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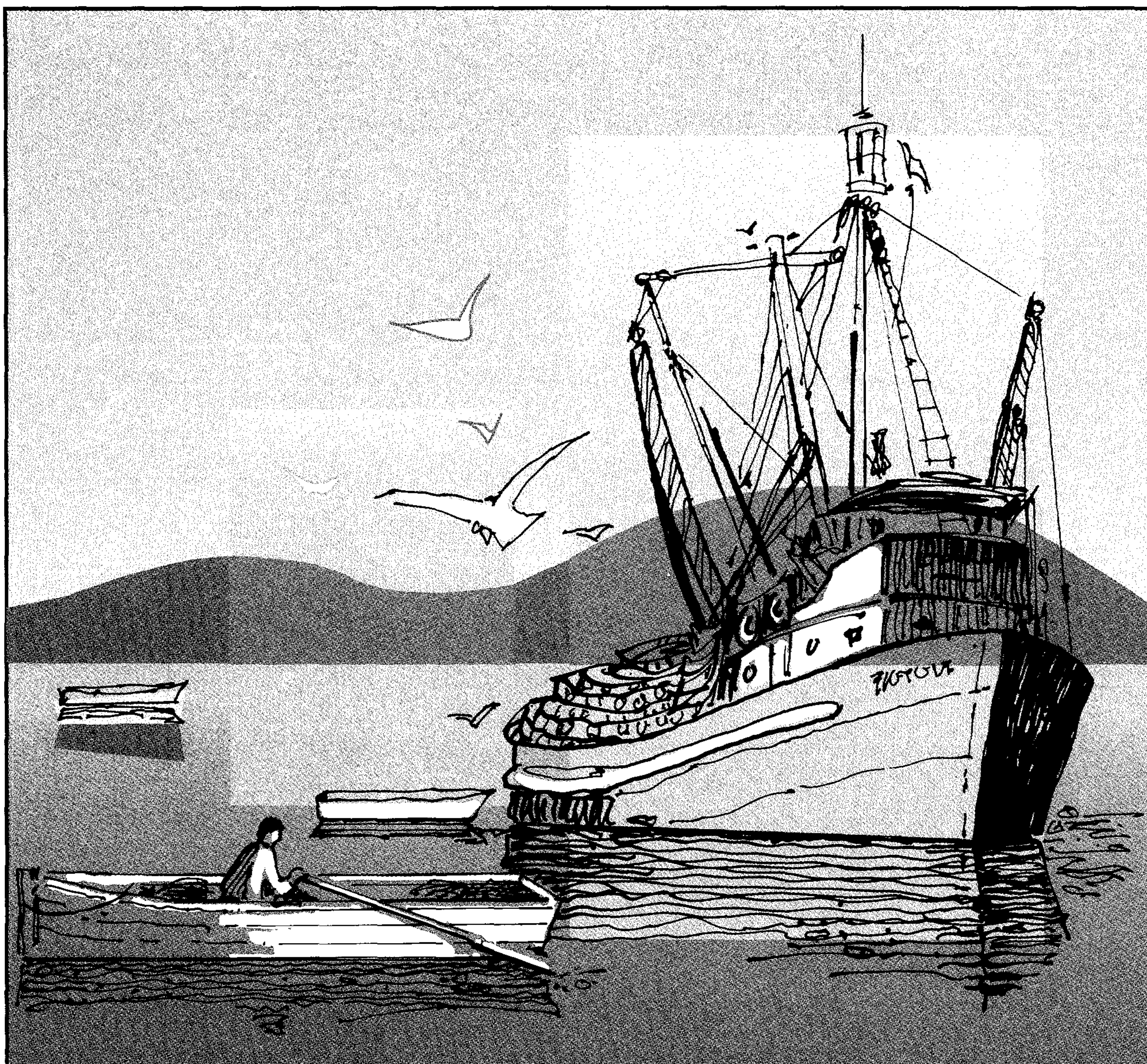
Tropical Aquaculture Development

Research Needs

The World Bank/United Nations Development Programme/Commission of the European Communities/Food and Agriculture Organization



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ABSTRACT

This report embodies the findings of the Working Party on the "Research Needs of Tropical Aquaculture Development". The Working Party conducted its deliberations in two sessions. Session 1 examined research needs from a development perspective and formulated general principles on research priorities. Session 2 dealt with research opportunities from the scientific viewpoint. It also reviewed potential applications to aquaculture that may arise from future scientific developments.

Current weaknesses affecting national research capacities and approaches to enhance international co-operation in aquaculture research were also discussed during the two Working Party sessions.

ACKNOWLEDGMENTS

The Members of the Mission are grateful to the following agencies for supporting this study:

Multilateral Agencies: (Steering Committee) The World Bank; United Nations Development Programme; Commission of the European Communities; and Food and Agriculture Organization.

