ENVIRONMENT AND AQUACULTURE IN DEVELOPING COUNTRIES

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Summary Report of the Bellagio Conference
on Environment and Aquaculture in Developing Countries
17-22 September 1990
Bellagio, Italy

Edited by

R.S.V. Pullin
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J.L. Maclean

1992

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INTERNATIONAL CENTER FOR LIVING
AQUATIC RESOURCES MANAGEMENT
Manila, Philippines

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DEUTSCHE GESELLSCHAFT FÜR TECHNISCHE
ZUSAMMENARBEIT (GTZ), GmbH
Federal Republic of Germany

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Foreword

The resources available to ensure the continuance of life on earth are finite. Any resource can only serve a limited number of purposes at the same time and place. This is particularly true of water which is a fundamental requirement not only for aquatic but also for terrestrial organisms. It similarly applies to nutrients and energy.

With an increasing demand for food, energy and space by a growing population, the pressure of exploitation is reaching alarming levels on an increasing number of species and over an expanding area. To avoid overexploitation and loss, the resources essential for human survival must be used efficiently and wisely. This requires channeling their utilization in ways that fulfill multiple and complementary objectives wherever possible.

Modern aquaculture appeared at a time when many claims for use of the resources had been made and competition was growing for those niches still available. Labor was becoming increasingly expensive, leading to intensification in terms of rationalization and mechanization to reduce costs. This meant higher stocking densities and higher demand for feed and energy. Among the most immediate environmental consequences were overloading of the waters with nutrients, contamination with chemicals for the treatment of diseases and pests, and ecological damage through the installation of voluminous infrastructure. The demand for feed increased the pressure on other living resources such as small pelagic fish utilized as fishmeal.

Most of the more conspicuous mistakes made so far were committed by developed countries. Some at least could have been avoided through more awareness, foresight and readiness to renounce fast profits which were both questionable and harmful in the long term. The most important lesson to be learnt from the past is more consideration for the need to understand better the environmental and social context in which aquaculture is being developed. Such better understanding should then lead to the establishment of a general policy to guide development action in the most promising directions and to keep negative side effects to a minimum.

In the majority of developing countries, intensification is of less immediate concern, though on a mid- and long-term basis related problems will gain in importance. The more urgent question is how to make the best possible use of the productivity of natural systems without radical environmental changes and at low levels of costly inputs. What is needed for the future is an approach which makes use of the experience available, adds to the existing know-how through continued research efforts, elaborates and refines guidelines, and creates appropriate frameworks for further development. Aquaculture production is in great demand, but it must not be achieved without due regard to safeguarding our basis of survival.

This summary report presents the conclusions and recommendations of an international conference convened by the International Center for Living Aquatic Resources Management (ICLARM) and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH at the Bellagio Conference and Study Centre of the Rockefeller Foundation in September 1990. The full proceedings of the conference are published by ICLARM and GTZ and are available from ICLARM. They contain detailed reviews of many of the pertinent environmental issues surrounding aquaculture development. Only for a few of these issues are clear solutions becoming apparent. Much remains to be done and only intensive collaboration among all parties concerned will bring us closer to success. The results of this conference will be seen as a step in this direction.

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Abstract

The relationship between aquaculture and environment in developing countries is described in terms of environmental benefits and costs; public health; conservation of biodiversity and habitats; disease control; harmful algal events; and reuse of water and byproducts. A schema for decisionmaking and a checklist of assessment factors are provided.

The Environmental Benefits and Costs of Aquaculture in Developing Countries

Aquaculture is defined as the farming of aquatic organisms, including finfish, invertebrates (mainly molluscs and crustaceans) and aquatic plants. Farming implies any or all of the following activities: captive breeding, hatchery and nursery operations and growout to marketable size with harvesting.

Aquaculture development can have beneficial as well as detrimental effects on the environment. The former are generally given less attention than the latter. Sustainable aquaculture requires wise management of water resources, so that water is not wasted and its quality is assured. The possible benefits of aquaculture development are summarized here, followed by an overall appraisal of possible environmental costs. Policies on aquaculture development should be formulated with regard to such benefits and costs.

