface	Marine Coastal
BOD_5 (5 days at 20°C) mg/l	30	50
COD (mg/l)	250	250
PH	6.0 - 8.5	6.0 - 8.5
Suspended solids (mg/l)	50	100
Temperature (°C)	30	35 at point of discharge
Oil and grease (mg/l)	10	20
Total Nitrogen (mg/l)	2.0	2.0
Phosphate (mg/l)	2.0	2.0
Phenolic compounds (mg/l)	1.0	5.0
Cyanides (mg/l)	0.2	0.2
Sulphides (mg/l)	2.0	5.0
Fluroides (mg/l)	1.0	1.0
Total residual chlorine (mg/l)	1.0	1.0
Arsenic (mg/l)	0.2	0.2
Cadmium (mg/l)	0.1	2.0
Chromium (mg/l)	0.1	1.0
Copper (mg/l)	3.0	3.0
Lead (mg/l)	0.1	1.0
Mercury (mg/l)	0.0005	0.01
Nickel (mg/l)	3.0	5.0
Selenium (mg/l)	0.05	0.05
Zinc (mg/l)	5.0	5.0
Pesticides	Absent	Absent
Radioactive materials		
Alpha emitters (μc/ml)	10^{-7}	10^{-8}
Beta emitters (μc/ml)	10^{-6}	10^{-7}

Effluent standards for brackish water aquaculture waste waters discharged into inland surface or marine coastal waters have been developed and agreed (Table A1.3). The standards are based on the assumption that the effluent flow will be diluted at least 8 times in the receiving water. Monitoring is carried out by the farmers themselves, as a report in effluent quality is required to renew the Environmental Protection Licence, although the Central Environmental Authority (CEA) intends to start it's own monitoring in the future. If an aquaculture farm fails to comply with the terms of its permit, the CEA will apply for a Court Order to suspend the farm's activities under Section 24 B (2) of the National Environmental Act. The activities of the developer will be suspended until he/she complies with the Directives of the CEA.

Problems

Despite a suitable legal framework and comprehensive environmental assessment procedures, there has been significant environmental degradation associated with shrimp culture, and water quality and disease problems have caused increasing problems for the industry itself. The cost of this failure is substantial: the shrimp farming industry is an important economic sub-sector of North Western Province as well as the economy of Sri Lanka.

Fig A1.3. Procedure for approval of aquaculture projects in Sri Lanka

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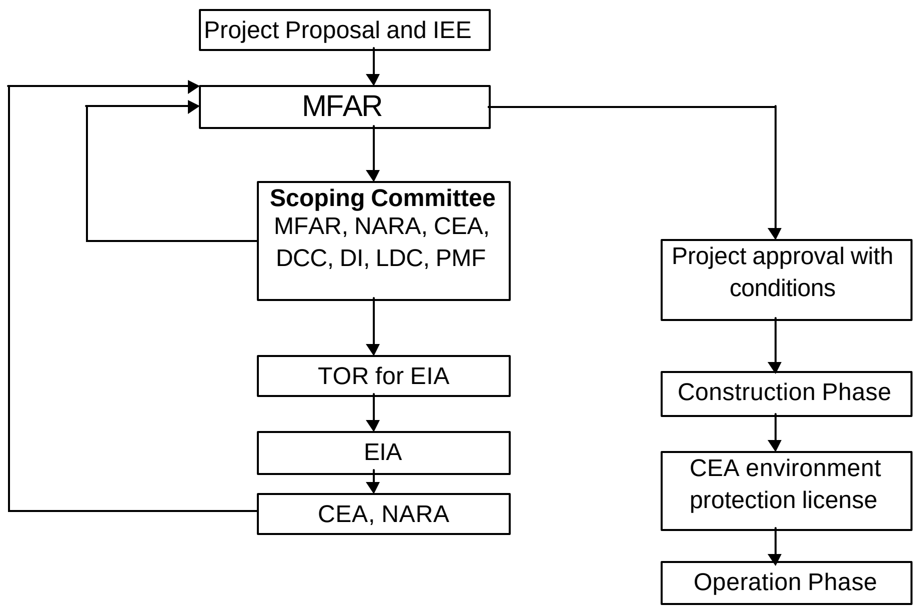


The immediate reasons for these problems may be summarized as follows:

- *Over-concentrated development (both official and unofficial) mainly along a single canal-lagoon system (the Dutch Canal) with inadequate infrastructure.* This has resulted in poor water quality and facilitated the rapid exchange of disease organisms.

- *Lack of any control over “unofficial” and small scale shrimp pond development.* This has led to the incremental and cumulative destruction of lagoon and wetland habitat despite the relatively comprehensive provisions for environmental management.

- *The plethora of institutions with diverse interests and overlapping responsibilities involved in environmental management.* Local and national institutions in particular have different perspectives. This may have led to ad-hoc decision making based on negotiation and compromize rather than consistent and strategic decision making. Planning efforts and the application of policy has been fragmented and inconsistent

- *The “one-off” basis of decision making related to individual aquaculture development approval.* Individual farms rarely have a significant impact in their own right, and can readily sign up to modest mitigation requirements. In practice the problem in the Dutch Canal has arisen because of the cumulative impact of the sector, rather than individual farms;

- *A lack of post approval monitoring and management.* This is mainly related to lack of manpower resources to both monitor and enforce.

- *Lack of extension and veterinary services and an overall disease prevention and management strategy.* Farmers currently rely on private extension services, which poorer or small scale farmers cannot afford.

The development of unauthorized farms cannot be controlled due to insufficient manpower, and socio-economic problems such as poverty and the disparity of income distribution prevailing in the rural areas, and the pressure from the local politicians.

Lessons to be learned, and possible solutions

Ironically, what at first sight appears to be a comprehensive approach to the environmental management of coastal aquaculture turns out to be bureaucratic, time consuming, expensive, lacking in transparency, and …ineffective.

The problems associated with rapid development in semi-closed estuarine and lagoon systems have been recognized for many years, and several scientists anticipated the disease problems in the Dutch Canal. Unfortunately the response has been bureaucratic rather than strategic, and ad-hoc rather than planned. It is exacerbated by the high profitability of shrimp farming creating enormous development pressures.

The single most important lesson to be learned is that, however sophisticated the environmental management system of a country in terms of laws and institutions, it is almost impossible to control aquaculture development by assessing or regulating individual farms. This is related both to the cumulative nature of impacts of aquaculture, and also to the political and economic pressures for approval in relation to specific projects.

The second important lesson is that failure may be extremely costly, and is very difficult to correct.

The Dutch Canal is a classic (semi-artificial) ecosystem requiring strategic natural resource planning. Sector, rather than project EA might have been undertaken, leading to an aquaculture development plan for the whole canal system. This may have involved gaining general agreement from all the stakeholders (farms and institutions) on an overall strategy in terms of location, density, intensity and scale of operations, designed to maximize the benefits to the economy while minimizing environmental impact. A suite of incentives and constraints might then have been developed – explicitly recognizing the real difficulties – to address development and environment issues as far as possible. These may have included necessary infrastructure and support services such as water supply and disposal; quality assurance of seed; extension and information services; credit; and a disease prevention and management strategy for the whole sector.

While it is understood that this is extremely difficult, it must nonetheless be attempted if the problems and opportunities of coastal aquaculture development are to be fully and sustainably realized. The investment is likely to be significant, but the potential returns from sustainable coastal aquaculture are very high.

Case Study 3

Kung Krabaen Bay Royal Development Study Center (KKBRDSC) Project, Thailand

Introduction

Kung Krabaen Bay (KKB) is an oval-shaped lagoon 4.6 km long and 2.6 km wide, with a single narrow water entrance of 656 meters. It is located in Chantaburi Province in E of Thailand on the Gulf coast. The bay, covering an area of about 640 ha, is an integral part of the KKB Royal Development Study Center (KKBRDSC) project, which was established to increase villagers' income by application of integrated environmental management practices. The area is surrounded by a mangrove fringe, behind which numerous small-scale shrimp farms have been established. In the high land between the bay and hill, rice fields and fruit orchards form the major component of the agro-ecosystem. The upland area is still covered with mixed forest, orchards and rubber plantations.

KKBRDSC was founded on 30 December 1981 as a Royal Project in coordination of the Department of Fisheries (DOF). The main objective of KKBRDSC was to build the bay as an ideal demonstration project for sustainable management of coastal resources with an integrated management approach. The approach involves optimum use and conservation of the natural resource base of the area, maintenance of ecological balance, and local participation in the planning and management of various development initiatives.

A significant activity of the project was to provide local poor farmers with the land and extension support to develop shrimp farming. A 1.6 ha plot was granted to each of 100 farmer households, of which 0.96 ha was for three ponds (0.32 ha each), 0.16 ha for dikes and ditches and 0.48 ha on the seaward side for houses and mangrove plantation. Most of the farmers have been successful, with production rates generally in the range of 5-10MT/ha/yr, providing a very high net income relative to their previous agricultural activities. The incidence of disease has however increased in recent years, with lower average earnings and significantly increased risk.

Environment and development issues

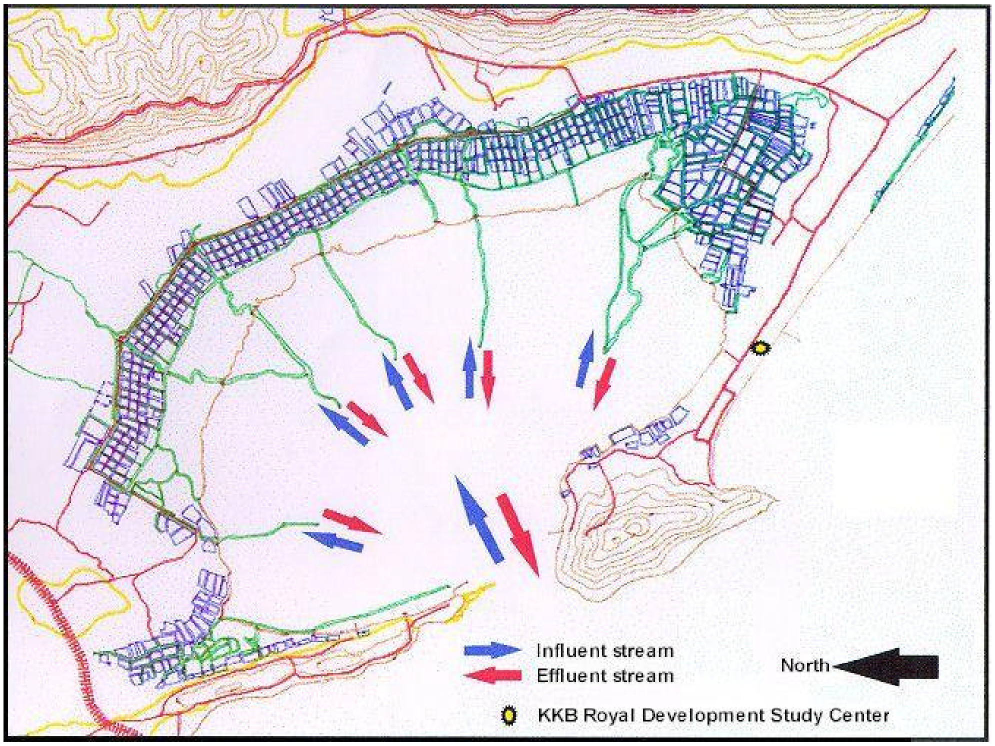
The area has been subject to a variety of pressures on the natural environment closey related to development activities:

Seawater Intrusion: Seawater intrusion and consequently salination of agricultural soil is a major concern especially for the paddy fields. Since the expansion of shrimp culture on the late 80s some agricultural land has been abandoned.

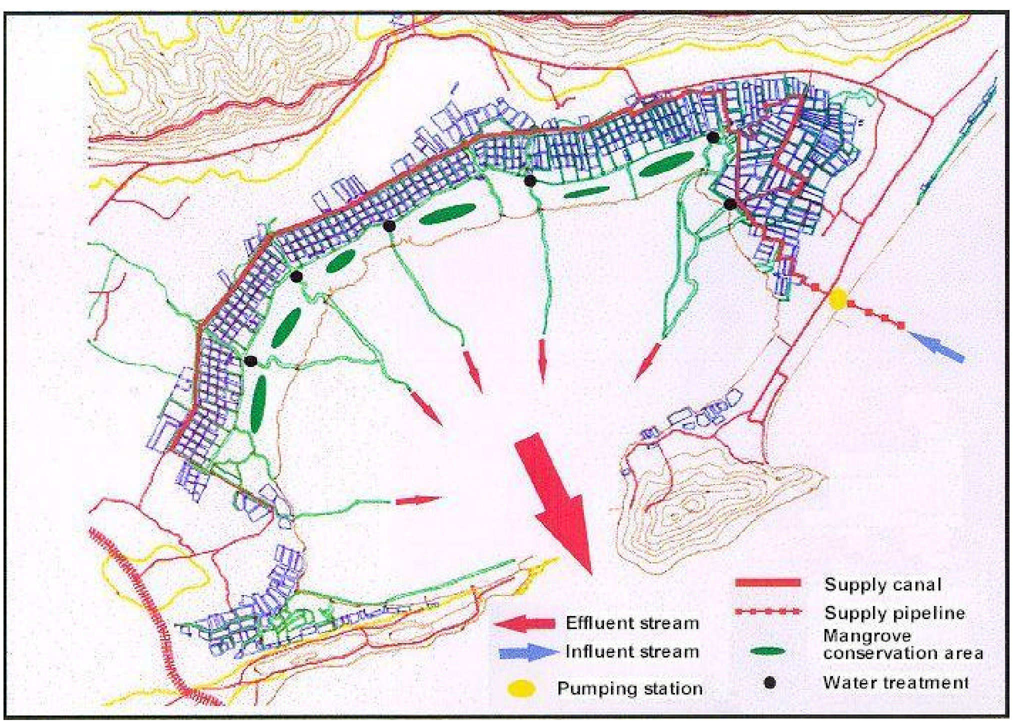
Mangrove Area: In 1955 34% of the coastal land area of Chantaburi Province was dominated by mangrove. This declined rapidly in subsequent years due to a suite of development pressures, including charcoal production, collection for firewood, conversion to agriculture and salt farming, and most recently conversion to shrimp farming. In the project area approximately 166 ha of deteriorated mangrove was converted to shrimp farming, leaving a narrow belt of mangrove (14 percent) along the coast. There is now limited cooperation from the project farmers to conserve and restore the mangrove resource.

Figure A1.4. Water supply for the KKB shrimp project.
(Diagram courtesy of Kung Krabaen Bay Royal Development Study Center)

1. Original Water System

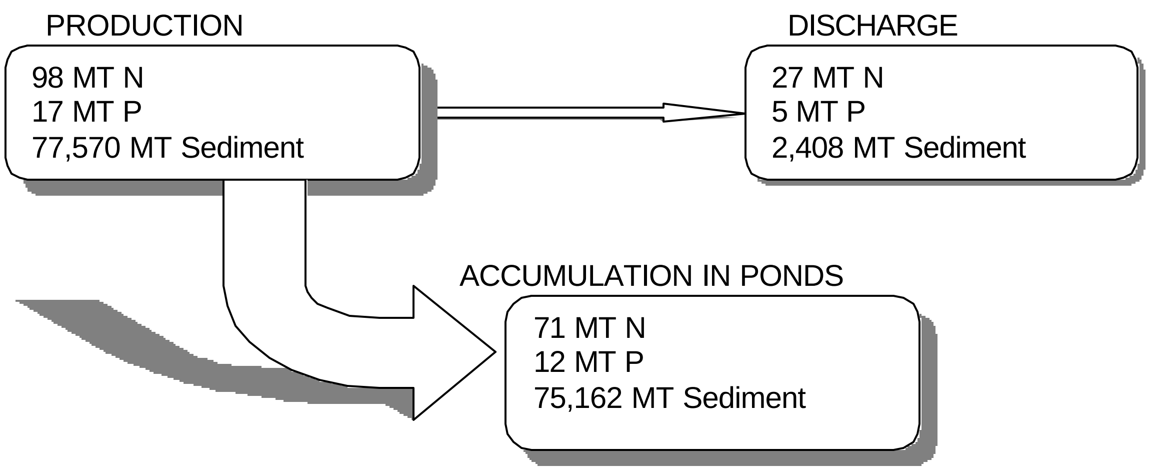


2. New Water System (seawater irrigation)



Waste Loading on the environment and "self-pollution": A portion of shrimp farming wastes, either in suspended or soluble form, are discharged to the coastal environment causing a threat to the shrimp culture itself. Figure A1.5 describes the significant nitrogen (N), phosphorus (P) and sediment loading from the shrimp farms of KKB. Because the Bay is a semi-closed ecosystem with a single inlet-outlet, there is limited dispersion of nutrients and sediment to the open sea. There is therefore a risk of serious impact on the lagoon ecosystem, which includes seagrass beds and nursery areas for shrimp and fin-fish. Furthermore, a significant proportion of waste materials discharged can re-enter the supply canals. The problem has been further exacerbated by the uncontrolled emergence of private farms adjacent to the project. Management of this loading to reduce impact on the bay, and on the shrimp farming itself, has become an important issue for the project management.

Figure A1.5 : Fate of wastes produced from the shrimp farm of the KKB (MT = metric tons)

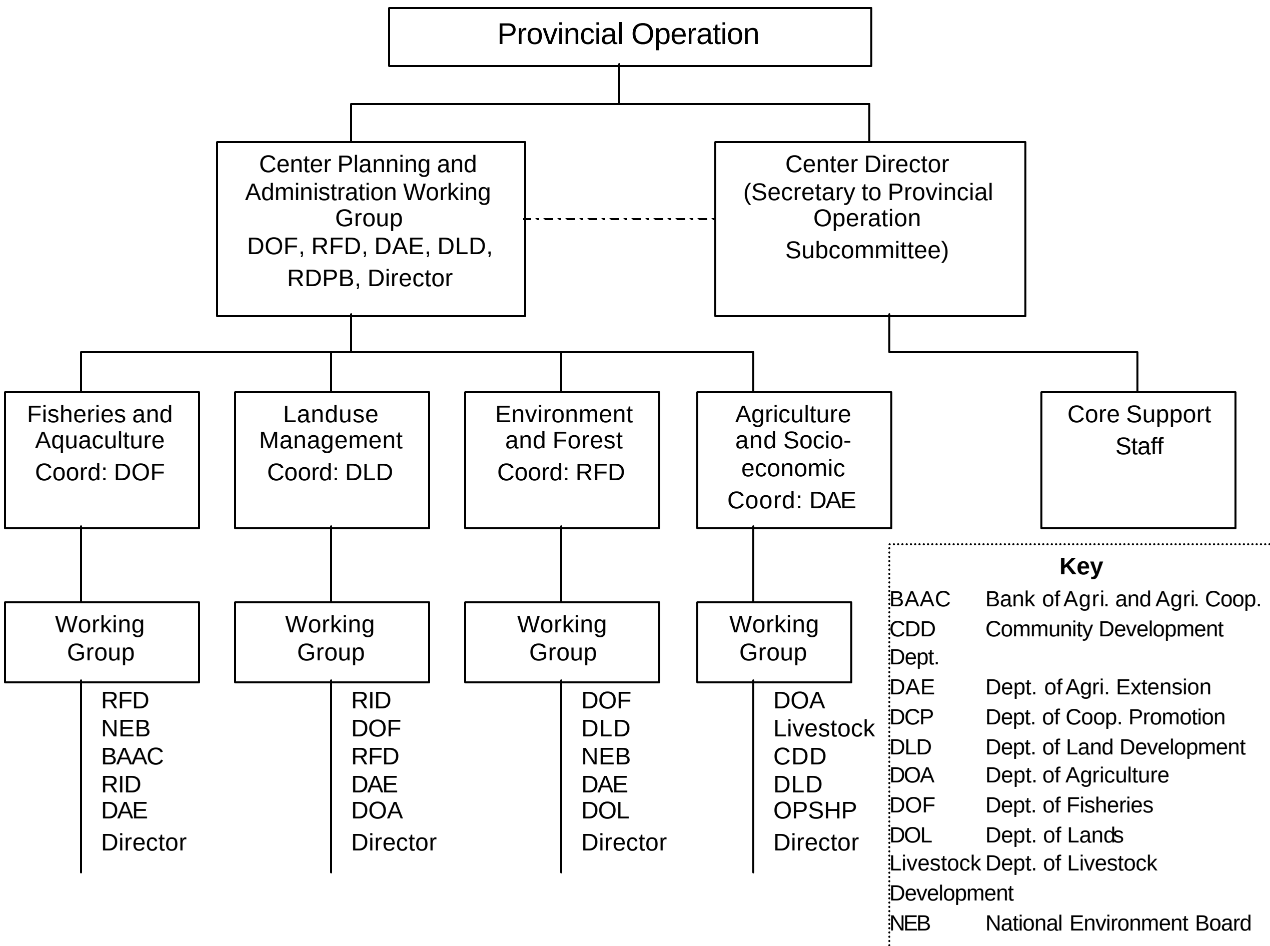


Mangrove:shrimp pond area ratio: If mangrove is to be effective as a buffer between shrimp ponds and the bay (sedimentation; nutrient absorption) a ratio of 1:5 is recommended. If sediments are exceptionally well managed, this ratio may be reduced to 1:1.6. The present ratio is 1:1.25.

Institutional framework

At least 19 governmental agencies are now cooperating with the center. These agencies are working together to promote and disseminate knowledge, skills and appropriate techniques on aquaculture, coastal environment protection and conservation, agriculture and animal husbandry through several "demonstration projects" and provision of training based on the study, research and experimentation work conducted by the center. Internal structure of the KKBRDSC is presented in the figure A1.6.

Figure A1.6. Institutional framework for the KKBRDSC



Environmental management

Environmental assessment

At the beginning of the KKBRDSC, no comprehensive EA was undertaken. This was because initial scoping and preliminary assessment assumed that extensive aquaculture technology would be used, and that activities would be restricted to defined aquaculture zones. In practice the shrimp farmers intensified very rapidly as their skills developed, in order to maximize their returns. In addition, other “unofficial” farmers were attracted to the fringes of the project, and significant unplanned and unregulated development took place, which affected both land use (significant areas of paddy have been converted), and the main water supply system (pond effluent was discharged into project supply canals).

Several environmental assessment related activities were subsequently initiated in response to some of the disease and water quality problems which have become increasingly common in recent years. These have included comprehensive monitoring of water quality in farm ponds and the bay, and a range of studies on environmental capacity of the lagoon, valuation of impacts, and impact management.

Regulations

Several policy and regulatory measures have been developed since the inception of the project to improve the environmental management of the shrimp farms and their surroundings:

- Mangrove land-use zoning policy;
- Rezoning of shrimp farming area;
- Preservation and reforestation of mangrove forest;
- Registration of shrimp farms;
- Requirement for settling pond construction by farmers;
- Prohibition of sludge discharge to public waterways.

Extension and promotion

- Extension and promotion of improved pond management;
- Demonstration and promotion of waste handling practices and waste treatment systems, including the use of oysters as bio-filters, and pond sediments as soil conditioner;
- Demonstration and promotion of grouper and seabass culture by the project, and by some of the farmers, with a view to diversifying the cultured species for brackish water ponds, and thereby reducing the risk of disease;
- Use of the mangrove forest to treat wastes;
- Environmental awareness raising among farmers.

Infrastructure

- Provision of pathology and veterinary service, including PCR testing of seed, disease identification, and advice on treatment.
- Development of a new sea water irrigation system.