Bilateral Agencies: DANIDA — Danish International Development Agency; AIDAB — Australian International Development Assistance Bureau; ICOD — International Centre for Ocean Development (Canada); NORWAY: ICEIDA — Icelandic International Development Agency; SIDA — Swedish International Development Authority; ODA — Overseas Development Administration (United Kingdom); ITALY; FRANCE; USAID — United States Agency for International Development; THE NETHERLANDS; GTZ — Deutsche Gesellshaft fur Technische Zusammenarbeit (Germany).

FOREWORD

This Technical Paper is one of seven mission and working group reports prepared during the Study of International Fishery Research (SIFR) in 1989-90. The juxtaposition of potentially high socio-economic benefits from fisheries and the relatively low level of success achieved in fisheries development projects has been a matter of serious concern and challenge to the donor community as well as to national fishery administrations. In view of this, the First Fishery Development Donor Consultation held in 1986 decided to undertake a Study of International Fishery Research to determine ways in which research could bring about improvements. This comprehensive effort has now been completed, thanks especially to the effective financial support of a group of multilateral and bilateral donors and the essential intellectual contributions made by virtually hundreds of professionals from academia, fishery administrations and donors who were associated with various stages of the Study.

The objectives of the Study were to identify the specific constraints to fisheries management and development (including aquaculture) posed by the lack of information or the inaccessibility of existing knowledge; to determine high priority research needs; to examine the capacity of developing countries to undertake research; and to propose a strategy and an action plan for improving donor support. It was carried out through a series of missions and by four working groups which addressed specific research topics under the direction of a Study Team Leader and a Deputy. SIFR identified a number of key strategic research areas which are vital for the future development of the sector. Institutes in developing countries may not immediately be able to carry out all of this research, but the Study clearly identifies them as the ultimate beneficiaries of its thrust. In the meantime, countries with important fishery resources and the willingness to further develop their research for improved management and sustainable use of their resources should be assisted in drawing up national research agendas and building up their capacities. In this context, the findings of regional missions are a useful starting point. This volume contains the report of the Working Party on "Tropical Aquaculture Development: Research Needs" and is intended as background information to support the main study which is being Published as "Study of International Fishery Research".

I wish to express my sincere thanks to the fisheries researchers, and fishery administrators in developing countries, as well as the leaders and members of the missions and Steering and Advisory committees for their vigorous effort and thoughtful contributions. It is my sincere hope that these Technical Papers will prove stimulating and provide practical guidance to donors, research institutions and fishery administrations in making progress toward sustainable resource utilization and the realization of new opportunities from fisheries and aquaculture in developing countries.

Michel J. Petit

Director, Agriculture and Rural Development Department

ACRONYMS

CGIAR	Consultative Group on International Agricultural Research
COPRAQ	Cooperative Program for Aquaculture
EIFAC	FAO's European Inland Fisheries and Aquaculture Committee
WHO	World Health Organisation

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Tropical Aquaculture Development: Research Needs

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Paris (France), 5 - 14 September 1989

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I. INTRODUCTION

A Study of International Fishery Research needs in developing countries (SIFR)[1] has been undertaken under the auspices of a group of multilateral and bilateral development and donor agencies[2]. The study sought to determine:

(i) the priority needs for fisheries and aquaculture research;

(ii) the present capabilities of developing countries to undertake the research that is needed; and

(iii) the ways in which donors could contribute effectively in supporting desirable investigations.

The decision to undertake the study was based on three considerations:

(i) the recognition that, during the past decades, development projects have had in average a low rate of success[3], and the desire of aid agencies to have a diagnosis of the sector to see whether development approaches could be improved by a better appreciation of the sector particular features and dynamics;

(ii) the suggestion, made on several occasions, to extend CGIAR activities to aquaculture research, to promote the development of small scale operations in developing countries;

(iii) the desire of donor agencies to improve, through better coordination, the impact of aid to research.

The Study was asked to assess the research needs for the next 25 years, and to propose a strategy for action for the next 10 years. The review, therefore, focused on strategic aspects.

The assessment of research capacities was carried out through a series of missions to selected groups of countries, while research needs and opportunities were evaluated in various ways, notably through the holding of working parties on research topics justifying special appraisal[4].

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1 A list of acronyms is given on page viii.

2 SIFR, 1989 - "Assessing Fisheries Research Needs in Developing Countries. An Assessment and a Framework". First Meeting of the Advisory Committee, Washington, DC, USA, May 15-17 1989.