Benefits

The aim of aquaculture development is to produce sustainable benefits for producers and consumers. Such development can benefit the environment as follows:

- Mixed farms that incorporate aquaculture manage and conserve water resources. This can lessen soil erosion and increase the abundance and diversity of crops and other plants, especially in rainfed areas. Moreover, aquaculture requires good quality water and its development can help to discourage pollution.
- Inland aquaculture can assist integrated pest management in wetland agriculture; for example, by fish feeding on weeds and insect pests and on some disease vectors, such as mosquito larvae.
- Both inland and coastal aquaculture can help to conserve natural waterbodies and adjacent wetlands and some of their fauna and flora. This applies to freshwater lakes and reservoirs, mangrove forests, lagoons and coral reefs. Aquaculture in mixed farming systems can facilitate better coexistence between agriculture and wildlife by providing more diverse, albeit restricted, habitats. This, however, depends largely upon the attitude of farmers and effective legislation, especially with respect to control of birds and other predators by cost-effective, nonlethal methods. Aquaculture can also be a source of replenishment of stocks of endangered species; for example, sturgeon *(Acipenser ruthenus)* in Europe, giant catfish *(Pangasianodon gigas)* in the Mekong basin, and Pacific salmon *(Oncorhynchus* spp.) in North America.
- Well-managed aquaculture facilities can improve the esthetic quality of some agricultural landscapes.

Costs

Aquaculture can cause environmental harm, mostly from unplanned and unregulated development, especially inappropriate site selection. Future expansion of aquaculture should be based on well-balanced, integrated zone management plans which consider aquaculture in relation to all other existing activities and developments.

- Policymakers and decisionmakers in developing countries need to develop expertise, tools and guidelines for the planning and execution of aquaculture development and for the formulation and enforcement of related environmental protection legislation, evolving to meet their present and future needs.
- Aquaculture in developing countries can best be maintained and expanded if sustainable, environmentally compatible, aquatic farming systems are developed through long-term, adequately funded research. This applies both to inland aquaculture, especially to research on the poorly understood nutrient dynamics and socioeconomics of the integration of fishponds with crop-dominated farming systems, and to the culture of seaweeds, invertebrates (principally crustaceans and molluscs) and finfishes in coastal areas, such as coral reefs, mangrove swamps and others.
- All development that uses or impinges upon waters with potential for aquaculture or enhanced fisheries should include fish production as an *integral* part of development plans - for example, multiple use of limited water resources when improving water supplies to growing urban areas and agriculture; existing and new plans for reservoir construction; and wastewater treatment and reuse.
- In certain instances, aquaculture produce, as well as its by-products and wastes, may possess the potential to damage public health; for example, if the farm environment or produce is contaminated by microbial pathogens, biotoxins, or trace pollutants. These problems usually result from inappropriate site selection for aquaculture facilities and choice of species. Their prevention is better than costly cures.

Public Health

- Aquaculture must not cause unacceptable risks to public health or harm that negates the benefits of the improved livelihood and nutrition that its adoption can bring. It should be subject to similar controls and safeguards as are applied to agriculture, irrigation and other aspects of food production and handling. This concerns all persons affected by and involved in aquaculture, and to other users of waters in which aquatic organisms are farmed or which are affected by aquaculture: the farm workers, handlers and processors, sellers and consumers of farmed aquatic produce.
- The health of aquaculture workers and other users of waters in which aquatic organisms are farmed or which are affected by aquaculture must be safeguarded. There must be effective measures against exposure to waterborne pathogens and parasites, to toxic chemicals used on aquatic farms, and against reduction of water quality for purposes such as domestic supply, watering crops and livestock, washing clothes and utensils,

bathing, sports and recreation. Examples of possible health risks to such persons include exposure to waterborne diseases, such as bilharzia and leptospirosis, and to chemicals, such as trace metals, pesticides, disinfectants, antibiotics and hormones; and the risks of working in the aquatic medium, including exposure to harsh climatic conditions and drowning.

- All available information on health risks from aquaculture should be compiled as a statistical database with the involvement of appropriate international organizations, such as the World Health Organization (WHO) and the International Labor Organization (ILO), so as to evolve guidelines and codes of practice. This database should be regularly updated as aquaculture expands and experience is increased.
- In order to mitigate or avoid public health risks from aquaculture development including consumption of aquatic produce, more research is needed on the real or perceived role of aquaculture operations and their produce in human disease transmission and the risk of chemical and microbial contamination. In particular, population-wide studies are required, especially in developing countries, of exposure to mercury, cadmium, organochlorine pesticides, polychlorinated biphenyls (PCBs) and dioxins. Consumption of aquatic produce may be an important source of exposure. Monitoring should employ noninvasive techniques (analysis of hair, urine, or breast milk - as appropriate) in addition to autopsy-derived samples, when available.
- Research is also needed on better methods for aquatic disease prophylaxis and control as an alternative to massive use of chemotherapeutants.
- Regarding the safety of aquatic produce, monitoring programs for trace contaminants, bioactive compounds and microorganisms are needed. Research and development programs are required to improve the tests available for ensuring the safety of aquatic produce. The present tests for biotoxins, for example, are inadequate to afford an acceptable degree of protection, even when widely employed. Very few of the many trace contaminants which may be present in aquaculture produce are monitored on a regular basis.