Of these, the most ambitious is the sea-water irrigation system, which is nearing completion (1998). This comprizes a major water intake on the open coast (outside the bay) and pumping facility to supply a network of supply canals (see Figure A1.4). It also includes provision for rationalizing effluent canals, and water treatment prior to discharge into the Bay. The objective is to provide high quality, low pathogen water to all farms within the project, thus maximizing shrimp health and minimizing disease. Water treatment, and an overall flushing of water, should also lead to improved water quality within the bay.

Socio-economic impact

A study was specifically commissioned by the funding Board to examine socio-economic consequences of the project, and especially the shrimp farming component. It concluded that the shrimp farming had made a significant contribution to increasing the income, education and standard of living of those closely associated with the project. Inequity between those with shrimp ponds and those without had increased.

Some lessons and conclusions

1. It is dangerous to assume that extensive aquaculture poses no threat to the environment and therefore requires no environmental assessment. There are three major reasons for this:

- Extensive aquaculture itself requires habitat conversion in ecologically sensitive zones on a significant scale. If it is successful it will attract other farmers, and the impacts may become very extensive;
- There are powerful financial incentives to intensify as farmer knowledge and skills increase. This is difficult to control, and in any case may be desirable from other development perspectives. It should therefore be planned for, rather than reacted to.
- Successful farms will attract other farmers, commonly resulting in unplanned and uncontrolled development, mixed influent and effluent within and between farms, and increased stress and disease in fish or shrimp ponds.

EA should therefore be applied to extensive as well as intensive aquaculture. Since it is unrealistic and probably pointless to undertake EA in respect of individual small or medium scale extensive operations, sector EA should be undertaken for specific systems. Kung Krabaen Bay and its surroundings is an ideal “ecological system” which could have formed the basis for such an assessment.

2. A strong permit or licensing system with effective implementation is essential if development is to be well organized and sustainable.

3. A variety of mitigation practices were adopted or tested with mixed success:

   - Simple settling is effective in significantly reducing nutrient and sediment loads especially if used at the time of harvest;
   - Many farmers have adopted semi-closed systems (greatly reduced water exchange, compensated by high levels of aeration) which they believe reduces the risk of disease, and incidentally reduces pollution loads (assuming pond sediments are effectively disposed of);
   - The conversion of pond sediments for use as a fertilizer or soil conditioner is possible, but salt removal is costly, and nutrient quality is not high;
   - The use of oysters as biofilters in effluent channels has been only partially successful, and has not been enthusiastically embraced by farmers. The impact on effluent quality has been limited since effluent suitability for oyster growth is highly variable, and the relative value of the oysters is low.

4. Despite a project with a strong environmental theme and significant potential for environmental planning and management, shrimp farming intensified rapidly with inadequate infrastructure in terms of water supply and disposal. Although this is now being addressed, it is in reaction to significant disease and water quality problems, which have significantly reduced the success of the project in recent years. A more thorough and planned approach might have pre-empted these problems.

5. The institutional and organizational structure is extremely complex and costly. It is questionable whether this kind of approach, desirable as it is, could be repeated more widely. An approach which gives more responsibility to the farmers for environmental management might result in more responsible farmers.

6. Seawater irrigation systems may well enhance the sustainability of aquaculture, but they are expensive. The impact of the new system should be monitored to assess the cost effectiveness of such initiatives.

Appendix 2:

Legal and Institutional Frameworks for the environmental assessment and management of aquaculture

1. **Legal and institutional frameworks in selected countries in Africa**
2. **Legal and institutional frameworks in selected countries in Asia**

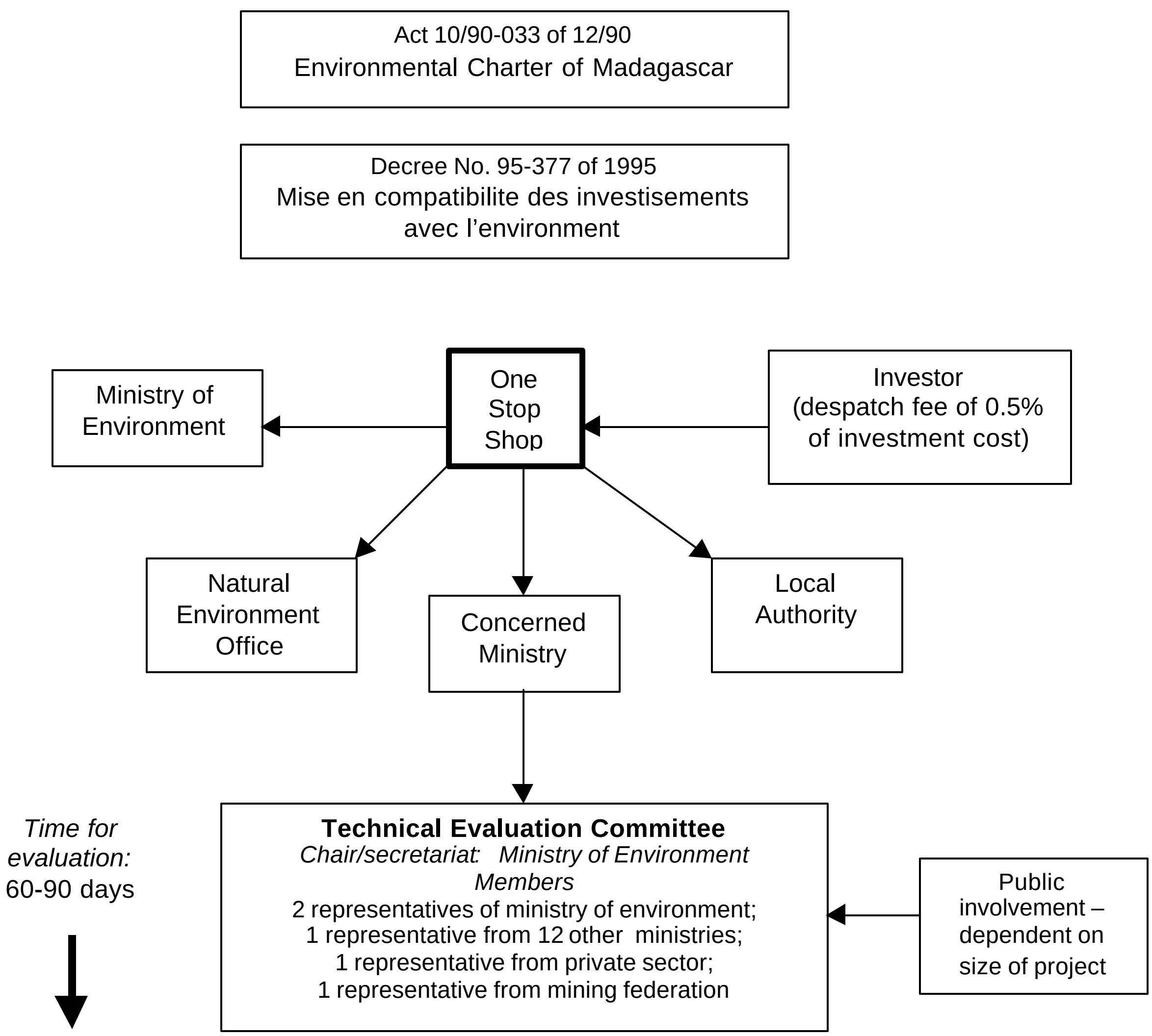
Legal and Institutional Frameworks in selected African countries

Madagascar[1]

Shrimp culture has begun to "take off" in Madagascar over the last few years, following significant assessment and planning activity, including a sector EA relating to shrimp culture.

The basic approval structure for major projects is presented in Figure A2.1. The main control on development activity is the Technical Evaluation Committee which screens projects and reviews EIAs. A Code of Conduct for shrimp farming has been developed and is currently under review. A Code of conduct for seaweed culture is also in preparation.

Figure A2.1: Framework for Technical and Environmental Evaluation of Investment projects in madagascar



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[1] Based on the output of a working group at the SEACAM Mariculture EA Training course, Dar Es Salaam, June 1999

Strengths

- The Technical Evaluation Committee represents a single integrated check on development proposals from social, economic and environmental perspectives;
- The Decree and associated ordinances have awakened environmental concerns in several Ministries;
- The concept of sustainable development is broadly accepted by investors and other stakeholders;
- The Decree provides a legal framework for EIA, which in turn encourages the confidence of funding agencies

Weaknesses

- There is an insufficiency of tools for environmental assessment;
- The evaluation structure is relatively heavy, especially for smaller developments;
- There is limited awareness of the decree;
- Some investors are reluctant to undertake EIA because of the high fees;
- The process does not apply well to small scale locally initiated aquaculture development

Opportunities

- A management plan for sustainable development of shrimp culture;
- Legislation to implement and strengthen the relevant codes of conduct

Mozambique[2]

The main institutions concerned with aquaculture and the coastal environment are presented in Figure A2.2

Relevant legislation and policy

- Fisheries Act
- Fisheries Master Plan
- Environmental Law
- Water Act
- Land Act
- Health Act

Strengths

- Coastal Zone Management Unit plays an effective role in coordinating different sectoral interests

Weaknesses and constraints

- Lack of an institution with a legal remit and mandate for aquaculture (National Directorate for Fisheries has no legal remit or responsibility for coastal aquaculture);
- Coastal zone management unit currently not involved in aquaculture;
- Supporting legislation is weak – no specific legislation in respect of aquaculture.

Opportunities for clarification of responsibilities:

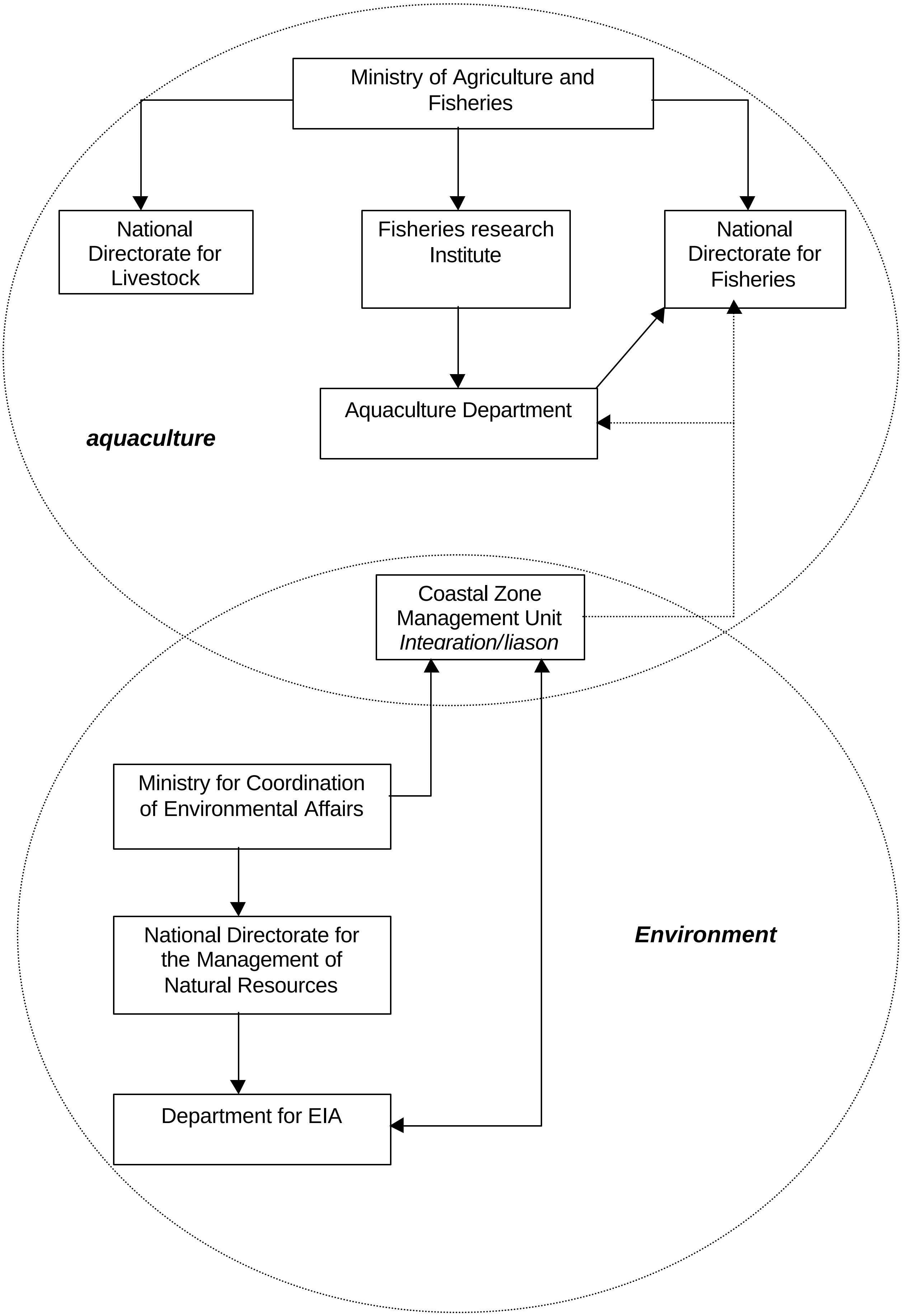
- Directorate for Livestock could serve as responsible authority for freshwater fish farming;
- National Directorate for Fisheries could serve as responsible authority for coastal aquaculture

Opportunities for action

- Ministry for Coordination of Environmental Affairs in association with the Department for Environmental Assessment to develop development guidelines;
- Ministry for Coordination of Environmental Affairs through the Coastal Zone Management Unit to coordinate sectoral interests;
- Research by Fisheries Research Institute;
- Draft law on aquaculture in preparation by Fisheries Institute in association with National Directorate for Fisheries.

[2] Based on the output of a working group at the SEACAM Mariculture EA Training course, Dar Es Salaam, June 1999

Figure A2.2 Institutional framework for aquaculture and environment in Mozambique



South Africa[3]

Main source: Cowley et al

Responsible authority

Mariculture was originally the responsibility of the Fisheries Development Corporation (FDC), a statutory body charged to:

- develop the industry;
- train researchers;
- offer grants to universities and research institutions;
- provide development finance.

This was phased out in the '80s. The Department of Agriculture is now the principal agency for aquaculture development (freshwater and marine). It convenes the Aquaculture Policy Committee which addresses national level issues. It also has organizational responsibility for freshwater aquaculture. However, the Department of Environmental Affairs and Tourism (DEAT), Directorate of Sea Fisheries (DSF) now controls and regulates coastal and estuarine mariculture.

DSF/DEAT functions :

- Permits;
- Research (mainly on environment issues so far);

Relevant legislation and policy

There is no national policy specifically for aquaculture, but the need is widely recognized and initiatives are afoot. However there is some provision for aquaculture within the Marine Fisheries Policy and the Marine Living Resources Bill.

Marine Fisheries Policy

- Development of mariculture operations will be encouraged within the limits of relevant appropriate environmental regulations;
- Mariculture research and the development of expertise will be a national effort, and will be promoted by the State as well as by the private sector;
- The introduction of foreign species will be controlled and care will be taken over possible environmental effects, particularly with respect to any resulting impacts on indigenous stocks;
- A full environmental, economic and social impact study will be carried out prior to the establishment of any commercial scale operations;
- The problems of the effect of pollution, or from, mariculture will be addressed

Marine Living Resources Bill

- No person shall engage in mariculture unless a right to engage in such activity has been granted to such person;
- An application to engage in mariculture shall be submitted to the Minister in the manner that the minister may determine;

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[3] Based on Cowley et al 1998. Estuarine Mariculture in S Africa. South African Network for Coastal and Oceanic Research, and the Foundation for Research and Development

- The minister may require an environmental impact assessment report to be submitted by the applicant;
- The right to engage in mariculture may be granted for the period that the minister may determine

Opportunities for change

Hecht (cited by Cowley et al) recommends **:**

- Each province should have active development programmes (promotion, extension and regulation);
- There should be a national policy statement – relating specifically to other policies and sectors

Cowley et al recommend:

- New policy relating to mariculture should be integrated in the CMPP of the DEAT
- A framework of planning procedures and management guidelines should be developed – linked to extension, technical assistance, and monitoring. This system must be flexible and adaptive.
- EIA should be promoted and developed not as legal constraint, but as an all encompassing regulatory mechanism and management tool to provide improved planning and execution of new projects;
- An information access system should be developed;
- A resource allocation strategy (essentially a zoning/aquaculture siting guidance system) should be developed from current research

Legal and Institutional frameworks in selected Asian countries

The following information has been provided by the Network of Aquaculture Centers in Asia (NACA), Bangkok.

Table A2.1: Environmental management of coastal aquaculture in selected ASIAN countries

	Registration of farms	EIA	Specific aquaculture legislation	Effluent Standards	Licence abs/disc water	Monitoring	Effluent treatment requirement
Bangladesh	NO	NO	NO	NO	NO	NO	NO
Cambodia	NO	NO	NO	NO	NO	NO	NO
China	YES	NO	NO	NO	NO	NO	NO
Hong Kong	YES*	YES	NO	YES	*	NO	YES
India	YES (Optional)	YES[3]	YES (for Goa)	UND. DEV.	*	NO	NO
Iran	YES	NO	NO	NO	NO	NO	NO
Indonesia			NO	YES	NO	NO	NO
Korea	YES	NO	YES (mollusc)	YES	NO	YES	YES
Malaysia	YES	YES	YES	NO	NO	NO	NO
Myanmar	YES	NO	YES	NO	NO	NO	NO
Philippines	YES	YES	NO	YES		YES	NO
Sri Lanka	YES	YES	NO	YES	NO	YES	YES
Thailand	YES	NO	NO	YES	NO	NO	YES
Vietnam	NO	NO	NO	NO	NO	NO	NO

= not available

Farm registration.

All of the countries (except for Bangladesh, Cambodia and Vietnam) reported a system of farm registration, which in most cases included restrictions or conditions under which the farm must operate. It is appropriate if farm registration requirements should be extended to cover all aquaculture farms, regardless of size.

Specific aquaculture legislation.

Only two of these countries returning had specific aquaculture legislation (Malaysia and Myanmar) although a further two had some specific legislation (India and Korea). In Thailand, coastal aquaculture is subject to a wide range of legislation that was originally formulated for other purposes, and it would be useful to have specific aquaculture legislation that identifies the parts of different existing statutes that are applicable to coastal aquaculture, and which provides additional legislation and regulations where there are gaps. Due to the length of time it takes to develop and promulgate legislation, it is recommended that Thailand begin the process of legislative development as soon as possible.

Environmental Impact Assessment.

Five countries in the region report a requirement for some form of environmental impact assessment, Hong Kong, India, Malaysia, the Philippines and Sri Lanka. In Hong Kong, instead of requiring EIA for individual developments the Government has carried out regional EIAs in some areas to assess the potential of the area for fin fish culture. This approach reduces the financial burden on individual farmers and allows coastal area assessment to be made taking into consideration other waste loadings and users. In India and Malaysia, farms exceeding 40 ha and 50 ha in size, respectively, are subject to

EIA. In Sri Lanka (see below), all proposed farms are required to submit basic data on the site and size of the proposed development (an Initial Environmental Assessment) and farms over 5 ha which are located in an environmentally sensitive area require a full EIA. Similarly, the Philippines requires an Initial Environmental Assessment for all aquaculture related activated.

Effluent standards

A number of the countries in Asia reported having effluent standards for coastal aquaculture (Hong Kong, Indonesia, Korea, the Philippines and Sri Lanka) whilst others (India) reported that they are under development. The recommended effluent standards for coastal aquaculture in Thailand are discussed in Section 10. Only Indonesia and Sri Lanka have standards for shrimp farming. Effluent standard for coastal aquaculture are shown in Table A2.2 .

Monitoring.

Only Korea, the Philippines and Sri Lanka carry out any monitoring of aquaculture effluents, and in the latter two countries the extent of this monitoring is very limited due to manpower and the logistical problems.

A brief summary of the procedures in countries which have developed environmental management practices for coastal aquaculture follows:

Sri Lanka - see Appendix 1

Indonesia

Indonesia uses the AMDAL process for assessing aquaculture development projects (ADB, 1992). Analysis Mengennai Dampak Lingkungan Method (AMDAL) is essentially an integrated review process designed to co-ordinate the planning and review of proposed development activities, particularly their ecological, socio-economic and cultural components as a complement to the technical and economic feasibility. Permits and licence conditions provide the means by which environmental mitigation and monitoring requirements developed in the AMDAL process can be made legally enforceable in the event of non-compliance. There are four main types of permit: Investment Permits; Location Permit; Activity Permit; and Nuisance Permit. The use of water effluent and air emission standards is critical to the effectiveness of the AMDAL process.

The Ministry of Agriculture of Indonesia has prepared regulations applicable to the preparation of Environmental Monitoring Plans of aquaculture (Decree No 719/Kpts/RC 220/10/89). In most cases the monitoring will involve collecting data on the following parameters from effluent and affected receiving waters: pH; $BOD_{5;}$ Total suspended solids; Nutrients (nitrogen total)

nitrogen, ammonia, nitrite and nitrate) and phosphorus (ortho-phosphate and total phosphorus) compounds; Temperature, dissolved oxygen, salinity/conductivity; and Chlorophyll a.

Hong Kong

Coastal aquaculture in Hong Kong is made up mainly of marine finfish cage culture and oyster culture and there is specific legislation. covering both activities. The Marine Fish Culture Ordinance protects and controls marine fish culture and requires that all marine fish culture operations be conducted under licence within a designated fish culture zone. The licence specifies the size and location of fish rafts, the size and use of structures permitted on the raft and regulations on moorings and installation of lights, licence number plate and refuse containers. The release of pollutants is prohibited as is the unauthorised entrance of vessels in to the fish culture zone. There are also restrictions on certain fish culture operations such as disposal of moralities and other wastes. There are no specific effluent standards for marine fish cage culture, but there are effluent standards for other discharges into inland and coastal waters in Hong Kong.

Republic of Korea

In Korea there are codes of practice for the utilisation of lakes, rivers and coastal areas for aquaculture which cover specific criteria governing site selection procedures and stocking rates for finfish, mollusc and seaweed farms. All cage culture and aquaculture operations of more than 1,000m^2 surface area should register with the Ministry of Environment under the Aquatic Environmental Protection Law. Major provisions aimed at mitigating the pollution loads form cage fish farms consist of the following:

- Supply drifting and low phosphorus feed only and the sinking rate should not exceed 10% in two hours;
- Feed fences 10cm above the surface of the sea should be erected to control the dispersal of feed outside the cages;
- Dissolved oxygen levels should not be more than 20% less outside of the cage than inside;
- There should be facilities on the cages to retain human faecal materials;
- Regulation of the use of antibiotics and drugs for fish disease;
- Immediate removal of dead fish.

There are no specific effluent standards for marine finfish culturists although under licensing and management regulations the following activities must be carried out:

- The seabed must be cleaned with dredges more than once every three years;
- A distance of more than 300 m must be kept between on licensed site and another;
- Licence areas are restricted to 0.5 to 10 ha for one finfish licence culture bed;
- Each cage should be 25 m^2;
- Cage area will not exceed 5-20% of the total licensed area;
- All finfish culture should have a licence from the municipal authorities.

Myanmar

Myanmar has recently adopted legislation to promote the development of aquaculture, including both coastal and inland aquaculture. However, this legislation does not cover the environmental management, EIA or effluent standards, although it does include registration and licensing for all aquaculture farms.