3 World Bank, 1984 - "Harvesting the Waters. A Review of Bank Experience with Fisheries Development". The World Bank, Operations Evaluation Department, Report N0. 4984.
" ", 1986 - " World Bank Paper on Harvesting the Waters. A Review of Bank Experience with Fisheries Development". Fisheries Development Donor Consultation, Paris, France, Oct. 13-15 1986

4 For a presentation of the SIFR plan of work, the reader is invited to consult the following document: SIFR, 1989 - "Assessing Fisheries Research Needs in Developing Countries. An Approach and a Framework'. First Meeting of the Advisory Committee, Washington, DC, USA, May 15-17 1989.

2. OBJECTIVES, SCOPE AND ORGANIZATION OF THE MEETING

A Working Party was specially devoted to aquaculture. This was justified by the importance of traditional aquaculture and the recent take-off of new systems, but also by the disparity of development performances with respect to production systems, target groups or geographical areas.

The Working Party was organized in two separate sessions. Session 1 examined research needs from a development perspective. Because the respective prospects of production systems differ markedly according to local conditions, and research needs change between systems as well as with their development stages, this approach was expected to yield general principles on research priorities that are masked by the diversity of needs at the species, discipline, or region levels. Such general principles are needed to formulate a strategy for international cooperation.

Session 2 looked at research opportunities from the angle of scientific disciplines. It reviewed potential applications to aquaculture that may arise from future scientific developments. This prospective examination of research opportunities was necessary for two reasons: (i) the infant stage of aquaculture, and (ii) the long time horizon given to the Study.

Although the time perspective of Session 1 was shorter, the review of research needs for development is made more difficult by the complexity of development under different ecological, economic and social contexts.

Current weaknesses affecting national research capacities, and approaches to enhance international cooperation in aquaculture research were also discussed during the two sessions. This was not, however, the primary objective of the Working Party, since fields missions were organized for this specific purpose[5], and international cooperation in fisheries research was the topic of a special working party[6].

The meeting on research needs for aquaculture development was part of the fact finding phase of the Study. Its report was an input to the Study. Its outcomes had to be integrated into an overall diagnosis and a strategy for international aid to fisheries, aquaculture and environmental research. Therefore, the present report does not contain formal proposals. Those are presented in the Final Report of the Study.

The agendas originally prepared for the two sessions are given in Annex 1. To ensure continuity in the discussions, some participants took part in the two sessions. The list of participants is given in Annex 2.

The work of Session 1 is reported in Sections III to V, while Section VI gives the conclusions of Session 2. Accounts of the discussions on the state of aquaculture research and on possible arrangements for international cooperation are given in Sections VII to VIII.

5 Respectively in Northwest Africa, Southeast Africa, India, ASEAN countries, Southwest America, Southeast America, and small island countries (see SIFR Reports No 5-11).

6 See SIFR Report No 15.

3. DEFINITIONS

THE IMPORTANCE OF FISH

In assessing the importance of fish and the role of aquaculture, the Working Party noted that, although on a global basis, fish is not a dominant source of animal protein and is still less important in terms of energy supply, aggregate statistics mask the fact that, in certain regions such as South-East Asia and in several parts of Africa, fish is the most important source of animal protein. It further observed that, though aquaculture still contributes moderately to the global supply of aquatic products directly by human consumption, the unit value of its output is substantially higher than fishery products, and new large- scale systems - e.g., shrimp, are contributing significantly to export earnings in certain developing countries.

Potential for expansion of aquaculture is large, even if its limits cannot be determined owing to the impossibility of assessing the aggregate effects of ecological, biological, technical, economic, social and institutional constraints affecting its development. The situation is different in fisheries which are bound by the natural productivity of wild stocks. Corresponding potential yields have been assessed.

THE ROLE OF AQUACULTURE

The current importance of aquaculture and its likely trends are difficult to estimate accurately on the basis of available statistics, particularly because yields are not properly separated between fisheries and major aquaculture systems. World aquaculture production is assumed to have reached 12 millions tonnes in 1987, and to grow at a pace of about 5 percent annually. Although this represents a significant and expanding component of the fishery sector, these aggregate statistics mask strong heterogeneities with respect to cultivated ecosystems, modes of production and regions. Production increases are still limited, on the one hand, to geographic areas where activities of economic significance existed before technical assistance programs were initiated and, on the other hand, to initiatives for large-scale operations taken independently by the private sector. In physical terms, 80 percent of the reported yield come from Asia, and 12 percent from Europe. Production has not taken off in rural areas of Africa and Latin America.

For the definition of aquaculture, the Working Party started from the one used by FAO for collecting fishery statistics (which excludes open systems of production). To the systems falling under this definition, it added culture-based fisheries and ocean ranching, since they correspond to human intervention - i.e., the artificial stocking of fry or spat - which is not a component of fishing.