Conservation of Biodiversity and Habitats

- Aquaculture development must not cause loss of or deleterious changes to the wild genetic resources of living organisms or their natural habitats. It should proceed with due regard for nature conservation and in the context of international, regional, national and local conservation and environmental management strategies.
- The likely consequences of escape of organisms from aquatic farms, their establishment in the wild and their effects on other organisms (including humans) and their habitats, should be thoroughly evaluated *before* any aquaculture development proceeds and especially before any transfers of aquatic organisms are made. This applies to all aquatic organisms, whether native or exotic species and whether close to wild types in genetic characteristics or developed for farming processes by any genetic modification. Genetic modification means selective breeding and genetic management technology (for example, hybridization, chromosome

manipulations, sex control and genetic engineering). These requirements also apply to research and development efforts in which aquatic organisms are purposefully released in natural or manmade waterbodies for enhanced (culture-based) fisheries, including ranching.

- All transfers of aquatic organisms for aquaculture research and development should follow established codes of practice; for example, those of the International Council for the Exploration of the Sea (ICES) and European Inland Fisheries Advisory Commission (EIFAC). These codes of practice should be applied to avoid adverse ecological impacts, including the spread of fish diseases among countries and ecological zones (such as river basins) and among farms and natural waters within the same zone. In intensive aquaculture operations in some developed countries, substantial losses have been caused by the introduction of diseases, parasites and predators. This has led to the enforcement of these codes of practice and other stringent measures to reduce this risk. Developing countries should implement similar strategies to safeguard their aquaculture operations as well as their wild stocks of aquatic organisms.

Disease Control in Farmed Aquatic Organisms

Disease can be a major constraint to aquaculture development by causing serious losses of farmed stocks. Treatment is generally by antimicrobial compounds and this has raised concerns regarding development of disease resistance and the ecotoxicology of these compounds. There is a general lack of information on the significance of diseases in developing-country aquaculture in terms of mortalities and reduced culture performance, on the range of available drugs, and on the extent of their use. These information gaps should be remedied, and clear, widely accessible publications prepared on the correct use of drugs in aquaculture.

- Widespread routine use of drugs should be discouraged. Medication (treatment) should be considered as the last tool in a management scheme when other measures have proven inadequate. Disease control strategies should be improved with a view to reducing drug use in aquaculture.
- To avoid the development of drug-resistant strains, the use of antimicrobial agents should be rotated and the persistent or frequent use of a single chemical discouraged.
- Training in the appropriate use of drugs should be implemented. Such training should include correct methods of application and dosages, approved methods for disposal of residues and proper storage, and pertinent standardized analytical techniques.
- The establishment of fish health services in developing countries should be encouraged. Such services should ensure that veterinarians promote preventive measures through good husbandry practices, thereby reducing the need for frequent treatment.
- Research is needed to determine the longevity and fate of drugs entering and leaving aquaculture facilities, with emphasis on microbial degradation and mobilization. The utilization rates of pesticides in integrated agriculture-aquaculture and their pathways and possible accumulation in local populations should be measured.

Harmful Algal Events

Phytoplankton (diatoms, dinoflagellates and microflagellates) can cause problems for aquaculture worldwide. For example, microalgal phycotoxins can kill fish and render bivalve molluscs toxic to humans. The severity of their adverse effects depends on the state of health of the farmed stock. The threshold densities can be very low: for example 1,000 cells$\cdot l^{-1}$ of *Chaetoceros convolutus* can kill farmed fish and 200 cells$\cdot l^{-1}$ of *Dinophysis acuminata* or *D. acuta* can render shellfish toxic.

There is clear evidence that hypereutrophication of coastal waters increases primary productivity and the occurrence of algal blooms, but statistically significant data for a global increase in harmful algal events are lacking. Such events are almost impossible to predict. This greatly hinders risk assessment, the cost-effectiveness of monitoring programs and the evaluation of potential adverse impacts.