China

There are several environment protection laws in China which touch upon aquaculture, although these laws are not specifically drafted for aquaculture. The scope of the Fisheries Laws of the People's Republic of China of 20/1/1984 includes protection of fisheries and aquaculture environments. In general in China, there is more concern about the protection of aquaculture and fisheries from industrial pollution and eutrophication, than with protection of the environment from aquaculture development. The Environment Division of the Bureau of Fisheries Management and Port Superintendence (Ministry of Agriculture) is planning to draw up further regulations on environmental protection for fisheries, including aquaculture, probably as a part of the existing environmental laws

The Fisheries Law states that "the state shall encourage the best use of suitable water surfaces and tidal flats to develop aquaculture". Aquaculture operations on state owned water surfaces and tidal flats that have been designated for aquaculture are required under this Fisheries Law to apply for an operating licence. Small-scale pond culture on private land does not require an operating licence. Licences are also required for using state and collectively owned land.

There are no set standards for effluent discharges from land-based aquaculture farms in China and no legal requirement for treatment of effluent from such farms. Under the Water Pollution Prevention and Control Law, it is prohibited:

(I) to deposit solid wastes and other pollutants on beaches and bank slopes below the highest water level of rivers, lakes, canals, channels and reservoirs, and

(II) to discharges pathogen-contaminates sewage unless it has been disinfected to meet the relevant national standards.

However, such regulations have not been applied to aquaculture.

The department of fisheries administration at various government levels are required under the Fisheries Law to monitor the pollution of fisheries waters. The monitoring network of fisheries environmental protection is incorporated into a national environment monitoring network. The monitoring of fisheries environment is co-ordinated at national level by the Bureau of Fisheries Management and Fishing Port Superintendence (of the Ministry of Agriculture), and undertaken at the national, provincial and local district or country level.

Environmental impact assessments (EIA) are not normally carried out prior to the development of an aquaculture farm although aquaculture projects supported by agencies such as the World Bank and Asian Development Bank incorporate an EIA. The Environmental Protection Agency, mandates EIA for mainly industrial, construction and large scale, non aquaculture development projects.
There are codes of practice for the use of some toxic substances, chemicals and pesticides in aquaculture.

The Water Pollution, Prevention and Control Law Decree No. 12 in China provides that competent central and local governments may define protected zones, and take measures to ensure that the water quality in those protected zones complies with the standards for their designated uses with regard to important fishery water bodies. "Fishery water bodies" are *"those parts of water bodies designated for the spawning, feeding, wintering, or migration passage of fish, or shrimp, and for breeding fish, shrimp, or shellfish, or growing algae*". The Regulations for implementation of the Fisheries Law also states that the "*natural spawning, breeding and feeding grounds of fish, shrimp, shellfish and algae as well as their major migration routes shall not be used as aquaculture grounds"*

Malaysia

There are a number of laws and regulations in Malaysia that deal with aquaculture. The Fisheries Act in Malaysia provides for a license system for coastal aquaculture systems (but not for aquaculture in inland waters - this is the responsibility of the State Authority) Under this act, aquaculture is defined as "*the propagation of fish seed or the raising of fish through husbandry during the whole or part of its life cycle*" and "culture system" as "*any establishment, structure or facility employed in aquaculture and includes bottom culture, raceway culture, raft culture, rope culture* *and hatchery*". The Director General of Fisheries (DGF) has the responsibility to grant coastal aquaculture licences.

Lately, the Department of Fisheries in Malaysia has started working on extending the licensing and permit regulations to encompass freshwater areas under the state's jurisdiction and it also plans to introduce a "code of practice" for aquaculture activities covering detailed operational procedures for different culture systems. The environmental Quality Act in Malaysia constitutes a basic instrument providing for a common legal basis to co-ordinate all activities of environmental control including EIA. Under the Land Conservation Act, the competent authorities ("collector") have certain duties with regard to the protection of land and water sources from soil erosion and siltation (physical pollution) from different activities, including coastal aquaculture. EIAs are only carried out in Malaysia for coastal aquaculture projects which cover an area of more than 50 ha (in mangrove areas). No effluent standards have been set for coastal aquaculture in Malaysia.

India

Under the Environment (Protection) Act, 1986, standards for effluent have been laid down, but these are not for aquaculture. Specific standards for aquaculture effluent are under development by state Pollution Control Boards. EIA in aquaculture was previously adopted for large donor supported projects, but now all large projects of coastal aquaculture (over 40 ha) are required under government guidelines to prepare an 'environmental management plan'. No regulations to control the use of chemicals and drugs exist. Pollution control Board general regulations on effluent discharges include hazardous substances, but they are not specific to aquaculture. Under the Notification of Union Ministry of Environment and Forests, each maritime state is expected to have its own coastal zone management plan, which includes zones for aquaculture. The zone up to 500 metres from the waterline along the sea is restricted against any construction activity, including aquaculture. In general, specific regulations for aquaculture are under development. Some states are considering enacting legislation for aquaculture development, as in the case of Tamil Nadu. The particularly relevant points of this Tamil Nadu legislation are as follows:

- establishment of an 'ecorestoration' fund, which can be used for environmental improvements in aquaculture areas, particularly where farms have been 'abandoned';
- licensing of aquaculture development, and the identification of areas where aquaculture can be carried out (and restriction on development in conservation/protected areas);
- need for consent from the Tamil Nadu Pollution Control Board (PCB) before approval of an aquaculture licence; and
- general management provisions for reduction of impacts of aquaculture effluent, including the use of settlement ponds, if deemed necessary by the PCB.

Table A2.2 : Effluent standards for coastal water in other Asia-Pacific countries

Parameter	Hong -Kong[1]	India[2]	Indonesia	Korea[3]	Philippines[4]	Sri Lanka[5]	Australia[6]
BOD (mg/l)	10-40	20-50	*	-	3	50	15
COD (mg/l)	50-85	75-100	*	-	-	250	-
PH	6.0-10.0	6.0-8.5	*	-	6.5-8.6	6.0-8.5	6.5-8.5
Suspended solids (mg/l)	25-40	100	*	-	30% increase	100	90-200
Temperature (°c)	40-45	-	*	-	30% increase	35	-
Total nitrogen	20-50	2.0	*	-	-	2.0	10

(mg/l as N)							
Total phosphorus (mg/l as P)	5	-	*	-	-	-	1
Phosphate (mg/l as P)	-	0.2-0.4	*	-	-	-	-
Total ammonia (mg/l as N)	-	0.5-1.0**	*	-	-	-	-
Nitrite (mg/l as N)	-	-	*	-	-	-	-
Nitrate (mg/l as N)	-	-	*	-	-	-	-
Turbidity	-	-	*	-	-	-	-
Dissolved oxygen (mg/l)	-	>3	*	-	5	-	4
Coliform (MPN/100 ml)	1,000	-	*	<70	70	-	-

Sources : 1 = Environmental Protection Dept., Hong Kong, 1991
2 = Ministry of Agriculture, India, 1995
3 = Ministry of Agriculture, Forest and Fisheries, RO. Korea, Ordinance No. 699, for shellfish culture in sea
4 = DENR, Administrative Order No. 3, Philippines, 1990, for mollusc culture in sea
5 = FAO/NACA, 1995
6 = e-mail data from Dr. Paul Smith, ACIAR, Australia
* = not available
**= free ammonia (as NH_3-N)

Philippines

A series of laws have been enacted for the aquaculture and fisheries industry, which are related to conservation of resources and the environment. There are, however, numerous local regulations promulgated by some municipal governments which are also directed to utilisation of resources and the environment for aquaculture purposes. A new Fisheries Code is being prepared to encompass the main issues related to the environmental management of aquaculture in the Philippines.
There is limited provision for EIA for coastal aquaculture in existing regulations, but it is planned to include more comprehensive coverage under the new Fisheries Code. Water quality standards exist for mollusc culture areas, but no standards exist for shrimp farming effluent. Philippines law requires the registration of all coastal aquaculture farms, including shrimp, fish, seaweed and mollusc farms.

Indonesia

Table A2.6: Outline of environmental impact assessment procedures for shrimp aquaculture projects in Indonesia (modified from: Phillips,1995).

Steps	Actions	Outcome/result
1. Project initiation	Investor/farmer to forward project plan to authorities	Advice given to investor/farmer on EIA procedures
2. Initial screening	Prepare preliminary environmental assessment covering: - project description - general environment at site - identification of major environmental concerns - follow up recommendations	Review indicates: project exempt or project unacceptable or EIA to be prepared under these circumstances: - introduction of new species - farm area > 5 ha - farm within mangrove area - hatchery > 40 million pcs/yr
	Prepare environmental impact assessment covering: - environmental issues during construction, operations and abandonment - effects on environment	Following review of EIA by authorities, project: - rejected - modified - accepted.

	- effects of environment on shrimp farm - identification of mitigative measures	Following acceptance, operational permit given defining mitigation and monitoring requirements developed in EIA procedure.
4. Farm start up and post permit monitoring	Environmental monitoring, particularly effluent quality: - pH, BOD and COD, solids, N and P, temp, chlorophyll. - other parameters as deemed necessary.	Action can be taken if non-compliance

In other countries world-wide

In industrialised countries world-wide there are a variety of measures used to control the environmental impact of aquaculture. Some of the planning and regulatory options in use by other countries for the control or minimisation of environmental impact of aquaculture developments are shown in Table A2.3 (NCC, 1989).

Table A2.3 : A summary of aquaculture control options used in various industrialised countries (NCC, 1989).

Control Option	Can	Den.	Fin.	France	Japan	New Zeal.	Norway	Sweden	USA
Substantial Legislation									+
Distance Limits									
between sites				+			+		
from conservation areas	+								
Limits on production									
per farm	+		+						
cage area or number	+				+				+
by volume							+		
by stocking density					+				
Water Depth Regulations						+			+
Restricted areas							+		
Moratorium on new farms		+					+		
Regulations on Ownership							+		
EIS required									+
Water quality monitoring			+						+
Management plan required				+					
Regulations vary with farm size			+					+	+

Some of the main points which emerged from this analysis were:

- In some countries (Denmark and Norway) the pace of development resulted in a temporary moratorium on new fish farm licences whilst environmental and other studies were undertaken;
- in some countries (Canada, Norway and France), regulations were made regarding the distance farms must be sited from conservation or other fishfarming sites;
- the size and scale of development is controlled in some way in most countries;
- most countries have some form of consultation procedure with interested parties prior to the granting of a licence - this may depend on the scale of the development.

In 1992, a study was carried out to compare different approaches to effluent management in EC countries (Rosenthal and Hilge, 1993). The results are summarised in Tables A2.4 for freshwater aquaculture operations and Table A2.5 for marine cage farms. It should be borne in mind that these controls relate to intensive finfish culture in cages in the marine environment and land-based tank or pond farms in the freshwater environment. There is also freshwater cage culture of finfish in some countries.

In the freshwater environment, the most common ways of controlling effluent quality are to have a requirement for water treatment and restriction on water abstraction. These restrictions delimit the quality and quantity of effluent that may be discharged. Other commonly used controls were to place restrictions on the nutrient and organic load through effluent standards, taxing the volume and quality of effluent discharged or a requirement for EIA. Less commonly used were restrictions on production capacity and chemical monitoring requirements.

Table A2.4: Comparison of Controls Governing Freshwater Fish Farm Effluents in EC and other states

EC Countries	Prod. cap	Wat treat	Wate xtr.	N&P load	Org load	Feed Comp	Feed Conv.	EIS reqd	Chem	Monit. reqd	Tax abst	Tax Disc
Belgium				Y	Y							Y*
Denmark	Y	Y	Y	Y	Y	Y	Y	Y				
France			Y	Y	Y			Y				Y
Germany		(Y)	Y	(Y)	Y					Y		Y
Greece		Y	Y	Y								
Ireland	Y	Y	Y	Y	Y			Y	Y	Y		
Italy		Y	Y	Y				Y				
Netherlands		Y	Y		Y							Y
England and Wales		Y		Y					Y		Y	
Scotland		Y		Y				Y	Y			Y
Northern Ireland		Y	Y						Y			
Non-EC Countries												
Austria		Y	Y	Y	Y							
Czechoslovakia				Y	Y							
Finland	Y	Y		Y		Y	Y					
Hungary				Y	Y							
Poland		Y	Y	(Y)	(Y)							
Norway	Y							Y	Y	Y		
Sweden	Y						Y		Y			
United States and Canada			Y	Y	Y					Y		

Source : Rosenthal and Hilge, 1993

In the marine environment, restrictions are commonly placed on production capacity, nutrient and organic loads, feed composition and stocking density. There is also a requirement for EIA, water quality monitoring and separation distances in some countries.

Table A2.5: Comparison of controls governing marine fish farm effluent in some EC member states.

	Prod cap	N&P load	Org Load	Feed Comp	Feed Conv.	Limit prod	EIS	Sep. dist	WQ	Dis Not.	S. D.
Belgium					Y						Y
Denmark	Y	Y	Y	Y		Y	Y				
France	Y	Y	Y				Y		Y		
Germany			Y	(Y)	Y		Y				Y

Greece		Y	Y	Y							
Ireland	Y					Y	Y	Y	Y		Y
Italy		Y	Y				Y				
Netherlands		Y	Y	Y	Y						Y
Norway	Y				Y	Y	Y	Y			Y
UK England and Wales				Y							
UK Scotland		Y		Y				Y	Y		Y
UK N. Ireland									Y		

Source : Rosenthal and Hilge, 1993

References

NCC 1989. Fishfarming and the safeguard of the natural marine environment of Scotland. Nature Conservancy Council, Scottish Headquarters, Edinburgh, UK

Phillips, M.J. 1995. Shrimp culture and the environment, pp. 37-62. In: Bagarinao, T.U. and E.E.C. Flores (eds.) Towards Sustainable Aquaculture in Southeast Asia and Japan. SEAFDEC Aquaculture Department, Iloilo, Philippines

Rosenthal, H. Hilge, V. and A. Kamstra (eds), 1993. Workshop on fish farm effluents and their control in EC countries. 23-25 November 1992 Hamburg, Germany. Institute of Marine Science, Kiel, Germany. 205 p

Appendix 3

Summary of environmental assessment procedures as recommended by different organizations

Outline of EIA Process according to selected guidelines

Agency	Preliminary Assessment		Detailed Assessment				Approvals	Follow up	
UNEP United Nations Environment Programme	**Screening** a. Whether EIA required	**Scoping** a. Identify key issues and impacts b. Prepare TOR	**Assessing** a. Impact Identification b. Impact analysis/Prediction c. Impact significance	**Mitigation** a. Redesign b. Planning for impact management	**Reporting**	**Reviewing** a. Document quality b. Stakeholder input c. Proposal acceptability	**Decision Making** a. Approved b. Not approved 1. Redesign 2. Resubmit	**Monitoring** a. Impact Management	**EIA audit and evaluation**
NORAD **Norwegian Development Aid Agency**	**IEE** a. Project description b. Description of the Environment c. Checklist								
IIED **International Institute for Environment and Development**	**Screening** a. Whether or not EIA is required b. Level of assessment needed	**Preliminary Assessment** a. Identify key impacts on the local environment b. Magnitude and significance of the impact c. Evaluate the importance of impacts for decision makers	**Scoping** a. Narrowing down of potential impacts b. What impacts will occur? c. Extent, Magnitude and duration d. Significance of impacts within local, national and international context e. Mitigate adverse impacts and optimize positive impacts f. Documentation	**Review** a. To address the adequacy of the assessment for decision making	**Monitoring** a. Assess the effect of the project on the natural and cultural environment b. Collecting data	**Post project Auditing** a. To learn from experience to refine project design and implementation			
ODA **UK Overseas Development Administration**	**Scoping** a. Identifying environmental issues.	**Screening** a. Identifying significant impacts b. Cost of EIA	**Commissioning EIA** a. What form? b. Who does? c. How to enforce?	**Managing EIA** a. Focus b. Team c. Presentation of report	**TOR for an EIA** a. Existing environment b. Impacts c. Measures	**Monitoring and Evaluation** a. Ensure mitigation b. Identify additional mitigation c. Improve EIA procedures			

ADB Asian Development Bank	IEE (Aquaculture & Coastal Zone Management)
	a. Environmental problems related to site selection b. Environmental problems relating to inadequate design c. Environmental problems during construction stage d. Environmental hazards relating to operations e. Critical environmental review criteria f. Other potential environmental problems

Kenya Government	TOR	Baseline Study	Assessment	Mitigation	Monitoring	Project Benefits	Recommendations
	a. Introduction of the project and the EIA people. b. Policies and Acts	a. Overview b. Project Description c. Description is existing environment	a. Identification b. Analysis c. Assessment of impacts	a. Mangroves b. Operational Impacts c. Socioeconomic Impacts	a. Environmental Monitoring b. Socioeconomic monitoring		

India Government (Aquaculture)	Screening	Scoping	Prediction of Impacts	Public Participation and Consultation	Mitigative measures related to:	Monitoring	Conclusion (do's and dont's)
	a. Impact on water course in the vicinity b. Impact on ground water quality c. Impact on drinking water sources d. Impact on agriculture, soil and salinisation e. Waste water treatment	a. Identify impacts during construction, operation and decommissioning phases. (activities listed for each phase)	a. Land use b. Water c. Socio-economics	a. Organizations to be consulted	a. Clearing/conversion of wetlands/mangroves c. Erosion and siltation d. Competition for water and land use e. Loss of production f. Disease spread g. Effluent quality h. Exotic species i. Socio-econimics j. Water pollution	a. Pond water quality b. Effluent water quality c. Receiving water quality d. Hydrologic effects e. Pathogens f. Coastal contamination g. Water borne vectors (public health) due to the project activity	A table is presented

References

ADB. 1987. Environmental guidelines for selected agricultural and natural resources development projects. Office of the Environment. Asian Development Bank

IIED, WRI, IUCN 1995. A Directory of Impact Assessment Guidelines. International Institute for Environment and Development, London.

NORAD. 1992. Environmental Impact Assessment (EIA) of Development Aid Projects. Initial Environmental assessment. 5. Aquaculture.

NORAD. 1993. Environmental Impact Assessment (EIA) of Development Aid Projects. Check lists for Initial Screening or Projects.

Overseas Development Administration (ODA) 1992. Manual of Environmental Appraisal. ODA, London.

UNEP 1990. Environmental Guidelines for Fish Farming. UNEP Environmental Management Guidelines No. 19 United Nations Environment Programme, Nairobi.

UNEP 1996 Environmental Impact Assessment Training Resource Manual. UNEP Nairobi

Kenya Wildlife Service 1998. Environmental Impact Assessment (EIA) Guidelines and Administrative Procedures (draft). SPARVS Agency Limuru Kenya

Appendix 4:

Check-list for an initial environmental assessment (IEA) of an Aquaculture Project

This checklist is adapted from *NORAD. 1992. Environmental Impact Assessment (EIA) of Development Aid Projects. Initial Environmental assessment. 5. Aquaculture.*

1. Project Description

Rationale/Need for project

- beneficiaries
- related or downstream activities and multipliers
- resource use

Alternatives

- technical
- location/siting
- resource/infrastructure differences for alternatives

Technical description

- maps, areas used, areas affected, context;
- technical diagrams;
- intensity; inputs/outputs; production parameters;
- labour, skills - interactions with other projects;
- establishment and operation

Implementation

- infrastructure;
- markets;
- credit;
- institutions
- skills/environmental competence

2. Description of the Environment – natural and man-made

Graphics, charts etc should be used where possible.
Sources of data should be presented, and reliability discussed.

- climate geology and soil conditions;
- hydrologic conditions (upstream and downstream);
- vulnerable or valuable species or ecosystems;
- unique natural or cultural areas;
- objects of
  - ❑ historic,
  - ❑ archaeological,
  - ❑ cultural,
  - ❑ aesthetic value;
- existing use of natural resources
  - ❑ demography/ethnography of user groups;
  - ❑ settlement patterns; means of production; division of labour among affected groups;
- environment related illness;
- existing or planned activities which might impact aquaculture;

3. Social impacts

The following should be addressed whether or not they are significant:

- Positive and negative effects on target group/beneficiaries;
- Effects on other groups;
- Demographic change resulting from project

4. Physical/environmental impacts

New species introductions (e.g. farmed animals; live feed; disease):

- impact on local species or ecosystems;
- impact on existing productivity;
- spread disease;
- import control.

Reduced or changed biodiversity (commercially or aesthetically valued or vulnerable):

- impacts from site activity;
- pollution;

Affect valued landscapes:

- visual impact affecting tourism and recreation;
- visual or physical impact on locally valued sites;

Waste and pollution from activity, or associated downstream/upstream activities:

- organic matter;
- nutrients;
- eutrophication, deoxygenation etc;
- processing waste - smell; hygiene; eutrophication;
- drugs, anti-foul, chemicals, disinfectants, pesticides;

Increase human disease

- farm organisms as intermediate hosts;
- farm habitat as shelter for water borne vectors;
- inputs (e.g. sewage) - impacts on workers or consumers);
- control of chemical use? quality control, residue checks?

Water and energy requirements:

- adequately assessed;
- competition with other users;
- level and salinity of water table;
- effect of evaporation on water quality;
- wood requirements for construction and eg smoking;
- energy and fuel needs of activity, & associated transport and processing;

Impact on local resource use:

- a novel use of resources?
- level of intensity and suitability to local technical skills;

- economic and social change indirectly affecting utilization of natural resources;
- gender issues;
- without project changes;

5. Mitigation

How can the likely impacts be reduced or *ameliorated.*

Siting e.g.:

- avoiding valuable habitat/resources;
- choosing locations with higher assimilative capacity;
- spreading or moving activities to reduce intensity of impacts;
- location to maximize socio-economic benefits.

Technology, e.g.:

- waste/pollution reduction;
- waste/pollution treatment or recycling;

Management:

- input selection and management (e.g. feed, chemicals);
- waste management;
- Best Management Practice

Infrastructure:

- canals;
- water treatment;
- waste handling and processing facilities;

Legislation/fiscal:

- effluent standards and control;
- licensing;
- taxation on pollution or inputs;
- Best Management Practice
- Price intervention on inputs or outputs

Market:

- opportunities for environment related product labeling

Appendix 5:

Matrices of aquaculture activities, impacts and mitigation measures

1. **Brackish water and marine hatcheries**
2. **Brackishwater pond culture**
3. **Coastal cage or pen culture**
4. **Coastal mollusc culture**

Brackishwater and marine hatcheries

Checklist of environmental impacts and mitigation strategies for land-based marine hatchery/nursery (shrimp, fish) aquaculture projects

Actions affecting environmental resources and values	Potential environmental impacts	Potential mitigation strategies for negative environmental impacts
A. Site selection		Appropriate site selection
1. Conflicts with other site users	On and off-site impacts resources and social conflicts	Appropriate regional land use planning Consultation process Participation of local people in aquaculture projects Resettlements/compensation agreements
2. Selection of ecologically sensitive site	Potential loss of biodiversity and wetland habitat	Careful site selection Management plan which identifies ecologically sensitive sites Habitat restoration, e.g. replanting of mangroves Maintain buffer areas around hatchery Prior assessments of impacts
3. Hazards to aquaculture from nearby pollution sources (e.g. agriculture, industry)	Water pollution from industry, agriculture affecting sustainability of aquaculture	Careful site selection Pre-treatment of water, selection of water sources Pressure from aquaculturists to reduce pollution from other sectors
4. Typhoons, flooding, hurricanes	Damage to physical facilities and loss of broodstock and pond discharge	Careful site selection. Hatchery design taking account of extreme climatic events. Buffer zones for wind breaks (e.g. mangroves)
5. Water quality	Water quality deterioration caused by self-pollution from hatchery effluent	Careful site selection in relation to other hatcheries. For large numbers of small-scale hatcheries, common effluent treatment systems Good hatchery management practices Design of inflow/effluent systems to control self-pollution. Treatment of effluent/effluent controls
6. Fish/shrimp broodstock availability	Potential impacts on biodiversity caused by over-harvesting of wild broodstock. Lack of sustainability of hatchery due to insufficient broodstock.	Careful assessment of requirements Development of hatcheries Sourcing of wild broodstock.
7. Disease problems	Potential impacts caused by presence of	Disease surveys of existing farms/broodstock sources to assess

	serious pathogens/disease problems	risk. Introduction of risk management strategies within hatcheries to reduce risk. Careful disinfection/health management protocols for broodstock and seed. Health certification and quarantine protocols. Adoption of SPF (specific pathogen free) technologies.
B. Hatchery design	B. Poor design can lead to environmental problems	B. Careful/appropriate design
1. Attention to problems A (1) to A(7) above	As above.	As above.
2. Socio-economic impacts	Social inequities.	Participation of local people in aquaculture projects. (*note: small-scale hatcheries/nurseries projects offer good scope for involvement of local people*) Understand socio-economic conditions prior to project, and ensure developments do not negatively impact local people.
3. Impacts due to infrastructure	Local hydrological or salinity changes caused by poor design	Roads, canals and other infrastructure should not block tidal flow. Maintain buffer areas around hatchery.
4. Aesthetics	Aesthetic impacts	Development of green buffer zones Avoid unsightly water supply/discharge canals, pipes. Locate away from tourist sites (e.g. high value beaches).
C. Hatchery construction	Poor construction practices can lead to various environmental problems	C.
1. Site clearance	Damage to terrestrial and wetland habitats and water quality problems during construction	Maintain buffer areas. Ensure site disturbance is limited to immediate construction area Roads, canals etc should be constructed to minimise vegetation clearance. Sediments removed during construction should be disposed of in suitable locations. Excavation/disturbance of potential acid-sulphate soils should be minimised. Regulatory requirements should be followed during clearance and disposal of soils and vegetation.
2. Infrastructure development (access roads, canals)	As above	As above.