It further noted that the existence of property rights for the use of fish stocks is not a criterion to separate aquaculture from fishing. Such rights have existed in traditional fishery systems, and are now being introduced in certain countries. In addition, open aquaculture systems are affected by shortcomings in access right systems similar to those encountered in fisheries (see PP 18-23). The history of agriculture shows that exclusive rights tended to extend over the various factors of production and to become formalized, as the natural resource - i.e. the land, became scarce, and its use intensified through technical innovations and capital investment. Today, fisheries and aquaculture are in a similar situation.

In aquaculture, production increases can result from:

(i) extensification, i.e., the expansion of existing systems into new areas; and

(ii) intensification, either through increase in stock density within a farming system characterized by a certain pattern of controls over the resource variables (i.e., the environment, the stock, and the organisms), or through the diversification of systems by the extension of controls over new resources variables.

Thus, the concept of intensification is ambiguous. It covers three distinct approaches to definition. In addition to the increase in stock density within a system and to system diversification, economists, when analyzing intensification, refer to the degree of investment in capital and/or labor per unit of stock or output.

THE KINDS OF RESEARCH

Finally, the Working Party examined its terms of reference with respect to research. In the field of science and technology, research can be defined as the set of intellectual investigations and practical experiments that are conducted for the development of new theories, laws and techniques. From the acquisition of knowledge to application, different kinds of research can be distinguished depending on its objectives and modes of operation.

Adaptive research consists of applications of available scientific methods for the improvement of existing production systems. It is demand-driven. Because its significance for development and management is direct and immediate, it generally enjoys a high demand. Problems are relatively easy to identify and to formulate. Feasibility of investigations and probability of success are high. Investigations are basically deductive. One important condition of effectiveness is the complementarity of investigations which have to be conducted simultaneously to match the multi-faced nature of development and management issues. Applied research has to be multi-disciplinary.

When production systems are bound by constraints that cannot be properly overcome using available theories and methods, or when the purpose is to develop new systems, or to introduce existing ones in regions where conditions differ, investigations of a more strategic nature are needed. New methods, approaches, and sometimes theories, have to be developed. This is the field of innovative research.

The conceptualization of new theories is intuitive; their validation is still deductive. The conduct of innovative research requires a knowledge of likely future developments of disciplines. Innovative research requires academic qualifications, a proper scientific environment, an adequate degree of autonomy, and funding that matches the span of investigations.

4. A SYSTEMS APPROACH FOR ANALYZING RESEARCH NEEDS

WEAKNESSES OF PAST RESEARCH APPROACHES

As an introduction to Session 1, Professor P. Edwards made the following remarks:

- so far, research for aquaculture development has been conducted along disciplinary lines, essentially by zoologists; this has been a major impediment;

- the recent involvement of social sciences, economics and resource management in aquaculture research corresponds, therefore, to a real need;

- for short-term applications, a systems approach in aquaculture research will be most beneficial in terms of immediate impact on development;

- but, for sustaining this development, longer-term innovative research, organized along specialized disciplinary lines is also required, although a systems approach still remains necessary;

- when analyzing research needs, it is useful to think of aquaculture development in relation to agro-ecological zones and to address the following questions:
  - is aquaculture technically feasible?
  - is aquaculture economically profitable?
  - is aquaculture socially suitable?
  - is aquaculture environmentally sustainable?

- with such appraisals, aquaculture development options can be modelled for different agro-ecological zones, keeping in mind that small-scale aquaculture must be considered in the broad context of rural development, with due regard to the socio-economic circumstances of the communities; aquaculture may not always be a feasible option and should not be promoted uncritically;

- aquaculture development can proceed by attracting new entrants or, with adequate adaptations, by introducing existing systems among new groups; by improving existing systems; or by developing new ones. In each case, the approach will differ, but the dominating factors for success will be the socio-economic organization of existing or potential producers, human motivations, knowledge, and supply demand.

THE CONCEPT OF FARMING SYSTEM

The absolute level of development and the current growth rate of aquaculture vary considerably between regions. Such disparities cannot be explained by differences in natural conditions only, nor in the availability of techniques or species.

Fish production can be intensified by extending man's control over different functions and variables of the cultivated organisms, the stock and their environment. Not all combinations of variables can, or need to, be simultaneously controlled. The concept of farming systems reflects the existence of relationships between resource variables: only certain patterns are ecologically, biologically and technically viable.

To give examples, the development of open modes of cultivation (seaweed and shellfish culture, culture fisheries, salmon ranching, ...) depends on the simultaneous ability to: (i) produce or collect, fry or spat, of adequate quality; (ii) effectively enhance the recruitment of populations in open ecosystems; and (iii) recapture a sufficient proportion of the released organisms (a condition which itself depends on stock accessibility at a proper stage of its life-cycle) and of the existence of adequate access rights. But no other control is initially required.