- In all shellfish culture areas where phycotoxin accumulation may be a threat to public health, routine detection and quantification of phycotoxin levels in farmed aquatic produce should be undertaken using well-established methods. Monitoring the presence of harmful algal species is also useful for public health purposes but must not replace the testing of produce for phycotoxins.
- The possibilities for the use of established and newly developed methods of detecting and measuring phycotoxins in the farmed aquatic produce of developing countries should be thoroughly assessed.
- For coastal aquaculture, farm sites should be chosen where harmful algal events are rare or absent. The possibility of relocating cage farms away from affected areas should also be considered.
- Finfish farm management strategies should include routine microscopic analysis of water samples for identifying harmful species in addition to gross measurements of water transparency or phytoplankton density by Secchi disc or chlorophyll measurements. Such monitoring need not be elaborate, time-consuming or expensive. When combined with actions designed to minimize losses in the presence of harmful algal events - such as cessation of feeding, towing cages to an unaffected area, and preemptive harvesting - it can be very cost-effective. This recommendation applies at present to coastal farms rather than inland (freshwater) farms where comparable harmful algal events have as yet not occurred.
- Research is urgently needed on the prevalence and ecotoxicology of cyanobacterial toxins in the freshwaters used for aquaculture in developing countries.
- Multidisciplinary research is needed to understand better the ecophysiology of harmful algal events in coastal areas used for aquaculture. This should include evaluation of relevance for application in developing countries of the monitoring protocols and management strategies developed by the ICES Working Group on Plankton and others who have considered approaches to understanding and mitigating the effects of these events in developed countries.

Wastewater Reuse in Aquaculture

The term 'wastewater' is used here in a generic sense to mean human excreta: whether fresh ('nightsoil'); in the form of sewage or wastewaters in the narrow sense (excreta, with added water to facilitate waterborne transportation); or other partially treated forms such as septage.

- The World Health Organization[1] recommendation that wastewater reuse should always be considered in schemes to improve sanitation is endorsed.
- More research on the public health aspects of existing wastewater-fed aquaculture systems is essential before they are further developed or promoted elsewhere. Such studies should include assessments of the risks and benefits to producers and consumers in addition to pathogen removal. Pathogen removal may occur in pretreatment and treatment processes before reuse of wastewater in aquaculture and during such reuse. Thereafter, aquaculture produce may also be treated for pathogen removal.
- Given that the scientific basis of wastewater-fed aquaculture was developed in Germany from the late nineteenth to the early twentieth century, culminating in the establishment in the late 1920s of the Munich sewage-fed fishponds (which are still in operation today), the voluminous German literature on the development of wastewater-fed fish culture should be comprehensively reviewed and the review published in English to facilitate global awareness and access.
- In wastewater-fed fish culture systems, the presence of industrial effluents should be closely monitored and minimized as much as possible. This is particularly critical for certain contaminants which may accumulate to relatively high concentrations in aquaculture produce; for example, mercury and hydrophobic pesticides.
- Wastewater should never be used for aquaculture without pretreatment. Fish should not be stocked in a wastewater-fed pond until it has an established and relatively stable community of plankton. This is important for pathogen removal. For raw sewage, a minimum detention time of 8-10 days in an anaerobic pond is recommended to remove settlable pathogens.
- A tentative critical density of $10^5 \cdot ml^{-1}$ total bacteria should not be exceeded in wastewater-fed fishponds, except locally for a few hours during loading of pretreated wastewater.
- Loading of wastewater into fishponds should be suspended for two weeks prior to fish harvest to eliminate *Cryptosporidium*. After harvest from wastewater-fed systems, fish should be held for at least a few hours in a suitable, isolated clean waterbody to facilitate evacuation of their gut contents.
- The threshold concentration of total bacteria in the muscle of fish harvested for human consumption from wastewater systems should not exceed $50 \cdot g^{-1}$. *Salmonella* should be absent.
- Viable eggs of human trematode parasites should be absent from wastewater-fed fishponds. Nightsoil should be stored for two weeks to eliminate such eggs before reuse in fishponds. For bilharzia (*Schistosoma* spp.) control, a carefully designed package of chemotherapy, health

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[1] World Health Organization. 1989. Guidelines for the use of wastewater in aquaculture. Report of a WHO Scientific Group. Technical Series No. 778. World Health Organization, Geneva.

education, improved sanitation and snail control in fishponds and other waters is recommended.