3. Obtaining filling materials	Removal of filling materials required for dykes, foundations, access roads may impact habitat, water quality	As above
4. Labour, worker safety	Possible impacts on environment caused by labour force (e.g. noise, groundwater drawdown, sewage)	Provision of suitable infrastructure/facilities to support labour.
D. Hatchery operation and management		
1. Solid waste disposal	Impacts on surrounding land-use/wetland habitats	Non-organic, solid waste materials should not be dumped into mangrove forests etc, but disposed of safely.
2. Waste water/effluent discharge	Impacts on local water quality and sediments	Use of settlement basins, borrow pits and other techniques to treat discharge water. Take particular care in treatment of water containing disease control/disinfectant chemicals. Water exchange minimised and water recycling when possible. Discharge of hatchery effluent into areas with adequate tidal flow. Avoid contamination of freshwater with saline effluent. Disposal of dead/diseased animals in sanitary manner. Minimise leaks from water pumps, generators etc
4. Water intake and conveyance	Drawdown of groundwater supplies Water pollution problems impacting water quality	Water supplies from well-flushed supplies. Minimise use of groundwaters (although may be most suitable disease free water source).
5. Use of chemicals/water treatment	Potential impacts on workers health Water pollution Impacts on aquaculture product quality (e.g. chloramphenicol)	Use of approved chemicals according to standard practices. Reduce disease problems through preventative management, not chemicals. Education of workers in safe use/handling of chemicals.
7. Broodstock collection/supply	Loss of biodiversity caused by harvesting of wild stocks.	Fishing techniques that reduce damage to non-target stocks. Use of environmentally sound fishing techniques. Fish/shrimp stocks harvested within sustainable limits. Integrate marine broodstock fish harvesting with marine park management for protection/management of adult fish stocks. Hatchery techniques which maintain genetic diversity and appropriate selection programmes.

8. Feed and feed management in hatcheries	Deterioration in tank environment and poor effluent quality, leading to water quality impacts on surrounding environments	Use low pollution/nutritionally appropriate diets Implement effective feeding strategies Careful feed control, monitoring
9. Disease outbreaks and disposal of mortalities	Economic impacts on stock, product quality and native populations.	Implement preventative health management strategies (e.g. quarantine, isolation of infected tanks, maintain strict hygiene). Sanitary disposal of mortalities.
10. Operational failures	Sudden impacts caused by loss of stock and discharge of saline and hatchery water	Accommodating operational failures in system design and management procedures. Routine hatchery/nursery maintenance essential.
11. Labour force	Impacts on water quality and habitats due to increased population.	Provision of sanitary conditions for workers. Environmental awareness training for workers

Brackishwater pond culture

Checklist of environmental impacts and mitigation strategies for land-based brackishwater pond (shrimp, fish) aquaculture projects

Actions affecting environmental resources and values	**Potential environmental impacts**	**Potential mitigation strategies for negative environmental impacts**
A. Site selection		A. Appropriate site selection
1. Conflicts with other site users and interference in livelihoods of local communities	On and off-site damage to resources and social conflicts	Appropriate regional land use planning Consultation process Participation of local people in aquaculture projects Resettlements/compensation agreements
2. Selection of ecologically sensitive site	Potential loss of biodiversity and wetland habitat	Careful site selection and integration of aquaculture into integrated coastal management Management plan which identifies ecologically sensitive sites Habitat restoration, e.g. replanting of mangroves Maintain buffer areas around farm Prior assessments of impacts
3. Hazards to aquaculture from nearby pollution sources (e.g. agriculture, industry)	Water pollution from industry, agriculture affecting sustainability of aquaculture	Careful site selection Pre-treatment of water Pressure from aquaculturists to reduce pollution from other sectors
4. Typhoons, flooding, hurricanes	Damage to physical facilities and loss of stock and pond discharge	Careful site selection. Pond design taking account of extreme climatic events (e.g. pond dyke height to prevent flooding). Buffer zones for wind breaks (e.g. mangroves)
5. Water quality	Water quality deterioration caused by self-pollution from aquaculture effluent	Careful site selection in relation to carrying capacity. Management practices and effluent controls Strategic planning to keep number of farms within carrying capacity.
6. Selection of site with poor soil quality	Soils inappropriate for aquaculture, e.g. acid-sulphate soils.	Soil surveys to identify problem soils (acid sulphate, peat). Construction and design to minimise disturbance of problem soils.
7. Fish/shrimp seed availability	Potential impacts on biodiversity caused by over-harvesting of wild stocks. Lack of sustainability of aquaculture due to insufficient seed supply.	Careful assessment of requirements Development of hatcheries Sourcing of wild broodstock.

8. Disease problems	Potential impacts caused by presence of serious pathogens/disease problems	Disease surveys of existing farms to assess risk. Introduction of risk management strategies to reduce risk.
B. Farm design	B. Poor design can lead to a variety of environmental problems	B. Careful/appropriate design
1. Attention to problems A (1) to A(8) above	As above.	As above.
2. Socio-economic impacts	Social inequities leading to social unrest	Participation of local people in aquaculture projects. Understand socio-economic conditions prior to project, and ensure developments do not negatively impact local people.
3. Impacts due to infrastructure	Hydrological or salinity changes caused by poor design	Roads, canals and other infrastructure should not block tidal flow. Maintain buffer areas
4. Aesthetics	Aesthetic impacts	Development of green buffer zones
C. Farm construction	Poor construction practices can lead to various environmental problems	C.
1. Site clearance	Damage to terrestrial and wetland habitats and water quality problems during construction	Maintain buffer areas. Ensure site disturbance is limited to immediate construction area Roads, canals etc should be constructed to minimise vegetation clearance. Sediments removed during construction should be disposed of in suitable locations. Excavation/disturbance of potential acid-sulphate soils should be minimised. Regulatory requirements should be followed during clearance and disposal of soils and vegetation.
2. Infrastructure development (access roads, canals)	As above	As above.
3. Obtaining filling materials	Removal of filling materials required for dykes, foundations, access roads may impact habitat, water quality	As above
4. Dyke compaction	Poorly compacted dykes will lead to seepage problems.	Dyke compaction testing during construction.
5. Labour, worker safety	Possible impacts on environment caused by labour force (e.g. noise, groundwater drawdown, sewage)	Provision of suitable infrastructure to support labour.

D. Farm operation and management		
1. Solid waste disposal	Impacts on surrounding land-use/wetland habitats	Non-organic, solid waste materials should not be dumped into mangrove forests etc, but disposed of safely.
2. Waste water/effluent discharge	Impacts on local water quality and sediments	Use of settlement basins. Environmentally sound disposal of pond bottom sediments. Water exchange minimised and water recycling Discharge of pone effluent into areas with adequate tidal flow. Disposal of dead/diseased animals in sanitary manner. Minimise leaks from water pumps, generators etc Construction of artificial wetlands for effluent clean up. Secondary aquaculture, e.g. of filter feeding fish or molluscs. Salination avoided by buffer zones, pond liners, pond dyke compaction and site selection on low seepage soils. Sandy soils require special liners to eliminate seepage.
4. Water intake and conveyance	Potential impacts on hydrology from poorly flushed tidal creeks. Drawdown of groundwater supplies Water pollution problems impacting water quality	Water supplies from well-flushed supplies. Reduce or eliminate use of groundwaters. Site selection to reduce/eliminate the need for use of freshwater in brackishwater ponds.
5. Harvesting and pond bottom management	Stirring up and discharge of pond bottom sediments leading to water pollution. Sedimentation caused by inappropriate disposal of pond sediment.	Harvesting techniques which do not stir up bottom sediments. Partial harvesting Settlement pond to catch and trap pond sediment. Sediment management techniques which do not require sediment removal (e.g. ploughing, drying). Sediment disposal away from waterways. No flushing of pond sediments with water.
6. Use of chemicals/water treatment	Potential impacts on workers health Water pollution Impacts on aquaculture product quality	Use of approved chemicals according to standard practices. Reduce disease problems through preventative management, not chemicals. Education of workers in safe use/handling of chemicals.
7. Seed collection/supply	Loss of biodiversity caused by harvesting of wild stocks.	Improved fishing techniques that reduce damage to non-target stocks. Development of hatcheries.
8. Feed and feed management in intensive culture	Deterioration in pond environment and water quality impacts on surrounding	Use low pollution/nutritionally appropriate diets Implement effective feeding strategies

	environments	Careful feed control, monitoring
9. Disease outbreaks and disposal of mortalities	Economic impacts on stock, product quality and native populations.	Implement preventative health management strategies. Sanitary disposal of mortalities.
10. Operational failures	Sudden impacts caused by loss of stock and discharge of saline and nutrient rich pond water	Accommodating operational failures in system design and management procedures. Routine dyke maintenance essential. Dykes should be designed to withstand flood events.
112. Labour force	Impacts on water quality and habitats due to increased population.	Provision of sanitary conditions for workers. Environmental awareness training for workers
E. Critical environmental review criteria?		
- how to assess/judge impact		

Coastal cage or pen culture

Checklist of environmental impacts and mitigation strategies for sea-based intensive fish cage/pen aquaculture projects

Actions affecting environmental resources and values	**Potential environmental impacts**	**Potential mitigation strategies for negative environmental impacts**
A. Site selection		A. Appropriate site selection
1. Conflicts with other site users and interference in livelihoods of local communities	On and off-site damage to natural resources and social conflicts	Appropriate regional land use planning Consultation process Participation of local people in aquaculture projects Resettlements/compensation agreements
2. Selection of ecologically sensitive site	Potential loss of biodiversity.	Careful site selection and integration of aquaculture into integrated coastal management Management plan which identifies ecologically sensitive sites Maintain buffer areas around farm Prior assessments of impacts
3. Hazards to aquaculture from nearby pollution sources (e.g. agriculture, industry)	Water pollution from industry, agriculture affecting sustainability of aquaculture	Careful site selection Pre-treatment of water Pressure from aquaculturists to reduce pollution from other sectors
4. Typhoons, flooding, hurricanes	Damage to physical facilities and loss of fish stock.	Careful site selection. Pond design taking account of extreme climatic events (e.g. pond dyke height to prevent flooding). Buffer zones for wind breaks (e.g. mangroves)
5. Water quality	Water quality deterioration caused by self-pollution from aquaculture effluent	Careful site selection in relation to carrying capacity. Management practices and effluent controls Strategic planning to keep number of farms within carrying capacity.
6. Fish seed	Potential impacts on biodiversity caused by over-harvesting of wild stocks. Lack of sustainability of aquaculture due to insufficient seed supply. Introduction of exotic species may impact on indigenous species	Careful assessment of requirements prior to farm development Development of hatcheries Sustainable harvesting practices for wild stocks Prior assessment of impacts from introductions of new species.
7. Disease problems	Potential impacts caused by presence of serious pathogens/disease problems	Disease surveys of existing farms to assess risk. Introduction of risk management strategies to reduce risk.

B. Farm design	B. Poor design can lead to a variety of environmental problems	B. Careful/appropriate design
1. Attention to problems A (1) to A(7) above	As above.	As above.
2. Socio-economic impacts	Social inequities leading to social unrest	Participation of local people in aquaculture projects. Understand socio-economic conditions prior to project, and ensure developments do not negatively impact local people.
3. Interference with navigation, traditional users	Impacts on existing uses	Site farms in ways which do not impact traditional uses. On-shore infrastructure development in ways which roads, buildings doe not cause environmental impact. Maintain buffer areas between farms and other uses
4. Aesthetics	Aesthetic impacts	Development of buffer zones Low profile cages, minimise use of unsightly structures.
C. Farm construction	Poor construction practices can lead to various environmental problems	C.
1. Siting	Impacts on benthos during construction and disturbance of wildlife	Maintain buffer areas. Ensure site disturbance is limited to immediate construction area
2. Infrastructure development (access roads, boats)	As above	As above.
3. Labour, worker safety	Possible impacts on environment caused by labour force (e.g. noise, groundwater drawdown, sewage)	Provision of suitable infrastructure to support labour.
D. Farm operation and management		
1. Solid waste disposal	Impacts on benthos, wildlife.	Non-organic, solid waste materials should be disposed of safely. Culture site may be rotated to prevent extreme local impact, improve growing conditions, and allow for periodic recovery
2. Waste water/effluent discharge	Impacts on local water quality and sediments	Efficient feeding practices (minimise use of trash fish). Site farms in areas with adequate tidal flow. Disposal of dead/diseased animals in sanitary manner on shore (e.g. bury in lime pits). Minimise leaks from water pumps, boat engines, generators etc Secondary aquaculture, e.g. of filter feeding molluscs, seaweeds in vicinity of cages.

4. Harvesting and post-harvest	Discharge of harvesting waster water causing water pollution	Harvesting techniques that capture wastes (blood, viscera etc).
5. Use of chemicals	Potential impacts on workers health Water pollution Impacts on aquaculture product quality	Use of approved chemicals according to standard practices. Reduce disease problems through preventative management, not chemicals. Education of workers in safe use/handling of chemicals.
6. Seed collection/supply	Loss of biodiversity caused by harvesting of wild stocks. Impacts on wild stocks through escapes of farmed stocks.	Improved fishing techniques that reduce damage to non-target stocks. Development of hatcheries. Siting in ways that minimise storm damage. Prior assessments of introductions of exotics. Adherence to ICES/FAO Codes of Practice (Turner 1988)
8. Feed and feed management in intensive culture.	Deterioration in pond environment and water quality impacts on surrounding environments	Use low pollution/nutritionally appropriate diets Implement effective feeding strategies Careful feed control, monitoring
9. Disease outbreaks and disposal of mortalities	Economic impacts on stock, product quality and native populations.	Implement preventative health management strategies. Sanitary disposal of mortalities. Quarantine procedures/health certification for introduced fish stocks
10. Operational failures caused by storms	Sudden impacts caused by loss of fish stock.	Accommodating operational failures in management procedures. Routine checking of nets, moorings. Farm structures designed to withstand storm events.
11. Boats, infrastructure support	Water pollution from boat engines	Use of appropriate fuel and maintenance of engines. Minimise leakage from oil, petrol
12. Labour force	Impacts on water quality and habitats due to increased population.	Provision of sanitary conditions for workers. Environmental awareness training for workers
13. Predators and wildlife	Wildlife disturbance Predators causing damage to fish stocks. Shooting of predators by farmers	Select sites with low numbers of predators. Implement management systems to reduce impacts (e.g. guards, double nets). Environmentally sound capture, removal of predators.
E. Critical environmental review criteria?		

Coastal mollusc culture

Check list of environmental impacts and mitigation strategies for sea-based extensive seaweed and mollusc aquaculture projects

Actions affecting environmental resources and values	**Potential environmental impacts**	**Potential mitigation strategies for negative environmental impacts**
A. Site selection		A. Appropriate site selection
1. Conflicts with other site users and interference in livelihoods of local communities	Social conflicts	Appropriate regional water use planning Consultation process Participation of local people in aquaculture projects Resettlements/compensation agreements Involve local resource users in aquaculture
2. Selection of ecologically sensitive site	Potential impacts on biodiversity (e.g. corals or seaweed).	Careful site selection and integration of aquaculture into integrated coastal management Management plan which identifies ecologically sensitive sites Habitat restoration, e.g. seaweed culture suitable on degraded coral reef areas. Maintain buffer areas around farm Prior assessments of impacts
3. Hazards to aquaculture from nearby pollution sources (e.g. agriculture, industry)	Water pollution from industry, agriculture affecting sustainability of aquaculture	Careful site selection Pressure from aquaculturists to reduce pollution from other sectors
4. Typhoons, hurricanes, storm damage	Damage to physical facilities and loss of stock (an important problem for sea-based aquaculture)	Careful site selection. Farm design, taking account of extreme climatic events.
5. Water quality	Water quality and benthic changes caused by aquaculture	Careful site selection in relation to carrying capacity. Management practices Strategic planning to keep number of farms within carrying capacity. Extensive seaweed and mollusc farms are net removers of nutrients from coastal systems and can contribute to water quality improvement).
B. Farm design	B. Poor design can lead to a variety of environmental problems	B. Careful/appropriate design

1. Attention to problems A (1) to A(5) above	As above.	As above.
2. Socio-economic impacts	Social inequities leading to social unrest	Participation of local people in aquaculture projects. Understand socio-economic conditions prior to project, and ensure developments do not negatively impact local people. Low cost, extensive aquaculture potentially appropriate for artisanal fishers
3. Infrastructure development	Structures (e.g. guard house, worker accommodation) may lead to negative impacts on habitat	Appropriate siting of structures.
4. Aesthetics	Aesthetic impacts	Selection of 'low value' sites without tourism of fishery value. Minimise use of unsightly sea-based structures.
C. Farm construction	Poor construction practices can lead to various environmental problems	C.
1. Site clearance	Damage to corals and existing habitat. Water quality problems during construction	Ensure site disturbance is limited to immediate area. Do not site farms on high value corals. Regulatory requirements should be followed during clearance.
2. Infrastructure development (guard houses, accomodation, processing areas)	As above	As above.
3. Labour, worker safety	Possible impacts on environment caused by labour force (e.g. noise, sewage, walking on reef flats)	Provision of suitable infrastructure to support labour. Limiting movements as far as possible to the construction site
D. Farm operation and management		
1. Solid waste disposal	Impacts on benthos and coral habitats	Non-organic, solid waste materials should be disposed of safely on-shore. Careful disposal of fouling organisms from molluscs/farm structures. Rotation of farm locations to avoid accumulation in specific areas.
2. Waste water/effluent discharge	No impacts from seaweed culture. Particulates may settle below mollusc farms .	Polyculture (mollusc, fish) can be promoted to improve productivity of water column. Site rotation. Keeping within carrying capacity.

3. Harvesting		
4. Use of chemicals	Minimal use in seaweed culture and mollusc culture.	Use of approved chemicals according to standard practices (including antifouling agents on structures). Education of workers in safe use/handling of chemicals.
5. Seed collection/supply	Introduction of exotic species can lead to negative impacts on biodiversity.	
6. Disease outbreaks and disposal of mortalities	Economic impacts on stock, product quality and native populations.	Implement preventative health management strategies. Maintain stocking density within carrying capacity.
7. Operational failures	Sudden impacts caused by storm damage	Siting in areas not prone to storm damage.
8. Labour force	Impacts on water quality and habitats due to increased population.	Provision of sanitary conditions for workers. Environmental awareness training for workers

Appendix 6:

Nutrient loads from aquaculture operations

Release of Nutrients from Aquaculture to Environment

If the nutrient composition of both feed and culture product is known, and food conversion is known or can be estimated, then the release of nutrients to the environment can be calculated quite simply (Box A6.1). Table A6.1 gives a range of figures calculated in this way for intensive shrimp farming in Thailand using a typical commercial pelleted feed.

Box A6.1 Example calculation of nutrient loading from intensive aquaculture

P content of trash fish 0.5%
P content of fish produced 0.3%
N content of trash fish 1.0%
N content of fish produced 1.2%
(all wet weight)
food conversion ratio 6:1

then per tonne of fish produced:

P in fish produced = 0.003*1000 = 3kg
P in food given = 0.005*6*1000 = 30kg
P released to environment = 30-3 = 27kg

N in fish produced = 0.012*1000 = 12kg
N in food given = 0.01*6*1000 = 60kg
N released to environment = 60-12 = 48kg

Note that these figures should be adapted according to particular species, and food conversion.

It is also important to understand the fate of the nutrients released in both space and time. They may remain within the farm system, be deposited in sediments, or enter the wider environment in solution or as fine particles. The quantities may vary greatly over the production cycle, and this can be used to improve the effectiveness of environmental management measures. The following provides a brief overview of what is known about these issues.

Table A6.1
Nitrogen, phosphorus and organic solids (kg) produced per tonne of shrimp in intensive production systems

FCR	Organic matter	Nitrogen	Phosphorus
1.0	500	26	13
1.5	875	56	21
2.0	1250	87	28
2.5	1625	117	38

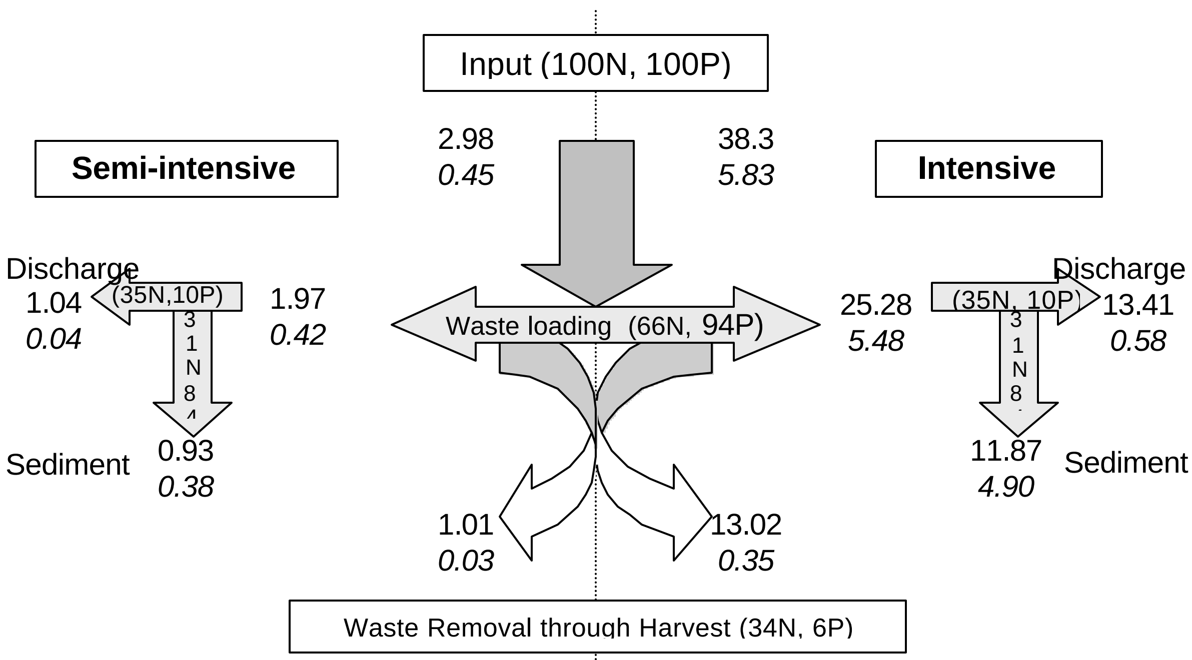
Pond Culture

Significant quantities of nutrients and chemicals are released to environment from pond aquaculture, though generally at relatively low concentrations. The quantity and quality of these releases are very variable between species and culture systems. Dissolved material from farm effluent enters the water column and may be widely distributed. Solid wastes on the other hand accumulate mainly in the pond bottom, or in the immediate vicinity of the farm. More nitrogen is released to the water column than phosphorus, most of which accumulated into the sediment. The typical fate of nutrients applied in an intensive shrimp pond is shown in the figure A6.1. However, the application of different management practices will affect significantly the proportion of wastes which end up in sediments, water column and wider environment.