Similarly, in semi-controlled and controlled systems, intensification and diversification are effected by stimulating the productivity of the cultivated milieu, by optimizing the configuration between the cultivated stock (species, density) and its environment (food, pollution, wastes,...), and by extending man's control over the organisms (sex, gene pool, diseases,...). This optimization is done through the manipulation of three functions: production, consumption and decomposition. The production function is enhanced through the provision of nutrients within the cultivated environment (fertilizers, nutrients); and consumption, through the supply of feed produced outside the culture unit.

In addition, the sets of variables that need to be controlled within a given system changes with its development stages. In open modes, the optimization of mature systems requires that the total stock biomass is adjusted to the "carrying capacity" of the cultivated environment. This is essential to prevent the negative effects of density-dependent processes (decline in growth rate, increase in mortality - including higher susceptibility to diseases). Similarly, in semi-controlled and controlled systems (e.g., in feedlot systems), the decomposition function can be stimulated by aeration to prevent waste becoming limiting.

The systems approach underlying the concept of farming system has several important implications on development and research effectiveness. It puts emphasis on:

(i) the comprehensiveness of systems: the object - e.g, the species or a specific environment - under investigations is part of a whole; it is its function in the system which matters; a component alone does not make a system;

(ii) the system structure determines the relevance of investigations which have to be conducted simultaneously;

(iii) since it is the goal which determines the scope of research agendas, research must be targeted; the selection of development targets should precede the development of techniques; and

(iv) the approach is 'bottom up' and not 'top down'; it recognizes that the farmer has good reasons to do what he does (see below).

CHARACTERIZATION OF FARMING SYSTEMS

The Working Party started from diagrams displaying aquaculture systems in Asia, their relationships and evolution through time. Aquaculture systems were then classified in six categories on the basis of:

(i) the dimensions of water bodies used for cultivation, and

(ii) the degree of controls over the resource variables.

The significance of the terms used in the headings of rows and columns of Table 1 is as follows:

(i) Farming systems and size of water bodies:

- Open seas:

Ranching of fish through the recruitment enhancement of wild or artificially created populations; applies essentially to fish;

- Open waters (coastal):

Stocking of fish in large coastal ponds, lagoons, fjords, estuaries; applies to finfishes, molluscs, crustaceans and other invertebrates, and seaweeds; includes the physical management of habitats (artificial reefs, "acadjas", fish aggregating devices;

- Open waters (inland):

Stock enhancement of natural or artificially created fish populations (capture fisheries) in inland lakes, large ponds, reservoirs, oxbows, swamps, floodplains; applies mainly to finfishes;

- Intermediate (water based):

Farming of finfishes, crustaceans and plants in pens, cages, or other structures in fresh and brackish waters; includes new systems , such as "acadjas-enclos"; natural feed produced in situ is a major contribution to production;

Table 1. Matrix of the major categories of aquaculture systems and the variables that control their development

	startup	*mature*	*startup*	*mature*	*startup*	*mature*	*startup*	*mature*	*startup*	*mature*	*startup*	*mature*
Ecosystem												
Productivity	0	0	1	2	1	3	1	3	3	2	0	0
Scale	0	0	0	1	1	2	3	1	3	1	2	2
Quality	1	1	3	3	3	3	3	3	2	2	3	3
Recruitment	3	3	3	3	3	3	0	0	1	1	0	0
Stock												
Seed	3	3	3	3	2	2	2	2	2	2	2	2
Feed	0	0	0	0	0	0	2	2	2	2	3	3
Breed[a]	0/3	0/3	0/3	0/3	0/3	0/3	3	3	3	3	3	3
Population	1	3	1	3	1	3	3	3	3	3	2	2
Disease	1	2	1	3	1	3	1	2	1	2	3	3
Catchability	3	3	3	3	3	3	1	1	1	1	0	0

0=No Effect; 1=Some Effect; 2=Strong Effect; 3=Limiting Factor

a. 0 = reliance on wild seed; 3 = use of strains bred in hatcheries, including exotic germplasm.

- Intermediate (land based):

Farming of finfishes, crustaceans and plants in ponds,and integrated agro-aquaculture systems; occupies land, usually in farming areas; natural feed produced in situ is a major contribution to production;

- Controlled:

Farming of finishes and crustaceans - possibly seaweeds in the future, in ponds, tanks, cages, raceways, silos, recirculation systems, in which production depends entirely on the supply of formulated feeds.