- Vegetation in wastewater-fed ponds should be kept to a minimum to reduce the breeding of insect and other disease vectors and intermediate hosts.
- The health and safety of farm workers in wastewater-fed aquaculture should be given particular attention.
- For consumers, good hygiene should be promoted at all stages of handling and processing fish (evisceration, washing, cooking) as these can be major sources of infection.
- The culture of molluscs in wastewater-fed systems is not advisable because of their propensity to accumulate large quantities of contaminants (for example, metals and pesticides) even when these are present only in trace amounts in the wastewaters employed. Finfish may be cultured under conditions where the culture of molluscs is inadvisable, due to the lower propensity of finfish muscle to accumulate certain contaminants. This should not, however, be accepted as a general rule. Each case should be considered on its merits.
- Culture of luxury aquatic produce, such as crustaceans and high value finfish, in wastewater-fed systems is not recommended as it may damage product image and cause marketing problems, especially for export produce. This could harm other existing or future aquaculture operations in developing countries.
- In societies in which the direct consumption by humans of fish cultured in wastewater-fed systems is socially unacceptable, wastewater reuse in aquaculture could be designed to produce fish or other organisms for use as high-protein components of feed for other animals, including carnivorous fish.

Reuse of Industrial, Agricultural and Agroindustrial By-Products in Aquaculture

By-products from industry, agriculture and agroindustrial processes are resources with potential for reuse in aquaculture. These include waste heat, effluents and solid residues.

- Few opportunities exist in developing countries to use industrial waste heat effluents for aquaculture. Since temperature is generally high in tropical and subtropical regions, the utility of waste heat to maintain temperatures slightly above ambient is usually of short duration and seasonal. If such use is considered to increase growth or in the management of broodstocks and hatcheries, these effluents need to be free from or contain acceptably low levels of contaminants. Moreover, the utilization in aquaculture of waste heat effluents from power stations may be difficult because this is generally not considered when a power station is planned and constructed.
- Organic residues or by-products (what is left after agricultural production on farms or following processing of agricultural produce in agroindustry) can be used directly, or after processing, as nutritional inputs to aquaculture systems. Such organic residues include the by-products of

animal husbandry (manure and slaughterhouse wastes), fisheries (trash fish and fish processing wastes), and the effluents of some intensive aquaculture systems.

- Organic residues from agroindustrial processing plants, in solid form or as effluents, may be used directly as feeds or as feed ingredients for farmed aquatic organisms or as fertilizers in fishponds. Their value as a nutritional input to aquaculture systems increases with their carbon to nitrogen ratio.
- Reuse of organic residues or by-products of agriculture, animal husbandry (and intensive aquaculture) in adjacent aquaculture systems comprises integrated farming. Agricultural and agroindustrial by-products are commonly traded as feeds or fertilizers for fish culture. Reuse of agroindustrial effluents as fishpond fertilizers is widely recommended but insufficient land to construct fishponds adjacent to factories (and intensive livestock and aquaculture systems) is a frequent constraint to the development of such integrated operations.
- Supplementation of agroindustrial effluents with inorganic fertilizers may be required to correct imbalanced C : N ratios and facilitate effluent reuse in fishponds, as a fertilizer to stimulate natural food production.

Standardization of Terminology, Units of Measurement and Format for Reporting

The implementation of basic knowledge in the development of aquaculture systems is not a unimodal scientific, engineering, economic, legal or political process but rather a complex combination of all of these. Fragmentary inputs from various disciplines, often derived from disharmonious efforts, have frequently resulted in the misuse and misinterpretation of terms and criteria, and consequently have led to incorrect applications and costly failures.

Intensification of aquaculture is associated with an increasing complexity of system design and component function which has not always been adequately described by researchers. The frequent misuse of aquaculture information is therefore not surprising. Descriptive and scientific information and technical data are used by people with widely differing professional backgrounds and objectives. Common examples include the establishment of standards for water quality, feeding practices, stock management, systems operation, technical advice and consultancies and economic judgements.

- It is, therefore, strongly recommended that those involved in aquaculture development take great care to avoid using, in ways that differ from their original usage and definition, terms derived from other disciplines.
- It is also recommended that extensive use be made of the terminology, units of measurements and formats defined by the Working Group of the European Inland Fisheries Advisory Commission (EIFAC 1986)[2]. This provides advice and definitions for the guidance of aquaculture researchers and developers who need completeness, consistency and clarity for their reporting.

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[2] EIFAC. 1986. Report of the working group on terminology, format and units of measurement. EIFAC Tech. Pap. 49, 100 p.

A Schema for Decisionmaking

First, the purposes of the development must be clearly stated and the aquaculture system(s) chosen to achieve those purposes fully described. Thereafter, evaluation should proceed along three parallel and, where appropriate, interactive lines of investigation: socioeconomic, technical and ecological. These lines of investigation are shown in the accompanying figure (p. 11).