Aquaculture effluent may also carry bacteria or disease carrying microorganisms. These are rarely harmful to humans, though they may represent a threat to other farmers or wild fish.

Various studies have shown that the amount and concentration of effluent from aquaculture is far below that of many other domestic, agricultural and industrial sources. The quality of shrimp pond effluent is compared with domestic sewage in the table A6.2. Standard domestic wastewater treatment is reasonably effective at removing solids and BOD but less efficient at removing N and P. Even after secondary treatment, domestic effluent is of significantly lower quality than that from intensive aquaculture except in respect of solids. (Beveridge et al. 1997).

Figure A6.1. Fate of nutrients from 1 ha semi-intensive and intensive shrimp culture ponds



Keys: N- normal font; and P- *italic*. Open figures are in MT ha^{-1} yr^{-1}. Figures in parenthesis and arrows indicate percentage

(information source: Briggs and Funge-Smith 1994; Muthuwan 1991; Satapornvit 1993).

Cage Culture

While much information relating to nutrient release, distribution and assimilation is available for temperate fin-fish culture, that relating to tropical and sub-tropical environments is scarce. While the quantity of nutrients released, and their physical, chemical and biological characteristics are likely to be similar in these different zones, the nutrient assimilation capacity is much higher in tropics. Angel et al (1995,1996) suggested that the capacity of sediments to absorb organic matter may be 3-4 times higher in warm than in temperate water.

Table A6.2. Characteristics of shrimp ponds effluent in comparison with domestic sewage (mg l^{-1}) (adapted from Beveridge et al. 1997)

Effluent characteristics (mg l^{-1})	shrimp pond effluent	Domestic water		
		Untreated	Primary treatment	Secondary treatment
BOD_5	4.0-10.2	300	200	30
Total N	0.03-3.4	75	60	40
Total P	0.01-2.0	20	15	12
Solids	30-225	500	-	15

A typical nutrient budget for finfish cage culture is presented in Figure A6.2. 80% of the food provided may be released to the environment in one form or another.

The effect of solids released from finfish cage culture includes a reduction in redox potential, increase in sedimentary C and N, and increase in H_2S, CH_4, and BOD_5 in the sediment. Major changes occur in the community structure of benthic fauna beneath the cages or rafts (Tsutsumi 1995). With the increase of pollutants, faunal dominance commonly changes from mollusks to polychaetes. Organic enrichment from marine cage-pen culture may contribute to the development of infectious disease, as deteriorated environment weakens the immune systems of the confined fish (Kusuda 1990).

Box A6.2 An example of carbon loading from tropical cage culture

Estimated the flux of particulate matter released from fish cages:

- 4.5 g C m^{-2} d^{-1};
- Area (approx.) 17000 m^2 under the fish farm.

(from a study by Angel et al. (1996) in the Gulf of Aqaba)

Raft or Rack Culture of molluscs

Additional food is not provided in mussel, scallop, or oyster culture, and since they feed on plankton and detritus, they operate as natural biofilters, resulting in a net overall reduction of nutrients in the water. However, if grown in dense culture, they *concentrate* nutrients through the production of faeces and pseudofaeces, and the release of ammonia and other dissolved metabolic products. This may cause local enrichment. Deposited organic matter from mollusc farms stimulates microbial activity, thus increasing BOD_5, sulfate reduction and

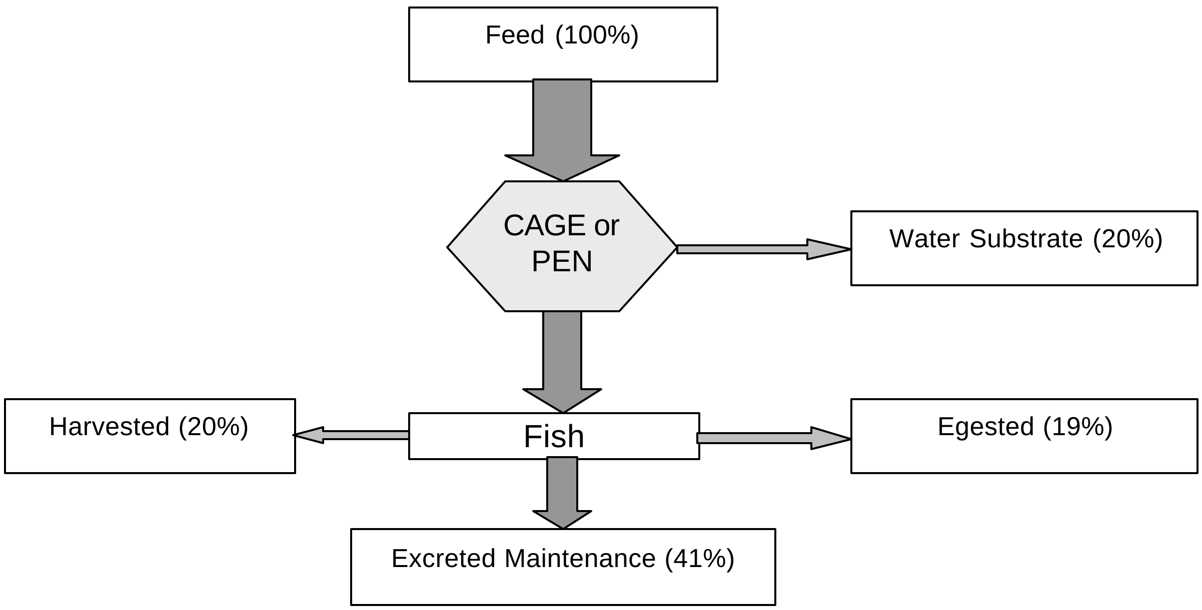
Box A6.3. Organic matter loading from mussel and oyster culture

- An individual mussel may produce 5.7 mg organic matter per day
- A typical oyster rack with 420,000 oysters can generate 16 t of faecal and pseudofaecal material during a nine month culture period

(Dankers and Zuidema 1995).

denitrification (Nunes and Parsons 1998). The release of ammonia may result in downstream plankton blooms. As with almost all forms of agriculture and aquaculture molluscs are 10-20% efficient at converting nutrients, implying 80-90% nutrient "regeneration".

Figure A6.2 Estimated average flux of nutrients in a fish cage
(Source: Nunes and Parsons 1998)



Assimilation of Nutrients

Molluscs

Culture of molluscs may help in removal of organic matter, while also serving as an important food source for a range of organisms, either directly, or indirectly by providing shelter and creating space for associated organisms. However, most of the organic matter filtered by mussels is deposited as pseudofaeces (see above). Figure A6.3 shows the mass balance of phytoplankton and detritus filter feeding by mollusks.

A problem with the high nutrient assimilation capacity of molluscs is the human health concern associated with accumulation of pathogens or toxic substances (Csavas 1993).

Box A6.4 Reported filtration rates and nutrient assimilation by molluscs.

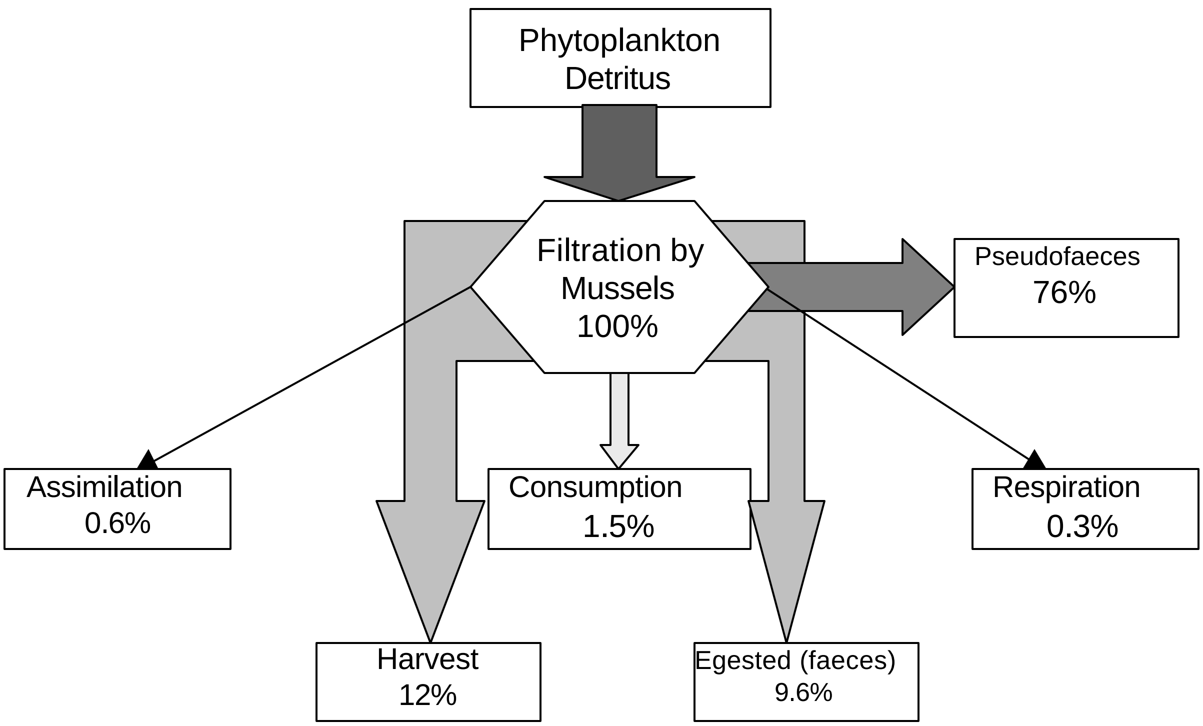
- An individual mussel can filter between 2 and 5 litres of water per hour*;
- A rope of mussels can filter more than 90,000 litres per day*;
- Oyster may remove 94% of nitrogen and 48% of suspended solids**;
- Green mussel can remove 68% of total nitrogen***
- Seaweed can remove 32% of N and 19% of P****

*Nunes and Parsons 1998; **Ryther et al 1995; ***Jones and Preston 1996.
Note Despite this impressive “instant removal” molluscs are unlikely to actually assimilate more than 10-20% of total nutrients, and the rest will be regenerated as wastes of one form or another

Seaweeds

Seaweeds are net nutrient removers from aquatic ecosystems. Seaweed can also absorb nutrients that can not be absorbed by molluscs (Chandrkrachang et al. 1991). The main problem associated with seaweed farming is the probability of heavy metal and industrial discharge accumulation (FAO/NACA 1995).

Figure A6.3 Mass balance of phytoplankton and detritus filter feeding by mussel
(information source: Dankers and Zuidema 1995)



Additional information

Table A6.3. Food, faecal and urinary wastes

Type	***Feed***	***Faecal***	***Urinary***	**Reference**
Salmon cage farm	5-10%			Juell, 1991
Fish and crustaceans		230-400g/ kg food		Beveridge et.al., 1991
Do			60% of TKN to the environment	Barg, 1992

Table A6.4. Nutrient budget in semi-intensive and intensive 1 ha shrimp ponds, Thailand

	Semi-intensive	***Intensive***
Production/ha/year (MT)	1.0	9.0
FCR	1.4:1	2:1
Nutrient input in production (t/yr)		
N	2.98	38.3
P	0.45	5.83
Nutrient removal in harvest (t/yr)		
N	2.66	23.99
P	0.18	1.59
Waste loading (kg/yr)		
N	29	1434
P	27	124
Waste loading (kg/t shrimp harvest/yr.)		
N	9.7	53.1
P	9.0	15.7
Waste loading (kg/ha shrimp harvest/yr.)	275.5 (discharge)45% 161.3 (sediment)26%	Muthuwan, 1991
N	66.4 (12%) 237 (37%)	Satapornvit, 1993
	285 (35%) 245 (31%)	Briggs and FungSmith, 1994
	50 (discharge)26% 45 (sediment)24%	Muthuwan, 1991
P	13 (14%) 38 (36%)	Satapornvit, 1993
	29 (10%) 243 (84%)	Briggs and Fung-Smith, 1994

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Appendix 7:

Calculating nutrient concentrations in receiving waters

Case studies and worked examples

1. **Assessment of impacts of nutrients from an intensive shrimp pond on water quality in a coastal lagoon.**

2. **Assessment of impacts of nutrients from an intensive shrimp farm on estuary water quality**

3. **Assessment of impacts of nutrients and suspended solids from tropical marine fin-fish cage culture**

Assessment of impacts of nutrients from an intensive shrimp pond on water quality in a coastal lagoon.

adapted *from GESAMP (IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP) 1996. Monitoring the Ecological Effects of Coastal Aquaculture Wastes. FAO. Reports and Studies No.57. 38 p.p.*

An intensive shrimp (*Penaeus monodon*) farm using 16 ponds (2500 m^2 each) is proposed for construction in the supratidal area of a coastal region adjacent to a 150ha coastal lagoon. The total pond area will occupy about 4.5 ha with additional land use for infrastructure (approx. 15% of the pond area). The units are to be constructed above sea level and water supplied by pumping from a sea-water intake located 60 m offshore. Effluents are returned to the lagoon via run-off canals where they disperse along the shore. Daily water exchange is by partial draining and refilling with pumped sea-water at 5-10% of total volume early in the production cycle, increasing to between 25 and 30% by the end of the four month production period.

Nutrient loads.

Total planned shrimp production is approximately 40 t y^{-1} derived from 2 production cycles per year with an average output of about 5 t ha^{-1} $cycle^{-1}$. Feeds used amount to 10 t ha^{-1} $cycle^{-1}$. Total nutrient loadings can be estimated from figures on shrimp production and feed input.

> Shrimp feed is estimated as 76.0 g N/kg and 14.2 g P/kg
> Harvested shrimp is estimated as 33.9 g N/kg and 4.0 g P/kg.
>
> With a Food Conversion ration(FCR) of 2:1, these figures imply a total waste load of 118.1 kg N/tonne of shrimp production and 24.4 kg P/tonne of shrimp production.

Estimates of the fate of nitrogen and phosphorus in shrimp ponds suggest that around 85% of the phosphorus and around 50% of the nitrogen will be lost to the sediments (or lost from the ponds as nitrogen gas in the case of nitrogen). The remaining amount will be discharged from the ponds as effluent.

> Based on these figures, the farm discharges around 2362 kg N (40*118.1*0.5) and 146.4 kg P (40*24.4*0.85) per year.

Note that the figures would be higher if the farm was to flush pond bottom sediment into the lagoon. However, the farm plans to dispose of dry pond bottom sediments away from waterways on nearby disused land thus reducing total nutrient and organic loads.

Hydrology of the lagoon.

The shrimp farm water supply and discharge point is a coastal lagoon. The lagoon covers a surface area of 150ha and has a mean depth of 6m at the high tide mark. There are two small freshwater streams that discharge small amounts of freshwater into the lagoon, but overall amounts are small. The tidal amplitude is 1.5m with two exchanges of water per day. The lagoon water appears to be well mixed, and based on these figures the water exchange rate can be calculated as once per two days.

Lagoon ecology

The lagoon is an important fish nursing area with extensive seagrass beds. The water is clear and water quality surveys during the rainy and dry seasons have shown that nutrient levels are low. There are also extensive coral reef flats just outside of the lagoon, and the local environmental authority are concerned that the nutrients discharged from the shrimp farm should not negatively impact on water quality.

No environmental quality standards (EQS) have been set for the lagoon, but a literature review indicates tentative seagrass standards as follows:

(a) no increase in suspended solids;
(b) light levels should not normally fall below 10% of surface levels at 2m; and
(c) mean total N not to exceed 500 ug/l.

Tentative EQS for coral reef habitats in other regions are that ambient nitrogen and phosphorus concentrations should not change by more than 5% of pre-development ambient concentrations.

Nutrient analyses carried out in four scoping surveys indicate mean nutrient levels of 25 ug/l total phosphorus and 150 ug/l total nitrogen in the lagoon water.

Impacts on nitrogen and phosphorus levels in the lagoon.

The assessment examines the effect of the farm on nitrogen and phosphorus levels in the lagoon using the following equation:

$$\Delta P = \frac{P_D}{V x T_w}$$

Where:
ΔP = Predicted increase in nutrient concentration (mg/m^3)
P_D = Daily nutrient load from the shrimp farm (mg/day)
T_w = Water exchange (times/day = reciprocal of flushing rate)
V = Volume of lagoon at high tide (m^3)

(i) Calculations estimating the increase in total nitrogen in the lagoon water are as follows:

P_D = 2362×10^6 mg N/ 365 = 6.47×10^6 mg N/day
T_w = 0.5
V = $150 \times 10{,}000 \times 6\ m^3 = 9 \times 10^6\ m^3$

Therefore, ΔP = 1.44 mg N /m^3 (or 1.44 ug/l) *(ii) Calculations estimating the increase in total phosphorus in the lagoon water are as follows:*

P_D = 146.4×10^6 mg N/ 365 = 0.40×10^6 mg N/day
T_w = 0.5
V = $150 \times 10{,}000 \times 6\ m^3 = 9 \times 10^6\ m^3$

Therefore, ΔP = $0.09\ mg/m^3$ (or 0.09 ug/l)

Compared to ambient levels, these calculations predict a change in mean nutrient levels of less than 0.5% in total phosphorus and 1.0% in total nitrogen. The calculations therefore suggest the proposed shrimp farm development will not cause significant impacts on nutrient concentrations within the lagoon, or adjacent coral habitats.

Related issues

Based on the tentative environmental quality standards (QS) for seagrass beds noted above, which raises concern over impacts of sedimentation on seagrass beds, the regulatory authority requests the shrimp farm to install a settlement pond to trap suspended solids during shrimp harvesting, and places a ban on flushing of pond sediments to the environment. Pond sediments are required to be removed from the pond after drying after harvest, and disposed of on dry land away from local waterways. The farm locates a suitable area of disused land for safe disposal of this pond sediment. It also introduces plastic liners on the pond walls to minimise erosion of earthen pond walls during shrimp grow-out operations.

Recommended monitoring programme

Based on the above, the regulatory authority requests the farm to undertake a water quality monitoring program in the lagoon. The water quality monitoring will include suspended solids, water turbidity and nutrient concentrations to be carried out initially four times per year.

Seagrass beds could be stratified into areas of high, medium and low probability of impact based on proximity to the discharge point. In annual sampling surveys, random sites should be selected within each stratum. Photographs of seagrass should be taken at the time of monitoring, and qualitative diver observations of site conditions and faunal abundance should be recorded.

Two years after the farm has reached maximum production, the scale of the monitoring programme should be assessed.

Assessment of impacts of nutrients from an intensive shrimp farm on estuary water quality

Adapted from an impact assessment of a proposed shrimp farm on the Ruvu river in Tanzania
AIT, 1995. Environmental impact assessment of a proposed prawn-farm project in Tanzania. Report to the Norwegian Agency for Development Cooperation (NORAD), October 1995. Asian Institute of Technology, Pathum Thani, Thailand. 52 p.

A medium scale shrimp farm, consisting of 40 ponds each of 4 hectares is planned to be built on the landward fringe of mangrove adjoining a medium sized river estuary. The estuary is important to local artisanal fishers, and is also a source of wild shrimp seed which will be used for the farm during the startup phase and before a proposed hatchery comes on line. The mangrove adjacent to the estuary is an important source of firewood, poles, and shellfish for poor local people.

Water source and discharge

A tidal creek, south of the main river outfall, will be the primary source of seawater. A canal of 2 to 2.5 km in length will be constructed from near the head of the creek to the seaward end of the farm site. The creek contains water of nearly full seawater concentration (approximately 35ppt). An inlet canal for river water, intended to dilute the seawater to optimal working salinity during the dry season, will be constructed by deepening the bed of an existing creek, which presently contributes to draining part of the farm area's upper reaches into the river.

Pond effluent will be discharged to the river through a channel similar to the one made for intake of river water, except that the outfall channel will enter the river about 1 km downstream of the intake channel. The outfall is several km from the river mouth through several meandering loops. The river flow varies seasonally, with monthly means typically ranging from 3 - 41 cubic meters per second in the dry and wet seasons respectively.

The discharge plan remains to be finalized pending technical consultation to be engaged by the farm, and consideration of issues discussed below.

Calculation of loadings, effluent concentrations and impact on river salinity

The feasibility study and project description provided little information on pond water management (such as water exchange rate). This varies widely between different countries and indeed farms, and has a major effect on the nature and concentration of the effluents discharged. Reduced water exchange results in lower quantities of effluent carrying higher nutrient concentrations, and greater retention of nutrients in pond sediments. Intensive farms in Thailand have greatly reduced their water exchange rates in recent years.

A simple spreadsheet was created to make estimates of nutrient and salinity dilution in the receiving water based on a range of assumptions about water turnover rate and other parameters. In addition, the area of mangrove required to assimilate nutrients was calculated using the assimilation estimates presented in Appendix 6 and 8. It was assumed that mixing of the effluent with the river water was simple and complete – in other words no attempt was made to model the effluent plume and its dispersion in the river, since impacts were not expected to be severe. A summary of the spreadsheet assumptions, and sample output is presented below.

1. Production parameters and other standard assumptions	
area (ha)	160
Stocking rate Post-larvae (PL)/ha	60,000
survival %	60%
harvest weight (g)	30
crops per year	2.4
Food conversion ratio	1.6
N content feed	7%
N content shrimp	3%
P content feed	1%
P content shrimp	0.2%
Dry season river flow (m^3/sec)	3
Wet season river flow (m^3/sec)	40
Pond effluent salinity	23ppt
river salinity	5ppt
Nitrogen assimilation capacity of mangrove (t/ha/yr)	0.219
Phosphorus assimilation capacity of mangrove (t/ha/yr)	0.02

2. Calculated nutrient production (see box A4.1 for sample calculation)	
annual production (t)	*415*
food requirement (t)	*664*
total N waste (t)	*34.01*
total P waste (t)	*5.81*

3. Estimated effluent concentration of nitrogen and phosphorus under different water management regimes
(assumptions normal font, *calculated values in italics*)

management system	**typical**	**semi-closed**	**closed**
proportion of N in effluent	23%	15%	10%
proportion of P in effluent	65%	30%	10%
N released in effluent	*7.82*	*5.10*	*3.40*
P released in effluent	*3.77*	*1.74*	*0.58*
water depth (m)	1.4	1.4	1.4
water turnover rate per day	12%	6%	1%
pond utilization	80%	80%	80%
Total volume of effluent (m3 pa)	*62,791,680*	*31,395,840*	*5,232,640*
N concentration mg/l(avg)	*0.12*	*0.16*	*0.65*
P concentration (avg)(mg/l)	*0.06*	*0.06*	*0.11*

4. Estimated area of mangrove required to assimilate nutrients			
management system	**typical**	**semi-closed**	**closed**
area of mangrove to assimilate N	*35.72*	*23.29*	*15.53*
area of mangrove to assimilate P	*188.70*	*87.09*	*29.03*

5. Estimated average nutrient concentration (mg/l) in river water			
management system	**typical**	**semi-closed**	**closed**
N dry season	*0.083*	*0.054*	*0.036*
P dry season	*0.040*	*0.018*	*0.006*
N wet season	*0.006*	*0.004*	*0.003*
P wet season	*0.003*	*0.001*	*0.000*

6. Impact on river salinity (ppt) without farm: 5ppt			
management system	**typical**	**semi-closed**	**closed**
dry season	20	13	6
wet season	6	6	5

It was concluded that the most significant impact was the effect on salinity in the river in the dry season, and that this would warrant further investigation in terms of possible local ecological impacts. Use of closed or semi-closed system minimized this impact.