(ii) Ecosystem

– Ecosystem:

The total environment used, affecting, and affected by cultivation;

– Productivity:

The food used by the cultivated stock, which is developed in situ in the environment, whether stimulated or not by exogeneous inputs such as fertilizers and offals;

– Scale

The size of the farming unit, ranging from small-scale farms to large-scale, corporate, operations;

– Quality

The "health" of the cultivated environment considered from the viewpoint of performance, ranging from adverse effects of pollution and toxic blooms in open waters, through the release of pollutants such as pesticides in semi-intensive systems, to the "self-polluting" capacity of more intensive systems, in terms of BOD, suspended solids and metabolites;

(iii) Stock

– Stock

The group of organisms cultivated as a unit;

– Seed

The supply of early life history stages (eggs, larvae, fry, spat, fingerlings) of the cultured organisms for "grow out" in the culture system;

– Recruitment

The processes and the resulting number of new fry or spat contributing to the stock renewal and production; this includes the fry or spat collected in the wild or artificially produced, and subsequently released in natural ecosystems;

– Population

In the strict sense, a natural, genetically discrete, self-sustainable group of organisms within a species;

– Breed

The genetic characteristics of a cultivated stock in relation to its specific culture environment; synonymous to strain, rather than to population or species;

– Feed

The food items provided from outside the cultivation unit to the stock, as opposed to the in situ production of natural food (productivity);

- Diseases

The impact of pathogens and parasites upon the cultivated stock and organisms;

- Catchability

The ease of harvesting of the cultivated stock and organisms.

In the matrix thus developed (Table 1), the relative importance of the variables characterizing each set of systems at the take-off and mature stages of their development have been indicated by the numbers in the table.

Actually, these six categories of farming systems can be further reduced into three, each reflecting a major step in the extension of man's control over the resources:

- Open systems:

Human intervention consists essentially of seeding natural, open ecosystems. These systems (shellfish, seaweed, capture fisheries, ranching) are associated with large marine or freshwater bodies, whose size precludes or strongly limits the possibility of other interventions.

- Intermediate systems:

In addition to stocking, human intervention extends to the stimulation of ecosystem productivity for the production of food; controls of certain biological functions (complementary supply of feed, genetic selection, disease control, ...) are initiated. Such systems correspond to water bodies (mainly inland) whose size is small enough to permit partial controls of the habitat and the stock.

- Controlled systems:

Human interventions are firmly established over the cultivation milieu, the stock (sex, gene pool) and the major biological functions of organisms (reproduction, nutrition, diseases). Conversely, in technically advanced systems, the use of the environment is reduced to that of a physical support. However, systems based on natural water supplies remain dependent on the environment quality. This is feasible only in small volumes. Being more independent of the natural environment, they are found in both small and large, fresh and marine, water bodies.

PRODUCTION SYSTEMS

Patterns of control variables are not restricted to the technical dimensions of cultivation modes. Similar relationships exist also in the economic mechanisms and social organizations that govern and structure the production function. The concept of production systems[7] recognizes the existence of links, not only at the technical level (which determine the productivity of natural resources), but also at economic, social and institutional levels, and between these different layers. In the history of rural societies (from hunting-gathering to industrial farming), technological innovations and changes in institutions have been permanently interacting and developing in step, as resource use intensified. For example, for the extensification and diversification of open systems, the adoption of adequate access rights is as critical as the release of fry or the effective enhancement of recruitment of the population. The concept of production systems emphasizes the importance of an holistic, as opposed to a reductionist, approach in agriculture development.

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7 For an introduction to the concept and bibliographic references, see for example: Brossier, J., 1987 -"Systeme et systeme de production". ORSTOM, Cah. Sc. Humaines, **23**, 3-4: 377-390.

Coherence within a production system is achieved first by the production unit: in small-scale agriculture particularly, the household is the backbone of the system. In polyculture systems, for example, where livestock, agriculture and aquaculture crops are combined, only certain assemblages of production are economically and socially feasible. Inputs and outputs between the different modules must be balanced.

The production function can be carried out by units of different size, interacting with other production and consumption units under different mechanisms of exchange, social organizations and institutional set-ups. These links determine certain socio-economic structures. Major sets of production systems can be distinguished according to the socio-economic structure of the production process (subsistence[8], semi-commercial, small-scale and large-scale commercial modes of production). Understanding these relationships is important for analyzing the advantages of production systems with respect to respective opportunities for intensification, extensification, diversification, given the prevailing ecological conditions, economic circumstances, target groups, and overall development goals (Table 1).

Relationships between social organization, types of economies and technological solutions are particularly important in small-scale, traditional systems. In such systems, the mobility of production factors is commonly lower. Risk minimization and family or group persistence can be more critical than profit maximization. When actions - e.g., transfer of technological innovations, are not matched to existing economies and social organization of target groups, development will not be feasible.

Relationships observed between farming and production systems can be interpreted. However, the correspondence between bio-technical solutions and socio-economic organizations are not as strict and permanent as those sketched in the presentation of farming systems. For example, the production of artificial feeds, or of selected seeds, and processing and distribution are the first to be industrialized. For the "grow out" phase, family business remains common, either because it presents advantages - e.g., when certain tasks require particular care whose quality is better or more easily ensured through family bounds -, or because of the land ownership regime, or for other reasons. If, in the development of agriculture, a long-term trend towards intensification, commoditization (concentration on fewer commodities), industrialization and extension of wage labor is observed, the process is considerably less advanced in aquaculture. Most of the world aquaculture production comes from open and intermediate systems operated by small-scale operators. Most controlled systems are operated under large-scale, capital-intensive, enterprises; their geographic extension is still extremely limited.