For socioeconomic appraisal, the main questions are: who will benefit? will the benefits be sustainable? what are the social costs? who will bear these? Such appraisals should be at national, community, household and individual (gender, age group) levels. Attention must be given to land tenure, labor issues, resource access, property rights, marketing and distribution channels, fish consumption patterns, public health and gender issues.

The technical line of investigation asks whether the development is technically feasible and sustainable for the intended users, or whether more research is needed to solve problems and reduce risks. The ecological line of investigation is for determining acute and chronic effects on the ecology of the development site and other areas.

It is essential that reliable, *quantitative* tools be used along all three lines of investigation. Where lacking or deficient, these should be developed through further research. Bioeconomic modelling software is evolving for this purpose but needs further development, particularly for investigating and simulating interactions among aquaculture and other farm enterprises at household and community levels and among aquaculture and other sectors at local, national and regional levels. Similarly, ecological modelling tools exist but need further development for application to aquaculture development.

The results of the three lines of investigation are merged, using appropriate risk assessment and decisionmaking tools, to pose the question of acceptability.

The schema has options thereafter for acceptance and subsequent monitoring of the effects of the development (along the same three lines) or rejection/reconsideration.

Checklist for the Assessment of the Possible Environmental Implications of Aquaculture Development Projects in Developing Countries

This checklist is intended as a supplement to the above schema for decisionmaking. It summarizes the broad categories of environmental implications of aquaculture development under which policymakers and developers seeking to use the schema can identify and appraise situation-specific issues.

Conditions and likely impacts at the development site

- Consider existing problems (pollution, social conflicts, public health) and how aquaculture development will affect these.
- Predict the effects of aquaculture development on the ecology of the site (soil and water quality), on the health of wild and farmed organisms and on the environment for humans (farm personnel, their families and the farming community).

Conditions in and likely impacts on other areas that the development may affect

- Predict the effects on water availability and quality, abundance and genetic diversity of wildlife, natural habitats, the status of other human activities (especially agriculture, areas used for social amenities, forestry and tourism), and public health (through discharge of chemicals and facilitating the spread of waterborne diseases).
- Consider the ecological and social implications of the changes required in use and supply of resources, particularly land, water, labor, capital, energy, feeds, fertilizers, other chemicals including drugs, and stocking material (eggs, larvae, fry, fingerlings and broodstock).
- Ensure the safety, quality, acceptability and affordability of farmed produce for consumers, particularly with respect to levels of chemical contaminants, presence of pathogens and parasites, composition and nutritional value, and suitability for preferred storage and cooking methods.

A Schema for Making Decisions on New Aquaculture Developments

This schema opposite has been developed from a flowchart devised by the ICES Working Group on the Environmental Impacts of Mariculture (ICES 1989).* It provides three major pathways for evaluating the potential impact of aquaculture development in terms of socioeconomic interactions, technical aspects (state-of-the-art and management requirements), and ecological interactions. The boxed subject areas in these three columns are indicative of major considerations and are not given in sequential order of appraisal or relative importance. These will vary from case to case. A stepwise approach is essential to evaluate interactions within and among the three columns *before* the establishment of any aquaculture operation can be approved. For example, the type of aquaculture system and its scale will certainly affect the expected interactions at the proposed site (or area) while competition for water resources may prohibit the sustainable development of aquaculture even when environmental concerns are negligible. *Conversely*, effective and affordable technology for improved waste handling or reuse may permit the enlargement of aquaculture operations at a site or an area which otherwise has very limited assimilative capacity.

Integrated systems may not only improve the cost-effectiveness of aquaculture activities but may also make them environmentally acceptable. Some ecological impacts have been studied in detail (mainly in industrialized countries) and mathematical models have been formulated which can be used, with caution, as tools to estimate the extent of impact in some situations.

The interactions among columns and the overall decision on acceptability is made where the three boxes labelled 'Acceptable?' are interlinked. It is hoped that quantitative tools and appropriate software will be developed for this.

If the development is technically feasible and the anticipated impacts (socioeconomic and/or environmental) are acceptable, one can proceed with an accompanying monitoring program (see loop). Monitoring cannot, however, be an exercise on its own. It should serve a purpose (e.g., environmental protection, farm management, research for the advancement of knowledge, etc.). The data obtained through monitoring can be used in an iterative evaluation process to identify changes and trends in environmental quality. The results can be used for regulatory purposes and may lead to the identification of environmental quality standards.