Note

A typical or traditional water regime involves relatively high rates of water exchange throughout the cycle to maintain optimal water quality

Semi closed systems use significantly less water exchange – usually only as required, and mainly toward the end of the production cycle when larger quantities of food are being added, and the total stocking rate is high. The reduced water turnover is compensated using more intensive and carefully timed aeration.

Closed systems also use a reduced water turnover regime, but in addition, settle and sometimes treat (with for example chlorine) the effluent water before returning to a reservoir for re-use.

Appendix 8

Environmental capacity

Introduction

Conditions for achieving environmental sustainability include "holding waste emissions within the assimilative capacity of the environment without impairing it". Environmental capacity models have been used to attempt to translate these concepts into practical siting and management guidelines for coastal aquaculture.

There are four components to environmental capacity relevant to aquaculture operations:

- the dispersal and dilution of nutrients in the receiving water;
- the assimilation of these nutrients in the water column or sediments;
- the effects that the absolute concentrations of nutrients, and their assimilation, have on resources or ecosystem integrity and functioning;
- environmental quality standards – which may be based on nutrient concentrations themselves; or the wider physical and ecological impacts of these concentrations.

A practical definition of environmental capacity could therefore be:

> *the total nutrient loading (or removal) which can be sustained in a particular defined area without leading to the breach of environmental quality standards.*

In practice this may refer to the rate at which nutrients are added without triggering eutrophication; the rate of organic flux to the benthos without major disruption to natural benthic processes; or the rate of dissolved oxygen depletion that can be accommodated without mortality of the indigenous biota" (GESAMP, 1996a). The use of environmental capacity and methods of application are discussed in detail by GESAMP (1986) and by Barg (1992).

It is important to distinguish this approach from those based on some assumed relationship between aquaculture production (measured for example in mt/yr for a particular area, or mt/yr/km of coast) and environmental quality. Beveridge (1996) for example defined environmental capacity in relation to aquaculture as *"aquaculture production that can be sustained by an environment within certain defined criteria".* These are more properly understood as "aquaculture carrying capacity" estimates, and imply a fixed relationship between nutrient production and aquaculture production rate. However, as shown in Appendix 6, relatively simple changes in management practice can dramatically change this relationship. It is therefore preferable to work with loadings (which can in any case be easily assessed) rather than production rate.

Factors likely to affect assimilative capacity

Some of the factors that might affect the assimilative capacity of coastal environments for shrimp culture, and which show the complexity of such analyses in multiple use coastal systems, are shown in Table A8.1.

Sector considerations

There is little point in examining environmental capacity in relation to aquaculture in isolation. Aquaculture is just one contributor (and in most cases a minor contributor) to nutrient and sediment loadings in estuaries, lagoons, and bays. Ideally environmental capacity estimates should be undertaken as part of a higher level integrated coastal or watershed management initiative, so that any incentives or controls can be applied to the sector(s) where they are likely to be most cost effective.

Such an approach is called for in so called *Integrated Environmental Impact Assessments,* which consider the absorption capacity of the whole coastal resource system, including all the various economic development activities. In the long term such approaches may be more cost-effective and more acceptable to all concerned.

Table A8.1: Some factors to be considered in determining the environmental capacity of coastal environments

(adapted from Phillips, 1994)

Important Factors	Environmental Significance
culture method/system	• management/system design influence amount of effluent reaching receiving water body; • increased effluent load with intensification.
pond or cage area	• increased pond or cage area can lead to greater water use and increased effluent load; • where ponds or cages cover a large area, then possible changes in local water quality, and absorptive capacity of local environment may occur.
water exchange in receiving waters	• increased water exchange leads to better flushing of pond effluent and increasing assimilative capacity.
Presence of conflicting water 'users'	• pollution from industry, agriculture, domestic sources reduces assimilative capacity of water body, leaving lower capacity for aquaculture.
Sensitivity of water body to effluent input	• coastal water bodies differ in their sensitivity to environmental change (related to ecological conditions) ➢ *e.g.* areas with coral reef can be particularly sensitive to nutrient inputs, hence have lower assimilative capacity.
Environmental variability/interactions	• predictions of carrying capacity become more difficult in 'open' *versus* 'closed' environments. • 'open' systems are likely to have higher assimilative capacity.
Adjacent natural habitat type	• the prevailing habitat may affect the capacity of the environment to accept nutrients and organic material from ponds, ➢ *e.g.* mangroves have excellent nutrient and organic material trapping capability. • changes in habitat type can change assimilative capacity.

However, the difficulty and complexity of these approaches, as indicated in Table A8.1, should not be underestimated, and considerable resources will be required to make realistic assessments.

Adaptation and management

In practice, even with the best science, the assessment of environmental capacity in coastal waters is extremely difficult. Preliminary working assessments should therefore be made, discharges, impacts and ecological conditions monitored, and assessments adapted and refined in the light of experience.

Estimation of carrying capacity

There are three main steps involved in the estimation of environmental capacity:

- Define environmental quality standards (EQS) - in terms of nutrient concentrations, physical or ecological state (environmental variables);
- Measure the current status of these variables;
- Assess the total loading (or removal) required to change from the current state to the EQS

The last of these requires an understanding of dilution/dispersion of nutrients from aquaculture, and also the assimilation of these nutrients in the sediments and the water column.

Dilution and Dispersion

Simple dilution in lagoons or rivers has already been dealt with in Appendix 5. More complex models of waste dispersion and dilution in the marine environment are widely used in relation to pollution from heavy industry, and have been applied to marine aquaculture in North America and Europe. They required detailed knowledge of water movement in terms of direction and velocity around the farm site. Coupled with knowledge of settling velocity and depth, the dispersion of solids and the dispersion and dilution of nutrients can be calculated. In practice this requires a large number of simple calculations and is normally done using computer software. These range from relatively simple packages (for example developed by Stirling Institute of Aquaculture) to highly sophisticated packages (for example those produced by the Danish Hydraulics Institute).

In practice the measuring of water movement can be very expensive, and rough estimates are usually more appropriate for assessing the impacts of aquaculture development. For example, it has been found that the bulk of fish farm sediments settle relatively close to the cages (within 50m even where currents are significant) while the rest is widely dispersed and has little direct impact. Soluble nutrient will be widely dispersed in most coastal environments, and rough estimates of overall dilution based on tidal exchange and overall water turnover should be adequate in most cases.

Assimilation by sediments

Measurements of organic matter decomposition in sediments under fish cages in the Gulf of Aqaba suggested that the capacity of sediments to absorb organic matter loadings may be 3-4 times greater in warm than in temperate waters (Angel et al, 1992). In practice acceptable loadings are likely to vary greatly according to local conditions and local water uses and environmental needs.

Assimilation in the water column and by other organisms

Mangroves

The buffering capacity of mangrove plays an important role in sustaining any coastal ecosystem. Robertson and Phillips (1994) provided an estimate of the area of *Rhizopora* forest required per hectare of intensive or semi-intensive shrimp ponds to remove nitrogen and phosphorus from the pond effluent (Table 5). The requirement of mangrove area to remove phosphorus (21.7 ha) from the effluent of a 1 ha shrimp pond is three times higher than that required to remove nitrogen (7.2 ha), which indicates low P assimilating capacity of *Rhizopora* mangrove forest.

Box A8.1 Reported filtration rates and nutrient assimilation by molluscs.

- An individual mussel can filter between 2 and 5 litres of water per hour*;
- A rope of mussels can filter more than 90,000 litres per day*;
- Oyster may remove 94% of nitrogen and 48% of suspended solids**;
- Green mussel can remove 68% of total nitrogen***
- Seaweed can remove 32% of N and 19% of P****

*Nunes and Parsons 1998; **Ryther et al 1995; ***Jones and Preston 1996.

Table A8.2. Estimates of *Rhizopora* mangrove forest area (ha) required to remove nitrogen and phosphorus loads produced during the operation of 1 ha of semi-intensive and intensive shrimp ponds (Source: Robertson and Phillips 1994)

Element from Effluent	Mangrove Forest Required (ha)	
	Semi-intensive shrimp ponds	Intensive shrimp ponds
Nitrogen	2.4	7.2
Phosphorus	2.8	21.7

Plankton

GESAMP (1996) provides a hypothetical example of assessing the assimilation of nutrients by plankton in the water column. However, there are a range of difficulties with these estimates, and it is likely that rules of thumb (in terms of allowable increases in nutrient concentrations), adapted in the light of experience, will be more useful for the overall estimation of environmental capacity.

General models

General environmental capacity models combining several of the above elements have been developed, mainly in relation to temperate lakes or reservoirs (e.g. Beveridge 1984). They have also been adapted for salmon culture. Though useful, they must be used with care and require further development.

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Appendix 9:

Characteristics of chemicals commonly used in coastal aquaculture

- Concerns over the use of chemicals
- Recommendations for governmental authorities
- Recommendations for the aquaculture industry
- Recommendations for the drug and chemical industry
- Recommendations for the scientific community

This Appendix is based on:

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). 1997. Towards safe and effective use of chemicals in coastal aquaculture. Rep.Stud.GESAMP (65): 40 p

Concerns over the use of chemicals.

The primary environmental and human health issues associated with chemical use in coastal aquaculture are:

- **Persistence in aquatic environments**

Many aquaculture chemicals degrade rapidly in aquatic systems. For example, formalin, a widely used parasiticide and fungicide, has a half-life in water of 36 hours (Katz, 1989). Furazolidone, an antibacterial, has a half-life in sediments of less than one day (Samuelsen *et al*., 1991). The half-life of dichlorvos, a parasiticide, in seawater is in the range of 100-200 h, depending upon water pH (Samuelsen, 1987). Other chemicals may persist for many months, retaining their biocidal properties. Metal-based compounds, such as the organotin molluscicides and copper-based algaecides are likely to be quite persistent in aquatic sediments, although precise data are lacking. Some antibacterials, notably oxytetracycline, oxolinic acid and flumequine, can be found in sediments at least 6 months following treatment (Weston, 1996). The persistence of chemical residues is highly dependent on the matrix and ambient environmental conditions. Very little is known about the environmental fate of many aquaculture drugs with available data being derived largely from temperate latitudes.

- **Residues in non-cultured organisms**

Use of pesticides, antibacterials and other therapeutants in coastal aquaculture has the potential to result in chemical residues appearing in wild fauna of the local environment. For example, uningested medicated feeds or faeces containing drug residues provide routes by which local fauna may ingest and incorporate medicants. Filter-feeding molluscs in down-current areas are particularly vulnerable to “secondary medication” from contaminated particulates. Such inadvertent chemical exposures and subsequent human consumption of aquacultural products theoretically can present hazards to human health although risks are probably extremely low in most coastal aquaculture situations.

- **Toxicity to non-target species**

Toxicological effects on non-target species may be associated with the use of chemical bath treatments, pesticides, disinfectants, or leaching of toxicants from antifouling chemicals employed in aquaculture. Among the pesticides that may have toxicological effects on the surrounding invertebrate fauna are the organophosphate ectoparasiticides, such as those employed in salmon culture. The use of carbaryl pesticides to eliminate burrowing shrimp from oyster beds in the north-western United States results in the unintended mortality of Dungeness crab, a commercially exploited species (WDF/WDOE, 1985).

- **Stimulation of resistance**

Since the first true antibacterial agents were introduced in the 1930s, users have been coping with the emergence of drug resistance among target organisms. As each new drug was developed, major successes in therapy were achieved but, within a few years, the first cases of drug resistant strains began to appear. In intensive aquaculture, antibacterial agents are used universally to treat bacterial disease and there is widespread prophylactic use. The most common routes of application are oral or by immersion. In both cases, significant quantities of antibacterial may reach the environment and lead to the selection of resistance. This has resulted in increased resistance both in obligate fish pathogens such as *Aeromonas salmonicida* and in the opportunistic pathogens such as *Vibrio* spp. and the motile aeromonads (Aoki *et al*., 1984; Zhao *et al*, 1992). It is theoretically possible for non-pathogenic bacteria in the marine environment to transfer resistance to human pathogens by plasmid transfer although it has been argued that such a scenario is unlikely (WHO, 1998).

- **Effects on sediment biogeochemistry**

The microbial communities of aquatic sediments degrade organic matter and recycle associated nutrients. Rates of oxygen consumption, ammonium and sulphide production in sediments are all highly dependent upon microbial activity. Accumulation of antibacterial residues in sediments has the potential to inhibit microbial activity and to reduce the rate of organic matter degradation. More studies are needed to assess such impacts.

- **Nutrient enrichment**

Fertilisers are often used in pond culture operations to increase primary productivity. If hypernutrified waters are discharged in the effluent, they could have similar effects in receiving waters, especially when the latter are nutrient limited. The nutrient input associated with the use of fertilisers could be additional to the contributions of feed in systems employing both feed and fertilisation. Whether these nutrient inputs are of significant ecological consequence depends on local conditions.

- **Health of farm workers**

There is potential for some chemical compounds used in coastal aquaculture to pose health risks to farm workers. Accordingly, proper training and the provision of adequate safety equipment is essential. Some chemicals, such as the organophosphates (dichlorvos and trichlorfon) and others that act as respiratory enzyme poisons (malachite green) must be handled with respect, especially in concentrated form. Rotenone in powder form is toxic by inhalation and may cause respiratory paralysis. If proper health and safety precautions for handling aquacultural compounds presenting significant health risk to humans are enforced, operator risk will be minimised.

- **Residues in seafood**

Perceptions regarding the hazards of chemical residues in aquacultural products are an increasing source of anxiety among consumers. Although most areas of aquaculture, particularly those which employ extensive production methods, use few or no chemicals that could give rise to persistent residues in the flesh of the products, these perceptions unfortunately affect the entire industry. Increasingly, developed countries are imposing restrictions on compounds used by their own fish farmers and introducing residue monitoring programmes for imports. Such monitoring programmes will also be required of producing countries who wish to continue exporting their aquaculture products into international markets. The protection of consumers against the risks of ingesting veterinary medicines is receiving much attention and although these risks may be difficult to quantify, it is essential that aquaculture products conform to standards no less protective than those already in place for many other areas of animal production (WHO, 1998).

These potential impacts can be mitigated by appropriate management practices and use of appropriate drugs and chemicals. The major chemicals used in coastal aquaculture are given in Table A9.1. Use of many of the chemicals classes mentioned in the table is common practice in animal husbandry (e.g., use of carotenoid feed additives in the poultry industry) and agriculture (e.g. .lime). Because adoption of many of these chemicals by the aquaculture industry is a relatively new phenomenon and because of the release of residues to the aquatic environment, this practice has come under scrutiny. The following gives some recommendations from the GESAMP working group which can be considered in environmental impact assessments and the development of mitigation strategies..

Recommendations for governmental authorities

1. A system of registration for “approved” chemicals for use in aquaculture is essential in order to protect public health, the natural environment and the export economy.

2. On the basis of scientific data relevant to local environmental conditions and the species being cultured, governmental authorities should establish withdrawal periods (i.e. non-use prior to harvest and marketing) specific to each chemotherapeutant. Governments should enforce the use of such practices, in part by adoption of a residue testing programme, and solicit aquaculture industry collaboration to ensure their effective implementation.

3. Quantitative data on the usage of aquacultural chemicals, particularly those of greatest environmental and human health concern, should be gathered as a means to determine regulatory and research priorities.

4. Opportunities should be provided for training in the safe and effective use of chemicals in aquaculture for farm workers, other aquaculture support staff and chemical sales personnel. This training could be provided by government agencies, universities or trade associations. Drug and chemical companies should support such educational efforts.

5. There is a need for enhanced collaboration among manufacturers, suppliers and users of chemicals in aquaculture. Government authorities should encourage and facilitate such collaboration and provide expert advice, where required, to promote the safe and effective use of chemicals by aquaculturists. For these purposes, it will be useful to compile and disseminate contact details of manufacturers, importers and suppliers of chemicals as well as of hatchery and farm operators and any relevant trade associations.

Recommendations for the aquaculture industry

1. Chemotherapeutants should not be the first option when combating disease but used only as a last resort after environmental conditions, nutrition and hygiene have been optimised.

2. Prophylactic treatment should be avoided since the selective pressure for development of antibacterial resistance poses a threat to the long-term efficacy of a drug.

3. When multiple chemical alternatives are available, aquaculturists should select drugs not only on the basis of efficacy data but also on available information regarding environmental persistence, potential effects on non-target organisms, propensity to stimulate microbial resistance and rate of residue elimination.

4. Aquaculturists should utilise antibacterials having as narrow a spectrum of activity as possible but without loss of efficacy, so as to minimise selective pressure for resistance in other micro-organisms.

5. In order to document cost-effectiveness and guide future treatment, aquaculturists should maintain records of chemical use including agents used, amounts, reasons for use, methods of application, dates of use, amount/number and size of stock treated, success/failure of treatments and times of harvest of treated stock.

6. Aquaculturists should not discharge to natural water bodies any effluent containing chemical residues at concentrations likely to cause adverse biological effects and should first reduce concentrations, preferably by residue removal or increased residence time, and/or by dilution with other effluent waste streams within the farm.

7. Farms in close physical proximity should collaborate in minimising the risk of contaminating of their water supplies and those of neighbouring facilities with chemical residues and drug resistant bacteria.

Recommendations for the drug and chemical industry

1. Producers of chemicals used in aquaculture should support the development of efficacy, fate and environmental effects data specific to the species and the geographical region(s) of chemical use.

2. Aquaculture chemicals should be provided to the aquaculturist with labelling and/or data sheets in the principal local language(s). Information should be provided on active ingredients, intended use, route of treatment, environmental and health hazards, species and life stage to be treated, storage conditions, expiration dates and disposal requirements. Aquaculturists should be encouraged to purchase only chemicals with complete labeling and to follow all instructions regarding their use.

Recommendations for the scientific community

1. Scientists should continue to document and quantify the frequency, severity and spatial extent of environmental alterations related to chemical use in aquacultural activities. Such efforts have been very limited to date and quantitative assessments are urgently needed by regulators and the aquaculture industry.

2. Research is needed to develop safe alternatives to chloramphenicol, malachite green and organotin molluscicides.

3. Research and development of alternatives to chemotherapy are needed including development of probiotics, bioremediation, immunostimulants and vaccines.

Table A 9.1: Main Characteristics of chemicals used in the aquaculture industry

Chemicals	Major use/purpose	Hazards and risks	Legal issues
Chemicals associated with structural materials			
• Structural materials, coatings, antifoulants (e.g. Tri-butyl tin (TBT))	Structural materials, protective coatings and antifoulants	TBT residues highly toxic to humans and indigenous biota.	TBT banned for use in aquaculture in some countries
Soil and water treatments			
• Alum	Alum (potassium-aluminium sulphate) is widely used as a flocculant to reduce turbidity.	Low environmental risk	
• EDTA	Water treatment for removing heavy metals in shrimp hatcheries.	Low environmental risk	
• Gypsum	Widely used floculant in ponds	Low environmental risk	
• Lime	Commonly used to neutralise pH and sterilise pond bottoms	Low environmental risk	
• Zeolites	Commonly used water treatment in ponds (of limited effectiveness)	Low environmental risk	
Fertilisers			
• Organic manures	Chicken and other manures used in brackishwater shrimp, fish culture.	Low environmental risks from eutrophication/dissolved oxygen depletion if used excessively	
• Inorganic fertilisers	Wide range of inorganic fertilisers used in brackishwater fish/shrimp culture	As organic manure	
Disinfectants			
• Chloramine	Disinfection of tanks and equipment and treatment of bacterial gill disease.	Active component is chlorine (available chlorine = 20%). See comments on chlorine below	
• Formalin	General disinfectant for	See below	

	equipment.		
• Hypochlorite	Widedespread disinfectant in hatcheries, some ponds for water treatment (particularly shrimp viral diseases)	Medium risk. Chlorine is highly toxic to aquatic life. Release of chlorinated water to the receiving water body without prior neutralisation with sodium thiosulfate could have localised biological effects.	
• Iodophores	Used world-wide as disinfectants for aquaculture equipment and fish eggs.	Medium environmental risk is associated with disposal, which should be to the soil	
• Ozonation	Occasional use by shrimp producers to disinfect hatchery water.	Low environmental risk	
• Quarternary ammonium compounds (e.g benzalkonium chloride)	Used as "topical disinfectants" to remove ectoparasites from fish., as bactericides and fungicides in shrimp hatcheries. Widely used in shrimp ponds to control viral infections.	Medium environmental risk	
Antibacterial agents			
• β-lactams**,**	Used occasionally in fish culture.	The β-lactams are important in human medicine.	
• nitrofurans,	Have been used extensively in fish and shrimp farming. Use in the Europe and North America has declined as more active compounds.	Potentially carcinogenic.	Prohibited for use on food animals within the European Union.
• Macrolides (erythromycin)	Erythromycin active against Gram-positive bacteria in fish culture and in shrimp hatcheries in Southeast Asia.	Occasional allergies	
• Phenicols (includes chloramphenicol, thiamphenicol, and florphenicol)	Occasional use in hatcheries.	Use and ingestion of chloramphenicols in humans is associated with aplastic anaemia. There are important uses of the drug in human medicine such as the treatment of typhoid. Resistance develops readily and is serious as chloramphenicol is the drug of last	Banned for use in aquaculture in several countries. No residue levels are tolerated in Europe and the USA which in turn imposes a control on countries wanting to export their products to these areas

		resort in human medicine for acute *Salmonella typhi* infection. The major environmental hazard of chloramphenicol is its potential to increase drug resistance.	
• 4-quinolones	Occasional use	Unknown	
• rifampicin	Synthetic antibacterial agents.	Low environmental risk but long persistance.	
• sulponamides	Antibacterial has been reported for treatment of luminous vibriosis in shrimp culture.	Unknown	
• Tetracyclines (oxytetracycline in most common use)	Oxytetracycline is probably the most widely used antibiotic in aquaculture effective against a wide range of Gram-negative and Gram-positive bacteria such as *Aeromonas* or *Vibrio* spp in fish and crustaceans.	Resistance increases readily so that now, in many situations, treatments are ineffective.	Widely licenced for aquaculture use
Therapeutants other than antibacterials			
• acriflavine	**Very occasional use as an** antibacterial and external protozoan treatment for fish eggs and fry.	Potentially mutagenic.	
• copper compounds	Limited use. Effective against external protozoans and filamentous bacterial diseases in post-larval shrimp. It can be used to induce moulting in shrimp as a means of reducing cuticular fouling.	Low environmental risk	
• dimetridazole/metronidazole,	An antiprotozoal agent of very limited use in coastal aquaculture although favoured more strongly by the aquarium trade. Presented as a medicated feed.	Low environmental risk	