Table 2. Relative importance of potential benefits by major categories of production systems and commodity groups

Commodity Groups	*Net Revenue*			*Employment*			*Food*		
	O	I	C	O	I	C	O	I	C
Seaweeds	3	3	3[a]	3	2	1	2	2	1[a]
Molluscs	3	2	-	3	2	-	2	2	-
Crustaceans	3	3	3	3	2	1	1	1	1
Finfishes	3	3	3	1	2	1	3	2	1

Symbols: O = open (extensive); I = intermediate (semi-intensive); C = controlled (intensive); - = not relevant; 1 = little importance; 2 = important; 3 = very important;
a. Applies to intensive culture in closed systems;
b. Does not include pearls.

8 Subsistence refers to self-consumption, and the exchange of fish against goods or services, through barter mechanisms within the group, and with other related groups.

As environmental and stock descriptors have been used to characterize farming systems, economic and social variables can serve to analyze the relationships structuring production systems. Among the relevant criteria are:

- the degree of specialization:
  - exclusive/full-time,
  - dominant/part-time, with emphasis,
  - co-dominant/part-time (50/50),
  - occasional/part-time (marginal);

- the type of labor/ownership:
  - kinship based,
  - family based,
  - corporate/communal,
  - corporate/private,
  - individual/private;

- the size of the production unit:
  - large/medium/small,

- the degree of maturity:
  - experimental (2-10 years),
  - recent (up to 25 years),
  - ancient/stationary,
  - ancient/mature;

- the balance between the production factors (intensity): resources (land water, stock, space), capital, labor:
  - extensive/semi-intensive/intensive;

- the nature of the labor process:
  - owner operated,
  - simple cooperation (simple operations, few people),
  - extended cooperation.

IMPLICATIONS FOR DEVELOPMENT AND RESEARCH STRATEGIES

In agriculture, the interest for the concept of production system was prompted by repeated failures of development approaches concentrating on technical solutions for enhancing resource productivity, and neglecting the farm and the farmer. Aquaculture development has not avoided the same bias. So far, development projects tended to concentrate on technical aspects and to be justified in terms of needs - e.g., the reduction of rural poverty, or of the supply gap created by the full exploitation of wild stocks. Unfortunately, there are no particular reason for those in the greatest need to be in a better position to grasp new aquaculture opportunities. "Economy does not operate to fulfill man's needs. Needs are as infinite as human dreams. Economy produces goods to satisfy the demand, and the demand is as small as the customers' wallet" (Keynes).

Not surprisingly, attempts at developing small-scale aquaculture in regions where there is no significant commercial production have been particularly deceptive. Progress in aquaculture production is largely restricted to traditional systems in regions where they developed centuries ago, or agriculture is relatively advanced (Asiatic and European inland fishculture, bivalve molluscs or seaweeds systems), or to large-scale operations in the developed (salmon in Norway, catfish in the USA) as well as in the developing (salmon in Chile, shrimp in Ecuador and South-East Asia).

Potential target groups and technical solutions (farming systems) would be better chosen, if selections were based on prior analyses of production systems and their likely developments. So far, typologies of aquaculture systems have been limited to biological and technological aspects - i.e., to the farming systems. However, production systems have seldom been analyzed thoroughly. Considerable experience is available in the history of agriculture, and certain disciplines (e.g., economic anthropology) would contribute to the formulation of sounder aquaculture development strategies. In the development of small-scale aquaculture in particular, it is the ecological and socio-economic conditions that determine the choice of technological solutions, and not the reverse. It is when the systems become controlled and large-scale that they become less site and group specific. Since they do not imply immediate basic changes in the socio-economic organization of producers, open aquaculture systems, for example, may well be better suited for enhancing fish production in traditional communities in continental and coastal areas.

More generally, development constraints are likely to differ structurally between:

(i) the improvement of existing systems and the introduction of new ones;

(ii) and between small-scale and large-scale operations.

When dealing with existing systems, the basic biological, economic and social factors have been matched into viable solutions. Constraints, as well as opportunities for improvement, are restricted to few aspects. Experienced producers are present. They are likely to assimilate technological innovations, step by step, and to capitalize upon them. Conversely, in the introduction of new systems, all factors which determine their feasibility have to be apprehended simultaneously. An overall experience is missing. In most cases, the chances of success of transferring arbitrarily selected technical solutions, from the top down, are negligible.