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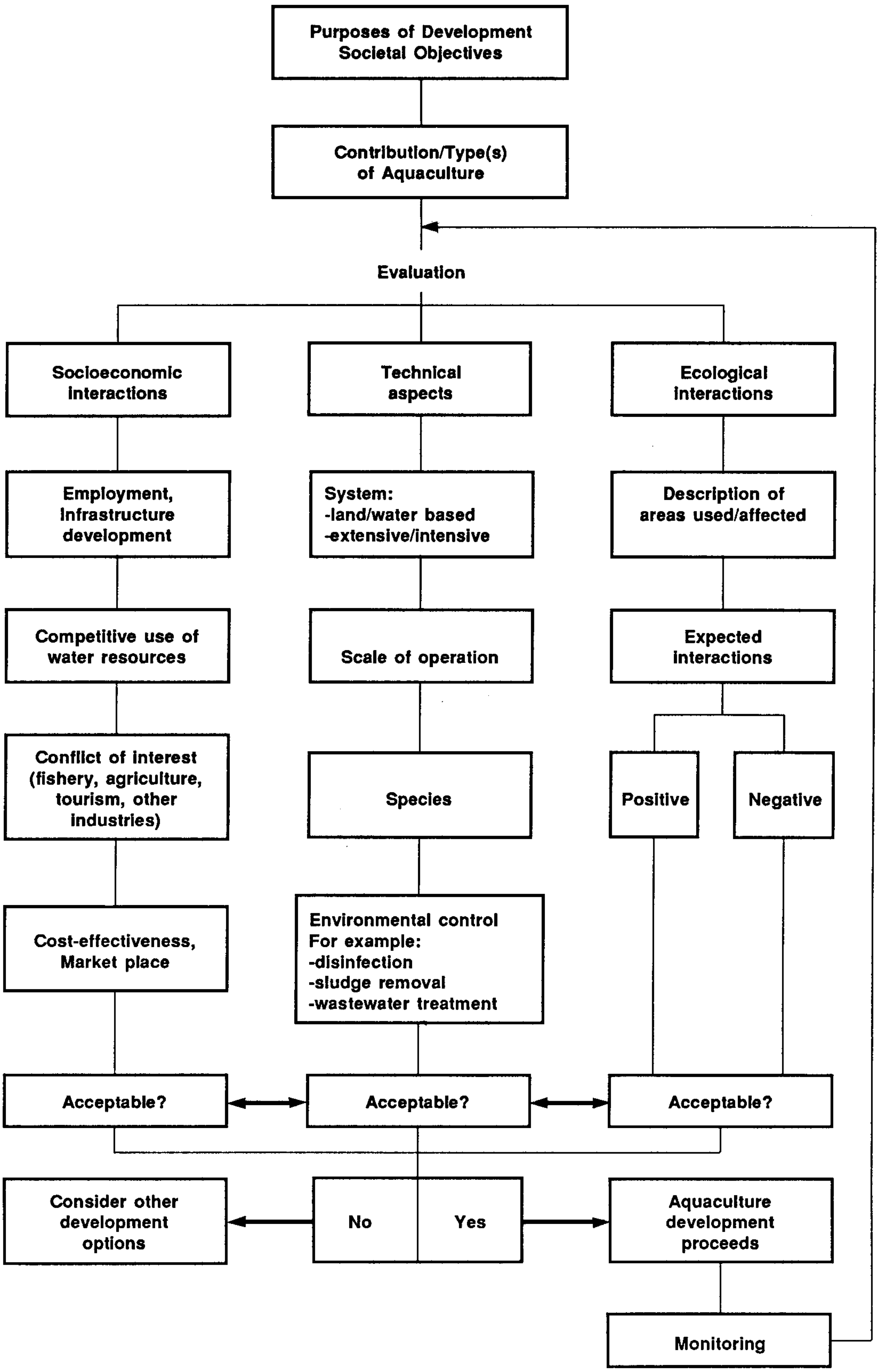
* *ICES. 1989. Report of the Working Group on Environmental Impacts of Mariculture. Figure 1. Flowchart on principal procedures for the evaluation of environmental impact of mariculture, p. 15. Marine Environmental Committee. Mariculture Committee. International Council for the Exploration of the Sea. C.M. 1989/F. Copenhagen, Denmark.*


Purposes of Development
Societal Objectives
Contribution/Type(s)
of Aquaculture
Evaluation
Socioeconomic
interactions
Technical
aspects
Ecological
interactions
Employment,
infrastructure
development
System:
-land/water based
-extensive/intensive
Description of
areas used/affected
Competitive use of
water resources
Scale of operation
Expected
interactions
Conflict of interest
(fishery, agriculture,
tourism, other
industries)
Species
Positive
Negative
Cost-effectiveness,
Market place
Environmental control
For example:
-disinfection
-sludge removal
-wastewater treatment
Acceptable?
Acceptable?
Acceptable?
Consider other
development
options
No
Yes
Aquaculture
development
proceeds
Monitoring