• formalin	Global use. Employed as an antifungal agent and in the control of ectoparasites, most often in hatchery systems.	Formalin is toxic to aquatic life at low concentrations. Dilution is necessary in order to insure that therapeutic dosages may be safely discharged to receiving waters. Formalin is a potential carcinogen and should be handled very carefully to avoid skin contact, eye irritation and inhalation	
• gluteraldehyde	Rare use in hatcheries/shrimp ponds	Potentially carcinagenic	
• malachite green	Use as an antifungal and antiprotozoal bath in the culture of shrimp and fish mainly in hatcheries.	Human health concerns relate to its role as a respiratory enzyme poison. Lengthy withdrawal period essential following application because of persistent residues.	Its use is not permitted in the USA, the European Union and some Southeast Asian countries (e.g., Thailand) .
• methylene blue	Occasional use. Effective against fungal and protozoan infections in fish culture operations.	Low environmental risk	
• niclosamide,	Limited use. Applied as an anthelmintic in fish culture, including turbot.	Low environmental risk	
• potassium permanganate,	Occasional use as a bath treatment for fungal infections of milkfish and other cultured finfish.	Low environmental risk	
• trifluralin (Treflan®)	Commonly used prophylactic fungicide; presented as a bath in shrimp hatcheries.	Low environmental risk	
Pesticides			
• **Ammonia,**	Employed occasionally in shrimp culture as a piscicide prior to pond stocking.	Low environmental risk	
• **Azinphos ethyl (Gusathion®).**	Has been used to remove molluscs from shrimp ponds in the Philippines .	High environmental and health risks - toxic effects on aquatic life	Widely banned

• **Carbaryl (Sevin®)**	Carbaryl pesticides are used to control burrowing shrimp in shrimp ponds of Central and South America and in on-bottom oyster culture in the north-western USA.	Medium environmental risk - Mortality to non-target species. Non-target crustaceans are likely to be at greatest risk	
• **Organophosphates.** Dichlorvos (Nuvan®, Aquaguard®), Dipterex®, Dursban®, Demerin® and Malathion®	Dichlorvos is a widely used organophosphate pesticide applied to control ectoparasitic crustacean infections in finfish culture. In addition to dichlorvos and trichlorfon, other organophosphates such as Dipterex®, Dursban®, Demerin® and Malathion® are employed to control ectoparasitic crustaceans in freshwater fish and monogenetic trematode infections in shrimp hatcheries.	For all the organophosphates, effetcs on non-target aquatic organisms, particularly crustaceans is a major concern. Discharge of pond water containing residues or direct release of organophosphates to waterbodies may result in adverse effects on nearby organisms Due to the high neurotoxicity of organophosphates, potential effects on the health of fishfarm workers are also of concern..	
• **Ivermectin (Ivomec®)**	Limited use to control sea lice in salmon	Unknown	
• **Nicotine (tobacco dust)**	Occasional use to control fish predators and snails during preparation of fish and shrimp grow-out ponds.	Low environmental risk	
• **Organotin compounds (Brestan®, Aquatin®, Thiodan®)**	Frequent use in the past in Southeast Asia for elimination of molluscs prior to stocking of shrimp ponds.	Organotin compounds are highly toxic, with acute toxicity to the most sensitive organisms occurring at concentrations in the nanogramme per litre range.	Severely restricted by Canada, France, Germany, Switzerland, United Kingdom, and the United States. Banned for aquaculture use in several SE Asian countries.
• **Rotenone (derris root)**	A compound derived from derris root and used as a piscicide to remove nuisance fish from ponds prior to stocking of shrimp or fish	Hazard to workers as inhalation may result in respiratory paralysis.	Use is strictly controlled by many countries.
• **Saponin (tea seed meal)**	Widespread use in Southeast Asia. Employed during the preparatory phase in ponds as a piscicide prior to stocking	Medium environmental risk	

	of shrimps. Also used in the Philippines, Thailand and elsewhere to induce moulting in shrimp.		
• **Trichlorfon (Neguvon®, Dipterex®)**	See entry under organophosphates	As organophosphates	
Herbicides/algaecides	Herbicides are widely used to control weed growth in freshwater aquaculture but have very limited applications in marine aquaculture. .	Low environmental risk	
• **Copper compounds (Aquatrine®)**	Limited use. Applied to shrimp ponds as a method of algae control	Low environmental risk	
Feed additives	There are no data on environmental or health effects specific to aquaculture, though many of these compounds are widely used as feed additives in terrestrial animal husbandry.	Low environmental risk	
Anesthetics			
• **Benzocaine, carbon dioxide**	A number of anaesthetic agents have been used in aquaculture to assist immobilisation of brood animals during egg and milt stripping. Anaesthetics are also extensively used to sedate and calm animals during transportation.	Anaesthetics are fundamentally employed at very low doses, such that their limited use in coastal aquaculture presents no environmental risk although there may be hazards to users.	
Hormones	Maybe added to feed and used for breeding of fish.	Although the potential human health and environmental effects of endocrine disrupting chemicals is now a matter of considerable debate, the use of such chemicals in aquaculture is not currently a major concern.	

Appendix 10:

Assessing coastal aquaculture against sustainability criteria

- Broad sustainability criteria
- Practical indicators at local or enterprise level
- Quantitative indicators at enterprise level
- Sustainability analysis of intensive shrimp farming
- References

Broad sustainability criteria

For many years economists have referred to the the "Hartwick Rule" (Hartwick 1977) as criterion for sustainable development :

The capital stock (manufactured capital + natural capital) should not decrease over time.

Hanley et al 1999 summarize and categorize the indicators of sustainability as follows:

Type	**Group**	**Example/units**
Ecological/environmental		
single	Air quality	NOx/Sox ppm
	Water quality	DO mg/l
	Soil erosion	Tonnes/ha/yr
Aggregate	Net Primary Productivity	Energy/m^2 or tonnes/ha
	Environmental space	varied
	Ecological footprints	Ha/person
Economic		
single	Consumption per capita	$/person
	Real wages	$/person
	Unemployment	No. employed/region
Aggregate	Green net national product (NP-depreciation in natural capital – increased pollution stocks)	$
	Genuine savings (savings – depreciation in natural and man-made capital)	$
Socio-political		
single	mortality	Deaths/1000
	literacy	Literacy rate/1000
aggregate	Index of social and economic welfare	$ or $/person
	Genuine progress indicator	$ or $/person
	Human development index	Index

In practice it is difficult to translate most of these to practical criteria for the assessment of individual enterprises, although this is possible (for example) with the ecological footprint (e.g. what area of land or water is required to support a fish farm when land/water required to generate the inputs is taken into account?)

Practical indicators at local or enterprise level

The following practical sustainability indicators were proposed by Flemming and Daniel (1995):

• Maintenance of habitat and ecosystems; • Preservation of native plant and animal species; • Preservation of areas of landscape and amenity value; • Preservation of areas of cultural value; • Reclamation and re-use of wastewater; • Wastewater disposal within assimilative capacity; • Groundwater extraction within sustainable yield; • Improvement in surface water quality; • Improvement in groundwater quality; • Productive use of fertile soils; • Prevention of erosion; • Application of clean technology; • Waste recycling or use; • Material utilization allowing recycling or re-use; • Increased use of metal substitutes	• Compatibility with existing operations or services; • Local infrastructure compatibility; • Minimization of greenhouse gas emissions; • Airborne disposal within assimilative capacity; • Use of renewable energy resources; • Energy efficiency; • Public acceptability; • Involvement of the community; • Improved recreational opportunities; • Improved access to public open space; • Full cost recovery for goods or services; • Annual equivalent cost benefit ratio; • Costs borne by consumers; • Equitable cost-benefit distribution; • Increased employment opportunities; • Unit cost for good or service; • Capital cost funding capability

Quantitative measures of sustainability at the enterprise level

Although useful, many of the measures noted above are not quantifiable or are difficult to quantify. Hambrey (1998) proposed the following quantifiable/measurable sustainability indicators relating to resource use on specific enterprises:

- *the efficiency of conversion of nutrients and raw materials into usable product; or*
- *the quantity of raw materials or nutrients used per unit product, or per unit land.*

Food conversion efficiency is a classic example of the latter. However, he suggested that these may be less appropriate in developing countries than indicators which compare resource use with income generated. For example:

- *Resource use, or waste production, per unit economic or social benefit*

Specific indicators of this kind include a wide range of simple ratios, which may include both environmental and social elements. For example:

- land/unit income;
- land/unit profit;
- land/NPV[4]
- annual cost of raw materials/employment

[4] Net Present Value

- nutrient waste/unit income;
- nutrient waste/unit profit;
- land/employment;
- investment/employment
- nutrient use/employment;
- nutrient waste/employment;

In the case of aquaculture and agriculture for example, it may be informative to calculate and compare income generated per kg of nitrogen consumed, per kg nitrogen discharged, or per kg protein consumed. The relative weights given to these various indicators will depend on local conditions in terms of nitrogen supply, nitrogen pollution, or protein shortage.

Sustainability analysis: intensive shrimp farming

The following provides a practical example of a broad qualitative analysis of the sustainability of shrimp farming (Hambrey 1996).

Sustainability Criterion	*Current Status of Shrimp Farming*	*Potential Improvement*
continuity of input supply	• wild seed supply erratic and seasonal; • hatchery supply may be erratic and subject to availability of wild broodstock; • feed shortage or expense may arise related to variations in industrial fisheries supplying fish meal	• further develop hatchery seed supply; • improve hatchery skills; close the breeding cycle; • reduce fishmeal content of diet; increase contribution of natural feed
quality of inputs	• seed from wild may carry disease; • hatchery seed may vary greatly in quality - multiple spawnings; poor feeding; excessive use of antibiotics; • feed formulation - quality may be compromized in favour of low cost; • feed quality may decline rapidly in tropical climate; • skills and training frequently inadequate; • quality and efficacy of many chemicals and other inputs questionable	• further develop hatchery production; • introduce seed quality certification; • introduce feed quality standards; • develop indigenous feedmill industry; • provide improved vocational training; • research efficacy of proprietary chemical products;
social, economic and environmental costs of inputs	• feed highly dependent on fishmeal from industrial fisheries, some of which are poorly managed and may not be sustainable; and whose intensive exploitation may reduce availability of other higher value marine species which feed on them.	• reduce fishmeal content of feed; develop alternative protein /amino acid sources;

	• a wide variety of impacts may be related to the production of chemicals • use of wild seed may reduce recruitment to capture fisheries; affect other species dependent upon them; and result in significant by-catch of discarded juveniles of other species	• reduce dependence on chemicals through disease prevention: better husbandry, feed quality, site and water quality, water management, water supply and discharge design and infrastructure • increase hatchery production of seed.
continuity of output	• disease is a major factor reducing the quantity and continuity of output; • declining pond soil and water quality may result in a steady decline in growth and output and increased susceptibility to disease	• emphasize disease prevention: better husbandry, feed quality, site and water quality, water management, water supply and discharge design and infrastructure • better pond soil and water management - training; water supply infrastructure
financial viability	• very high while production is maintained; • often negative following poor management	• encourage moderate levels of intensity while skills are limited; intensify only slowly and steadily; • initiate, facilitate and encourage training
socio-economic impact	• return to labour, and employment potential/ha very high compared with agricultural alternatives in the coastal zone; • investment/job high relative to more traditional agricultural and artisanal fishery activities; • displacement as a result of increased land value; salinization; interference with navigation; destruction of habitat yielding susbsistence products for local people	• develop lower cost technologies • consult all stakeholders prior to allocating previously commonly held land; • zone aquaculture and agriculture to minimize chances of salinization
environmental impact	• previously unused brackishwater environments (eg mangrove, estuarine flats, saltmarsh) may be converted, resulting in destruction of relatively natural habitats; • significant quantities of nitrogen and phosphorus released to environment (water, pond soil, air); • significant quantities of organic matter (resulting in BOD) released to the environment; • a wide variety of chemicals released to the environment, including disinfectants, pesticides, and antibiotics, the latter having the potential to cause increased resistance in bacteria.	• identify high quality natural habitat and enforce protection; • set standards/guidelines/best management practice codes for effluent quality; encourage compliance through quality labelling initiatives related to both physical quality and production process; • ban excessive and inappropriate use of antibiotics, and use of those of particular value for the treatment of serious human disease; • research possible impact of chlorination (disinfection) and production of chloramines and other complex chlorinated organics;

input productivity/resource use efficiency[5]	• poor conversion of protein (nitrogen) and phosphorus; • moderate-high energy productivity; • very high land and labour productivity; • high capital productivity	• improve feed quality and reduce N and P content; • good siting and infrastructure to reduce pumping requirement; improved aerator efficiency;

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[5] see earlier discussion for more detail on these sustainability criteria

Appendix 11:

Codes of Practice

- **FAO Code of Conduct for Responsible Fisheries – Aquaculture**
- **Global Aquaculture Alliance Code of Practice**
- **Synthesis of available codes of practice**

FAO Code of Conduct for Responsible Fisheries

Section 9 - AQUACULTURE DEVELOPMENT

9.1 Responsible development of aquaculture, including culture-based fisheries, in areas under national jurisdiction

9.1.1 States should establish, maintain and develop an appropriate legal and administrative framework which facilitates the development of responsible aquaculture.

9.1.2 States should promote 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.

9.1.3 States should produce and regularly update aquaculture development strategies and plans, as required, to ensure that aquaculture development is ecologically sustainable and to allow the rational use of resources shared by aquaculture and other activities.

9.1.4 States should ensure that the livelihoods of local communities, and their access to fishing grounds, are not negatively affected by aquaculture developments.

9.1.5 States should establish effective procedures specific to aquaculture to undertake appropriate environmental assessment and monitoring with the aim of minimizing adverse ecological changes and related economic and social consequences resulting from water extraction, land use, discharge of effluents, use of drugs and chemicals, and other aquaculture activities.

9.2 Responsible development of aquaculture including culture-based fisheries within transboundary aquatic ecosystems

9.2.1 States should protect transboundary aquatic ecosystems by supporting responsible aquaculture practices within their national jurisdiction and by cooperation in the promotion of sustainable aquaculture practices.

9.2.2 States should, with due respect to their neighbouring States, and in accordance with international law, ensure responsible choice of species, siting and management of aquaculture activities which could affect transboundary aquatic ecosystems.

9.2.3 States should consult with their neighbouring States, as appropriate, before introducing non-indigenous species into transboundary aquatic ecosystems.

9.2.4 States should establish appropriate mechanisms, such as databases and information networks to collect, share and disseminate data related to their aquaculture activities to facilitate cooperation on planning for aquaculture development at the national, subregional, regional and global level.

9.2.5 States should cooperate in the development of appropriate mechanisms, when required, to monitor the impacts of inputs used in aquaculture.

9.3 Use of aquatic genetic resources for the purposes of aquaculture including culture-based fisheries

9.3.1 States should conserve genetic diversity and maintain integrity of aquatic communities and ecosystems by appropriate management. In particular, efforts should be undertaken to minimize the harmful effects of introducing non-native species or genetically altered stocks used for aquaculture including culture-based fisheries into waters, especially where there is a significant potential for the spread of such non-native species or genetically altered stocks into waters under the jurisdiction of other States as well as waters under the jurisdiction of the State of origin. States should, whenever possible, promote steps to minimize adverse genetic, disease and other effects of escaped farmed fish on wild stocks.

9.3.2 States should cooperate in the elaboration, adoption and implementation of international codes of practice and procedures for introductions and transfers of aquatic organisms.

9.3.3 States should, in order to minimize risks of disease transfer and other adverse effects on wild and cultured stocks, encourage adoption of appropriate practices in the genetic improvement of broodstock, the introduction of non-native species, and in the production, sale and transport of eggs, larvae or fry, broodstock or other live materials. States should facilitate the preparation and implementation of appropriate national codes of practice and procedures to this effect.

9.3.4 States should promote the use of appropriate procedures for the selection of broodstock and the production of eggs, larvae and fry.

9.3.5 States should, where appropriate, promote research and, when feasible, the development of culture techniques for endangered species to protect, rehabilitate and enhance their stocks, taking into account the critical need to conserve genetic diversity of endangered species.

9.4 Responsible aquaculture at the production level

9.4.1 States should promote responsible aquaculture practices in support of rural communities, producer organizations and fish farmers.

9.4.2 States should promote active participation of fishfarmers and their communities in the development of responsible aquaculture management practices.

9.4.3 States should promote efforts which improve selection and use of appropriate feeds, feed additives and fertilizers, including manures.

9.4.4 States should promote effective farm and fish health management practices favouring hygienic measures and vaccines. Safe, effective and minimal use of therapeutants, hormones and drugs, antibiotics and other disease control chemicals should be ensured.

9.4.5 States should regulate the use of chemical inputs in aquaculture which are hazardous to human health and the environment.

9.4.6 States should require that the disposal of wastes such as offal, sludge, dead or diseased fish, excess veterinary drugs and other hazardous chemical inputs does not constitute a hazard to human health and the environment.

9.4.7 States should ensure the food safety of aquaculture products and promote efforts which maintain product quality and improve their value through particular care before and during harvesting and on-site processing and in storage and transport of the products.

Global Aquaculture Alliance – Code of Practice

Global Aquaculture Alliance

Codes of Practice

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PREFACE
CODES OF PRACTICES

The "Guiding Principles for Responsible Aquaculture" are broad statements that summarize primary environmental and social responsibilities of the aquaculture industry. Specific guidelines on how to conduct environmentally and socially responsible shrimp farming are provided as a series of Codes of Practice, each containing recommended management practices, for use by aquaculture associations, companies, and individuals. Codes address the following issues:

- Guiding Principles for Responsible Aquaculture
- Mangroves
- Site Evaluation
- Design and Construction
- Feeds and Feed Use
- Shrimp Health Management
- Therapeutic Agents and Other Chemicals
- General Pond Operations
- Effluents and Solid Wastes
- Community and Employee Relations
-

A background document, "Principles for Sustainable Shrimp Farming" provides the technical justification for individual codes.

Management practices in the individual Codes of Practice must be applied judiciously. Shrimp farms and their settings differ tremendously, and there will be few instances where all of the management practices will be necessary to afford environmental protection and community acceptance. Moreover, the specific methods for implementing a particular management practice will differ depending upon shrimp farm production methods and goals and local conditions. It also must be recognized that as technology advances, some of the management practices will require revision. Thus, the Codes of Practice are intended as flexible guidelines for use in formulating site-specific systems for responsible shrimp production, and their use should be guided by common sense. Nevertheless, adherents to the Codes are expected to comply with the management practices as appropriate for their situation and to strive for continuous improvement in environmental stewardship and community and employee well-being. There also are benefits to the shrimp producer who complies with these codes. Shrimp are sensitive to environmental conditions, and improvements in water quality and other environmental aspects, both on farms and within adjacent waters, will make conditions better for shrimp production.
In addition to encouraging the use of better management practices to reduce possible adverse environmental impacts, the producer should strive to use "environmentally-friendly" products and equipment.

Guiding Principles for Responsible Aquaculture

There is a great demand for shrimp in the world market, and to meet that need, shrimp farming has burgeoned. Like all human endeavors, shrimp farming can effect the environment and influence people's lives. However, with proper planning and management, shrimp farming is environmentally-benign, socially beneficial, and economically rewarding at all levels. To aid in promoting environmentally and socially responsible shrimp farming, the Global Aquaculture Alliance has developed a series of management recommendations based on guidelines for responsible aquaculture presented by the Food and Agriculture Organization (FAO) of the United Nations in Article 9 - Aquaculture Development of the Code of Conduct for Responsible Fisheries. To comply with the Guiding Principles for Responsible Aquaculture, companies and individuals engaged in shrimp farming, singularly and collectively:

1. Shall coordinate and collaborate with national, regional, and local governments in the development and implementation of policies, regulations and procedures necessary and practicable to achieve environmental, economic, and social sustainability of aquaculture operations.
2. Shall utilize only those sites for aquaculture facilities whose characteristics are compatible with long term sustainable operation with acceptable ecological effects, particularly avoiding unnecessary destruction of mangroves and other environmentally significant flora and fauna.
3. Shall design and operate aquaculture facilities in a manner that conserves water resources, including underground sources of freshwater.
4. Shall design and operate aquaculture facilities in a manner that minimizes effects of effluent on surface and ground water quality and sustains ecological diversity.
5. Shall strive for continuing improvements in feed use and shall use therapeutant agents judiciously in accordance with appropriate regulations and only when needed based on common sense and best scientific judgement.
6. Shall take all reasonable measures necessary to avoid disease outbreak among culture species, between local farm sites, and across geographic areas.
7. Shall take all reasonable steps to ascertain that permissible introductions of exotic species are done in a responsible and acceptable manner and in accordance with appropriate regulations.
8. Shall cooperate with others in the industry in research and technological and educational activities intended to improve the environmental compatibility of aquaculture.
9. Shall strive to benefit local economies and community life through diversification of the local economy, promotion of employment, contributions to the tax base and infrastructure, and respect for artisanal fisheries, forestry and agriculture.

Mangroves Code of Practice

Purpose
The Code is designed to foster greater environmental awareness within the shrimp farming industry to assure continued protection of mangrove forests from potentially adverse impacts of coastal aquaculture. Recognizing the multitude of different conditions impacting mangroves in different countries and regional locations, this Code is to be interpreted as a flexible set of criteria to be used to assist any and all interested parties in formulating codes, regulations, and principles for protecting mangrove forests.
The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" by encouraging the following:

- The shrimp aquaculture industry will promote responsible and sustainable development and management practices ensuring the preservation of mangroves and the sustainability of shrimp aquaculture.
- Shrimp aquaculture industries will promote alternative development programs aimed at protecting mangroves while benefiting local communities in mangrove areas.
- Producers shall adhere to national and local regulations applicable to mangroves and to shrimp farming.
-

Management Practices
It shall be the objective of all adherents to this Code to not harm mangrove ecosystems, and whenever possible, to preserve and even enhance the biodiversity of these ecosystems. The following practices will ensure the protection of mangrove ecosystems:

1. New shrimp farms should not be developed within mangrove ecosystems.
2. Realizing that some mangrove must be removed for canals when new shrimp farms are sited behind mangroves, a reforestation commitment of no net loss of mangroves shall be initiated.
3. Farms already in operation will continue ongoing environmental assessments to recognize and mitigate any possible negative impacts on mangrove ecosystems.
4. All non-organic and solid waste materials should be disposed of in an environmentally responsible manner, and waste water and sediments shall be discharged in manners not detrimental to mangroves.
5. The shrimp aquaculture industry pledges to work in concert with governments to develop sound regulations to enhance the conservation of mangroves including regulations regarding restoration of mangrove areas when old farms located in former mangroves are decommissioned
6. The shrimp aquaculture industry will promote measures to ensure the continued livelihood of local communities that depend upon mangrove resources

Site Evaluation Code of Practice

Purpose
The Code is designed to promote site evaluation as a means to ensure that new shrimp-farming projects are harmoniously integrated into local environmental and social settings. Site evaluation can identify limitations that influence the suitability of a site for farm construction and operation, reveal the possibilities of negative environmental and social impacts, and allow estimates of technical and financial requirements for mitigation of unfavorable conditions. Recognizing that enormous variation in environmental and social conditions exists from site to site, this Code presents adaptable guidelines to assist any and all parties interested in making site evaluations for shrimp farms.

The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" and promotes the following:

- Use of site evaluation to avoid siting farms where significant technical, environmental, and social problems are likely.
- Prevention of significant negative environmental and social impacts through use of site evaluation findings in planning mitigation methods. A proper site evaluation will provide most of the information required to produce an environmental impact assessment (EIA).