Appendix I
Conference Agenda/Papers Presented

Tuesday, 18 September
Session I; Introduction and Overview
Chairman : J.L. Maclean

- Opening Remarks - J.L. Maclean
- Welcoming address : background, purposes and organization of the conference - R.S.V. Pullin
- An overview of environmental issues in developing-country aquaculture - R.S.V. Pullin

Session II; Developing-Country Aquaculture and the Natural Environment
Chairman : H. Rosenthal

- Chairman's overview - H. Rosenthal
- The impacts of aquaculture development on socioeconomic environments in developing countries: toward a paradigm for assessment - K. Ruddle
- Aquaculture and management of freshwater environments, with emphasis on Latin America - M. Martinez-Espinosa and U. Barg
- Aquaculture and conservation of genetic diversity - S. Cataudella and D. Crosetti

Session III; Regional Issues and Experience
Chairman : M. Bilio

- Chairman's overview - M. Bilio
- Aquaculture development and environmental issues in the developing countries of Asia - I. Csavas
- Environmental aspects of aquaculture development in industrialized countries : lessons for developing countries - H. Rosenthal
- Aquaculture development and environmental issues in Africa - H. King
- Aquaculture development and environmental issues in Latin

America and the Carribean - E. Arellano
- Aquaculture development and environmental issues in the tropical Pacific - J.L. Munro

- Discussion; Chairman's summing up

Wednesday, 19 September
Session IV; Special Environmental Issues in Aquaculture Development in Developing Countries
Chairman : I. Csavas

- Chairman's overview - I. Csavas

- Environmental issues in integrated agriculture-aquaculture and wastewater-fed fish culture systems - P. Edwards

- Shrimp culture and the environment - Lessons from the world's most rapidly expanding warmwater aquaculture sector - M.J. Phillips, C. Kwei Lin and M.C.M. Beveridge

- Environmental management of coastal aquaculture practices and their development - T.E. Chua

- Environmental impact of tropical inland aquaculture - M.C.M. Beveridge and M.J. Phillips

- Environmental impact of marine cage aquaculture - R. Gowen

- Environmental issues in the control of bacterial diseases of farmed fish - B. Austin

Session V; Public Health Issues in Aquaculture Development in Developing Countries
Chairman : K. Bögel

- Chairman's overview

- Aquaculture development and water-borne diseases in developing countries - V.S. Palmer

- Aquaculture and toxic algal blooms in developing countries - J.L. Maclean

- Microbial safety of farmed aquatic produce in relation to the environment - N. Buras

- Aquaculture and trace environmental contaminants in developing countries - D.J.H. Phillips

- Discussion; Chairman's summing-up

Thursday and Friday,
20-21 September
Session VI; General Discussions Leading to Formulation of Recommendations
Chairmen : F. Moriarty, R.S.V. Pullin and H. Rosenthal

Thursday, 20 September
Environment-Aquaculture Interactions
Chairman - R.S.V. Pullin

- Adoption of discussion agenda; suggestions for additional topics.
- Chairman - K. Bögel
  Theme - People (Producers/Consumers)
- Chairman - F. Moriarty
  Theme - Natural Resources (Living/Nonliving)

Friday, 21 September
Future Action/Recommendations
Chairman - H. Rosenthal

- Mechanisms/Priorities for Future Action: Policy/Research/ Development Projects
- Preparation of Draft Recommendations
- Chairman - M. Bilio
  Discussion and Adoption of Recommendations

Appendix II
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International Center for Living Aquatic Resources Management

The International Center for Living Aquatic Resources Management (ICLARM) is an autonomous, nongovernmental, nonprofit, international scientific and technical center which has been organized to conduct, stimulate and accelerate research on all aspects of fisheries and other living aquatic resources.

The Center was incorporated in Manila 20 January 1977 and its operational base was established in Manila in March 1977.

ICLARM is an operational organization, not a granting entity. Its program of work is aimed to resolve critical, technical and socioeconomic constraints to increased production, improved resource management and equitable distribution of benefits in economically developing countries. It pursues these objectives in the fields of aquaculture, capture fisheries management, coastal area management, and information through cooperative research with institutions in developing and developed countries. ICLARM's work is international. The programs of ICLARM are supported by a number of private foundations and governments.

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