Management Practices
All adherents to the Code shall thoroughly evaluate potential sites for shrimp farms to assure that local ecological and social conditions are protected and even enhanced. The following practices will ensure that appropriate sites are selected for shrimp farms:

1. Evaluate hydrologic features including tidal patterns, freshwater influences and flood levels, offshore currents, and existing water uses.
2. Determine water quality characteristics of coastal waters in the vicinity of the site.
3. Ascertain the suitability of topography, soil, and ecosystem for siting and construction of ponds.
4. Make sure that previous site use has not resulted in contamination of water or soils.
5. Acquire long-term climatological records to determine the likelihood of drastic events such as flood, droughts, or severe storms that could negatively impact the project.
6. Survey the existing flora and fauna with particular concern for effects of the project on ecologically sensitive areas such as migration routes and nesting grounds or protected areas such as parks and refuges.
7. Document regulatory requirements for the site, and consider alternatives for compliance with regulations.
8. Consider alternatives to mitigate potential negative environmental impacts and to alleviate conditions not conducive to shrimp farm construction and operations.
9. Survey local communities to determine demography, resource use patterns, availability of work force, and compatibility with project goals.
10. Consider alternatives to mitigate potential negative social impacts.
11. Determine if any areas within the site are of significant archeological or historical importance and consider methods for their preservation.

Design and Construction Code of Practice

Purpose

The Code is intended to promote environmental protection through proper shrimp farm design and good construction methods. Good site selection and incorporation of mitigative features in the farm design are the best ways to avoid problems related to flood levels, storms, erosion, seepage, water intake and discharge points, and encroachment on mangroves and wetlands. Planning of clearing and earth moving activities can prevent or greatly limit ecological damage during farm construction. Recognizing that a site-specific approach to design and construction is necessary, the Code provides basic design and construction criteria for environmentally-responsible shrimp farms.

The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" and it promotes:

- Use of design features and good construction methods to overcome site limitations and to prevent or mitigate potential negative environmental and social impacts.
- Adoption of successfully proven and accepted design and construction procedures.

Management Practices

Adherents to the Code shall strive to design and construct shrimp farms in a responsible manner to protect the environment and coastal communities. The following practices can afford this protection:

1. Farms should not be built on ecologically sensitive mangrove areas or other wetlands and in places where it is impractical to correct site-related problems such as highly-acidic, organic, or permeable soils.
2. Comply with all environmental impact assessment (EIA) procedures before initiating construction and abide by EIA restriction during construction.
3. Embankments should be designed to prevent erosion, and where practical, methods for reducing seepage through pond bottoms should be included.
4. Ponds should have separate intake and outlet structures to permit control of filling and draining.
5. Inlet and discharge canals should be separate so that water supply and effluent are not mixed.
6. Storms and flood levels should be considered in earthwork design.
7. Infrastructure and access roads should not necessarily alter natural water flows, cause salinization of adjacent land or water, or impound flood water.
8. Canals should be designed to prevent excessive water velocity and scouring.
9. Water intake point(s) should provide a sufficient volume of high quality water available.
10. Pump intakes should be screened, vegetative buffers provided around pump stations, and containments installed to prevent fuel spills.
11. Where possible, vegetative buffer zones, riparian vegetation, and habitat corridors should be maintained, and vegetative cover provided on exposed earthwork.
12. Sediment traps and basins should be incorporated in the design where suspended solid concentrations are expected to be high in effluents.
13. Outfalls should be designed to prevent erosion and avoid discharge of effluents into stagnant water.
14. Disturb as little area as possible during construction.
15. Erosion should be controlled during construction.
16. Cut and fill construction techniques are preferable, and earthwork should be compacted.
17. Degraded areas such as unused soil piles, barrow pits, and uncontrolled refuse dumps should not be created.

Feeds and Feed Use Code of Practice

Purpose
The Code is designed to improve the efficiency of supplemental feeds and feed management in shrimp farming and to minimize the waste load in ponds. Feeding is a standard practice in shrimp production, because it permits higher production than can be achieved from natural pond productivity. Recognizing that feed is expensive, it should be used wisely to reduce production costs. However, using good feeds and feeding practices also are important steps towards reducing waste loads in pond effluents. Guidelines presented in this Code can be used by feed manufacturers and shrimp producers to improve feeds and feeding practices.

The Code helps to achieve several of the "Guiding Principles for Responsible Aquaculture" and promotes awareness of two major issues:

- Shrimp feed should be made from high quality ingredients by good manufacturing techniques and stored properly.
- Feed should be used conservatively to ensure efficient conversion to shrimp flesh and minimize waste and expense.

Management Practices
Those supporting the Code shall strive to improve feed quality and feeding with the goal of optimizing the conversion of feed to shrimp and reducing the amount of waste entering ponds. This goal can be achieved through the following practices:

1. Feed ingredients should not contain excessive pesticides, chemical contaminants, microbial toxins, or other adulterating substances.
2. Pellet binders and suitable manufacturing techniques should be used to provide a water-stable pellet.
3. Manufacturing processes should provide adequate vitamin and nutrient concentrations in feed.
4. Feed should be purchased fresh and not stored for more than a few months.
5. Feed should be stored in cool, dry areas to prevent mold and other contamination. Do not use contaminated feed.
6. Feed management practices should be implemented to assure the shrimp consume the maximum amount of supplemental feed and not leave excess amounts decomposing in the pond attributing to poor water quality.
7. Feeding rates should be determined from standard feed curves and adjusted for shrimp biomass, appetite, and pond conditions. Feed trays can be used to monitor feeding and prevent under or overfeeding.
8. The most efficient supplemental feeding can be obtained by distributing the supplemental feed several times through the day and night. Supplemental feed should be widely distributed throughout the pond, either by manual or mechanical dispersement or use of feed trays.
9. Appropriate feed curves commensurate with shrimp biomass and appetite should be utilized on a site specific, species specific basis and with the recommendation of shrimp feed specialists.
10. Medicated feed should be used only if necessary for the control of a specific diagnosis of disease.
11. Cut fish should not be used as shrimp feed.
12. Research to reduce the level of fish and other marine meals in shrimp feed should be encouraged.
13. Pond managers should keep careful records of daily feed application rates so that feed conversion ratio (FCR) can be assessed. Reductions in FCR through careful feeding will improve production efficiency and reduce waste loads.

Shrimp Health Management Code of Practice

Purpose
The purpose of this Code is to promote shrimp health management as a holistic activity in which the focus is on disease prevention instead of disease treatment. Authorities on shrimp health management recognize that stress reduction through better handling, reasonable stocking densities, good nutrition, and optimal environmental conditions in ponds can prevent most infectious and non-infectious diseases. Treatment should be undertaken only when a specific disease has been diagnosed. Also, effective measures must be taken to minimize the spread of diseases between farm stocks and from farm stocks to natural stocks. This Code provides adaptable guidelines that should provide effective management of shrimp health.

The Code helps to achieve several of the "Guiding Principles for Responsible Aquaculture" and advances three basic premises as follows:

- Many disease problems can be prevented through stress management.
- Disease treatments should be made only after a clear diagnosis of the causative factors.
- Spread of disease should be minimized by reasonable regulation of importations of broodstock and larvae and by isolation and disinfection of affected ponds.

Management Practices
Adherents to the Code shall adopt the principles of good shrimp health management to reduce the incidence of diseases and to protect natural fisheries. The following practices should be used to achieve these goals:

1. Shrimp farming associations should work with governments to formulate and enforce regulations to include quarantine procedures for importations and exportations of broodstock, nauplii, and postlarvae.
2. Healthy postlarvae should be used for stocking ponds. Survival of postlarvae should then be optimized by preparing the pond to ensure adequate availability of natural food, by properly acclimating postlarvae before stocking, and by avoiding stress by using appropriate handling and transportation techniques.
3. Good water quality and bottom soil management should be used. Stocking rates should not be excessive and high quality feed and good feeding practices should be used.
4. Strong chemical treatments that can stress shrimp should not be employed.
5. Shrimp should be routinely monitored for disease, and a definite diagnosis obtained for any observed shrimp health problem.
6. For non-infectious diseases related to pond conditions, carry out the best option for disease treatment or for correcting pond conditions.
7. For mild infectious diseases with potential to spread within a farm, quarantine the pond and carry out the best option for disease treatment.
8. For serious infectious diseases that may spread widely, isolate the pond, net harvest remaining shrimp, and disinfect the pond without discharging any water.
9. Dispose of dead, diseased shrimp in a sanitary manner that will discourage the spread of disease.
10. When disease occurs in a pond, avoid transfer of shrimp, equipment, or water to other ponds.
11. Drug, antibiotic, and other chemical treatments should be done in accordance with recommended practices and comply with all national and international regulations.
12. The shrimp industry should work with governments to develop certification programs for disease diagnosis laboratories and pathologists.
13. Each country or geographical area should develop its own pond dry-out, farm situation, and biosecurity strategy.

Therapeutic Agents and Other Chemicals Code of Practice

Purpose
The Code is intended to foster greater awareness within the shrimp industry of the proper use of certain potentially toxic or bioaccumulative compounds in shrimp production. Careful control over the use of therapeutants and other chemicals in production will assure that farm-reared shrimp are less likely than wild-caught shrimp to contain residues of pollutants or contaminants. Environmental benefits also will accrue from responsible chemical use. This Code contains flexible criteria that will allow prudent use of certain drugs, antibiotics, and other chemicals in production without endangering food safety or threatening the environment.

The Code helps to achieve several of the "Guiding Principles for Responsible Aquaculture" and promotes three basic objectives:

- The shrimp farming industry in each nation should work with governmental and international agencies to develop lists of approved feed additives, pesticides, drugs, antibiotics, and other chemicals and to specify approved uses for each compound.
- Shrimp farmers who adhere to the Code will rely on good management to prevent water quality and disease problems and chemicals should be used only when necessary.
- Chemical use in ponds should only be done after an accurate diagnosis of the situation and treatments should conform to acceptable protocol.

Management Practices
Adherents to the Code should strive to produce a wholesome product for consumers through responsible use of drugs, antibiotics, and other chemicals. Use of the following practices will assure this goal:

1. Shrimp health management at hatcheries and farms should focus on disease prevention through good nutrition, sound pond management, and overall stress reduction rather than disease treatment.
2. Where countries have approved lists of chemicals and chemical uses, only approved chemicals should be used in ponds and only for the use approved. Where such lists are not available, the shrimp industry and individual producers should work with governments to prepare such lists.
3. Shrimp farmers should follow information on product labels regarding dosage, withdrawal period, proper use, storage, disposal, and other constraints on the use of a chemical including environmental and human safety precautions.
4. When practical, antibiograms should be used to select the best antibiotic for use in a particular case, and the minimum inhibitory concentration (MIC) should be used.
5. When potentially toxic or bioaccumulative chemicals are used in hatcheries and ponds, waters should not be discharged until compounds have naturally decomposed to non-toxic form.
6. Careful records should be maintained regarding use of chemicals in ponds as suggested by the Hazard Analysis and Critical Control Point (HACCP) method.
7. Store therapeutants in a cool place and in a secure manner where they will be inaccessible to unauthorized personnel, children, and animals, and dispose of unused compounds by methods that prevent environmental contamination.
8. The shrimp-farming industry should work with governments to develop regulations for labelling the content and percentage of active ingredients in all chemicals including liming materials and fertilizers.

General Pond Operations Code of Practice

Purpose
The purpose of the Code is to prevent eutrophication, salinization, reductions in biodiversity, and other environmental perturbations by using responsible pond management practices. Experience demonstrates that it is possible to optimize efficiency of shrimp production and be good stewards of the environment at the same time. This Code contains broad guidelines on pond management that can be used to standardize and improve operations for sustainable shrimp farming.

The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" and asserts that:

- Responsible pond operations can protect or even improve environmental quality and enhance sustainability.
- Both profitability and environmental sustainability can be achieved at the same time.

Management Practices
It shall be the objective of adherents to the Code to use pond operation methods that are environmentally responsible while allowing profitable shrimp production. The following practices should be used to promote profitable, yet sustainable shrimp farming:

1. Farms should be encouraged to use hatchery larvae rather than wild-caught larvae.
2. Where wild caught postlarvae are used, a screening method should be used to separate by-catch and return it to the estuary.
3. Native species should be cultured whenever feasible; however, if non-native species are used, all applicable regulations should be obeyed regarding importation and inspection.
4. Only healthy postlarvae should be used.
5. Good water quality should be maintained by using stocking and feeding rates that do not exceed the assimilative capacity of the culture system and by using high quality feeds and good feeding practices.
6. Water exchange should be reduced as much as possible.
7. Fertilizers, liming materials, and all other chemicals should be used in a responsible manner and only as needed.
8. Good shrimp health management should be used.
9. Aerators should be positioned and operated to minimize erosion and creation of sediment mounds in pond bottoms.
10. Freshwater from wells should not be used in ponds to dilute salinity.
11. Effluents, sediment, and other wastes should be disposed responsibly.
12. Bottom soils should be evaluated periodically between crops and necessary treatments applied to remediate deterioration in soil conditions that occur during culture.
13. Water inlets and outlets to ponds should be screened to prevent entrance of competitors and release of culture species.
14. Predator control methods that do not require destruction of ecologically important species should be used.

Effluents and Solid Wastes Code of Practice

Purpose
The Code is designed to increase the awareness of proper waste management within the shrimp farming industry and enhance protection of coastal land and water resources. Recognizing that a number of production activities produce wastes, shrimp producers and processors should formulate systems of waste management for protecting lands and waters in the vicinity of their activities. This Code provides a set of guidelines that can form the framework for responsible waste management that will benefit all coastal resource users including shrimp farming.

The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" and specifically recognizes that:

- The shrimp aquaculture industry should promote responsible methods of effluent and solid waste management to protect environment quality and public health.
- Effluent and solid waste management is a continuous activity, and each member farm should strive to improve waste management procedures and reduce amounts of waste released to the environment.
- In countries where quality and volumes of effluent are not regulated by permits from governmental agencies, adherence to the Code is an alternative way of protecting the environment.

Management Practices
Adherents to the Code should continuously strive to improve waste management. Particular attention should be given to the following practices:

1. Canals and embankments should be maintained to reduce erosion of above water portions.
2. Minimize water exchange to the extent feasible.
3. Use efficient fertilization and feeding practices to promote natural primary productivity while minimizing nutrient inputs.
4. Store and use fuels, feeds, and other products in a responsible manner to avoid accidental spills that could contaminate water. An emergency plan should be made for containing accidental spills.
5. Ponds should be drained in a manner to minimize resuspension of sediment and prevent excessive water velocities in canals and at effluent outfalls.
6. Where feasible, pond effluents should be discharged through a settling basin or mangrove forest.
7. Design outfalls so that no significant impact of effluents on natural waters occurs beyond the mixing zone.
8. Shrimp pond effluents should not be discharged into freshwater areas or onto agricultural land.
9. Sediment from ponds, canals, or settling basins should be put back into areas from which it was eroded, used as earthfill, or disposed in some other environmentally-responsible way.
10. Sanitary facilities for disposal of human wastes should be provided at hatcheries, farms, and processing plants.
11. Garbage and other farm wastes should be burned, put in a land fill, or disposed of by other acceptable methods.
12. Shrimp farms, hatcheries, and processing plants should comply with existing governmental regulations related to effluents and other wastes.
13. Processing plants, and where necessary, shrimp hatcheries should install effluent treatment systems of appropriate type and capacity.
14. Managers should routinely evaluate waste management procedures and continually attempt to improve them.

Community and Employee Relations Code of Practice

Purpose
The purpose of the Code is to foster good relationships among shrimp farm officials, workers, and local communities. Aquaculture can be a powerful stimulus to improving the standard of living in coastal communities by providing jobs and services, contributing to the tax base, improving the physical and social infrastructure, and creating a larger and more diverse and dynamic economy. Recognizing that public relations and employee welfare are complex issues, this Code is intended to provide some general guidelines for enhancing the prospects for harmonious interactions with workers and the local community. Conditions, expectations, and mores are highly variable from place to place, so considerable flexibility will be necessary in applying these guidelines.

The Code helps to achieve several of the "Guiding Principles for Responsible Aquaculture" and specifically promotes the following:

- Shrimp farms should employ local workers to the extent possible, provide good working conditions, and wages commensurate with local pay scales.
- Shrimp farms should abide by local laws and regulations regarding the rights of local people to use coastal resources.
- Shrimp farms should be supportive of local communities and engage in community activities.

Management Practices
Shrimp farms range in size from small, family operations to large corporate enterprises. Most of the guidelines given below apply primarily to large shrimp farms:

1. Shrimp farm owners should have clear title or right to their property or other current, legal land concession agreements.
2. Shrimp farm management should schedule meetings with local communities to exchange information. This is particularly important in the planning stages for new farms or expansions.
3. Shrimp farm management should attempt to accommodate traditional uses of coastal resources through a cooperative attitude towards established local interests and environmental stewardship.
4. Shrimp farm management should contribute to community efforts to improve local environmental conditions, public health and safety, and education.
5. Local workers should be employed to the extent possible, and all practical means made to prevent conflicts between local people and workers from outside.
6. Workers should be fairly compensated with respect to local wage scales.
7. Healthy and safe living and working conditions should be provided. Procedures should be established for dealing with illness and accidents, and employers must be responsible for making sure that workers are fully aware of these procedures.
8. Shrimp farm management should have clearly-defined and posted security policies.
9. Employees should have a clear understanding of their duties and of company expectations regarding their performance

Synthesis of main guidelines and codes of conduct for the promotion of sustainable aquaculture development*

1. Policy level

Principles

- Conserve genetic diversity and ecosystem integrity;
- Conserve water and aquatic resources including underground water;
- Reduce impacts on sensitive habitat through the identification of alternative enterprise or livelihood;
- Minimize pollution of water resources;
- Minimize disease spread;
- Use native species wherever possible;
- Careful and responsible species introductions;
- Bring benefits to local and community life, and address social/poverty issues;
- Use participatory approaches to develop responsible aquaculture practices;
- Improve food safety and product quality;
- Coordination and collaboration between aquaculturists and government;
- Improve research, education and information exchange;
- Comply with all relevant existing regulations and protocols;
- Continually evaluate and improve waste management procedures

Policy, legal, regulatory and administrative frameworks

- Devise and introduce an appropriate national legal and administrative framework;
- Develop aquaculture development strategies and plans;
- Clarify title or right to resource use;
- Title or rights to resource use tied to siting, design and/or management practices;
- Legal bans or restrictions on the use or conversion of environmentally sensitive habitat;
- Develop pollution control standards;
- Introduce enforceable legislation and protocols relating to species introductions and transfers;
- Introduce procedures and protocols relating to genetic change of broodstock;
- Protect trans-boundary ecosystems;
- Introduce quarantine and disease prevention protocols;
- Develop disease certification programs
- Develop feed quality certification/regulation schemes;
- Advance evaluation of genetic and ecological impacts;
- Use tax incentives (positive and negative) for sustainable aquaculture practices;
- Use conflict resolution;
- Provide/facilitate effective veterinary services;
- Research on impact of introductions;
- Improve education, training and extension;
- Effective information collection, exchange, storage, synthesis, and dissemination;
- Industry/government collaboration to develop lists of approved feed additives, pesticides, drugs, antibiotics, and other chemicals and to specify approved uses for each compound;
- Improved and accurate labeling of therapeutants and other chemicals used in aquaculture;
- Develop alternatives to fish meal in aquaculture feeds

Credit

- Provide appropriate credit availability, including cost recovery procedures;
- Tie credit tied to siting, design and/or management practices;

Impact assessment and monitoring

- Assess possible effects of aquaculture development on biodiversity and ecological functions; identify and protect biodiversity;
- Advance evaluation of genetic and ecological impacts;
- EA to include social/poverty/livelihood/cultural assessment;
- Quality baseline data and effective monitoring;
- Integrate aquaculture with broader coastal management initiatives;
- Improve monitoring and reporting;
- Promote government/NGO/business partnerships;

2. Farm level

Site selection
- Use of EIA and integrated coastal management to guide site selection;
- Thorough assessment of hydrology, existing water quality, and susceptibility to climatic disruption;
- Thorough assessment of soil (including possible previous contamination), topography and ecosystem;
- Responsible siting to avoid social, technical and environmental problems;
- Know and apply/comply with existing siting regulations;
- Avoidance of environmentally sensitive habitat;
- Specific principles or restrictions relating to mangrove use or conversion, including the principle of no net loss of mangrove;
- Scale of development within carrying capacity of environment;
- Performance requirements/standards relating to adjacent natural habitat;
- Define mitigation opportunities

Pond construction
- Buffer zones between farms and adjacent farms, water bodies, or conservation areas (e.g. distance limits);
- Removal of solid wastes to non-wetland areas;
- Sediment and waste water treatment;
- Minimize erosion (in ponds and canals) and seepage;
- Separate intake and outlet;
- Separate inlet and discharge canals;
- Minimize off site damage related to borrow pits etc

Operation and Management (General)
- Responsible management;
- None destructive solutions to predation;
- Safe storage of all materials and inputs;

Feed and fertilizer management
- Use fresh, high quality, water stable, well stored feed;
- Maximize efficiency of utilization of, and minimize waste associated with feed, fertilizer and other inputs through improved management;

Health management
- Minimize stress and disease through good nutrition, and sound stock and pond management;
- Correct, safe (enclosed), effective, and *minimal* use of therapeutants, hormones, drugs, and chemicals - administered to the water or the feed;
- Safe storage of chemicals and drugs;
- Delay discharge of chemical contaminated water until natural degradation has taken place;
- Routine monitoring of stock for disease;
- Quality records and information relating to disease outbreaks and chemical use;
- Isolation and quarantine of diseased units or stock;
- Avoid discharge of infected water;
- Safe and effective waste (related to inputs or dead stock) disposal;
- Balance stocking rate and productivity against disease risk;

Water and waste management
- Minimize water exchange and drainage;
- Minimize re-suspension of sediments at harvest;
- Discharge water to settling basin, or some buffer zone (e.g. mangrove) if possible;
- Design out-falls to minimize impact;
- Avoid discharge of saline effluents to agricultural lands or fresh-water environments;
- Dispose of solid wastes responsibly or to specially prepared sites;
- Use water recycling and waste treatment where possible;
- Investigate polyculture systems to reduce waste and increase resource use efficiency;
- Avoid use of fresh well water to reduce pond salinity;
- Screen intake and outlet;
- Maximize in pond waste treatment (eg through effective circulation and aeration);
- Develop/use environmentally friendly chemicals/water treatments;
- Maintain pond soil quality;
- Inter-crop pond treatment;
- On-going mitigation of external impacts on sensitive habitat;
- Specific water quality standards for effluents

Stock management
- Use healthy stock;
- High quality husbandry;
- Minimize escapes;
- Protocols for dealing with dead or diseased stock (e.g. dispose or burn in location isolated from farm; rapid and effective disinfection of ponds with chlorine)
- Report diseases to responsible authority

Seed and hatcheries
- Develop hatcheries;
- Use hatchery in preference to wild seed;
- Protect and rehabilitate by-catch of wild seed fishery;
- Close the breeding cycle (ie use captive as opposed to wild reared broodstock);

Employment and community relations
- Clear resource rights or title;
- Public involvement in design and management;
- Minimal disruption of traditional resource use;
- Involvement in community development and environment initiatives;
- Maximum employment of locals;
- High standard of working conditions;
- Clear statements of duties, roles and responsibilities

Sources: Donovan 1997; FAO 1995, 1997, 1998; GAA 1999; Hempel and Winther 1997; Huntingdon and Dixon 1997; Maharavo 1999.

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