Small-scale and large-scale systems differ significantly with respect to the respective mobility of production factors, and their access to markets. Economies of scale are also different. Economic and social constraints are likely to be particularly tight for rural groups of small-scale producers, living at the limit of poverty.

The adoption of a systems approach has implications on the kinds of expertise required for project identification and formulation. The probability of success will be improved if projects, instead of being identified and formulated in isolation by disciplinary specialists, were components of long-term development policies, based on prior multidisciplinary analyses involving the required range of professional expertise. The systems approach requires inputs from resource economists and sociologists (particularly for the small-scale sector) with experience in aquaculture.

For shaping international cooperation in tropical aquaculture research, the concept of production systems can provide a framework and a rationale for formulating a strategy and scheme which would overcome the diversity of research needs and the dispersion of efforts, which characterize assessments of research needs by species, disciplines or geographic regions. If a few inter-connected programs could be initiated on major research areas determined by needs of presently and potentially dominant aquaculture systems in tropical regions, the somewhat antagonistic requirements of geographic distribution, discipline coverage and program comprehensiveness would be easier to satisfy.

5. RESEARCH NEEDS FOR TROPICAL AQUACULTURE DEVELOPMENT

ECOLOGY, BIOLOGY AND ENGINEERING

The Working Party started from the information contained in Table 1 to identify and rank research needs in ecology, biology and engineering. Relevant disciplines were determined by the variables that are controlled in each farming system. Tables (Annex III) indicating the relative importance of research disciplines and the time period of investigations involved (short: 10 years; long: up to 25 years) by major systems and commodity groups were prepared.

Important observations on research needs in relation to opportunities for intensification and diversification, and management needs, in aquaculture can be derived from that analysis:

(i) from fisheries to controlled aquaculture, there is a range of farming systems which can be grouped into distinct categories on the basis of specific sets of variables that are simultaneously controlled;

(ii) these variables determine research needs: from the enhancement of population recruitment, to the physiology of organisms, research needs cut across major categories of systems according to patterns determined by the nature of farming systems; innovative research agendas cannot be partitioned by farming systems;

(iii) the need for research in biology, physiology and technology increases and diversifies as aquaculture intensifies; conversely, the relative importance of ecology and resource management declines with the degree of control over the cultivated habitat, the stock and the organisms;

(iv) controlled, intensive, large-scale systems are less site specific and require less fine tuning to local conditions; the situation is opposite for open and intermediate systems for which ecological and social factors are dominant;

(v) within a system, research needs change also with development stages (take-off and mature):

(vi) although the long term trend in aquaculture is towards intensification and industrialization, open and intermediate systems dominate aquaculture production; this reflects the fluidity of aquatic ecosystems which hinders their domestication, the dependance of poor rural communities on natural resources (land and water), and the competition with fisheries whose output until recently grew faster than world demand;

(vii) short term prospects for intensification are inversely related to the dimensions of the water bodies under cultivation; however, open bodies offer large volumes where use conflicts are less intense;

(viii) because they rely on natural productivity, or they have limited feed requirements, open and intermediate systems present advantages over controlled systems to reduce the global gap in fish supply;

(ix) with progress in technology, intensification possibilities extend progressively towards larger water bodies;

(x) so far, research agendas have been unbalanced and fragmented; development and research approaches, focusing on close systems and intensification, overlooked current and potential importance of open systems.

Tables in Annex III indicate only research needs, not priorities. To determine priorities, the economic and social importance and likely development of particular farming systems in a given country or region should also be taken into consideration. The Working Party did not have sufficiently detailed information to undertake this work. There are no global statistics of aquaculture production by major categories of farming systems either, from which research priorities at world level could be determined. However, the relative importance of the three major farming systems can be guessed from reported productions by major species groups (finfish 44 percent; molluscs 32 percent; seaweeds 23 percent; crustaceans 1 percent[9]). Most molluscs and seaweeds, and an appreciable but unknown part of finfish (capture fisheries), come from open systems. Intermediate systems mainly product finfish in freshwater ponds. Production of controlled systems (crustaceans and finfish) is still comparatively small in physical terms (but not in economic terms). Thus, in physical terms, the bulk of aquaculture production comes, in roughly equivalent proportions, from open and intermediate systems[10]. The production of closed, large-scale systems is considerably less, but growing rapidly in economic terms.

With the priority given by aid agencies to the promotion of small-scale producers in rural areas, three broad priority areas emerge where research could make important contributions for the progress of aquaculture in developing countries:

(i) intensification of intermediate (semi-intensive) freshwater (ponds) finfish systems, essentially in Asia;

(ii) evaluation of opportunities and conditions for small-scale aquaculture development in new rural areas (essentially Africa and Latin America) for the identification of potential producer groups and suitable farming systems;

(iii) development of open systems to enhance the resource base of small-scale groups in regions where small-scale aquaculture has not taken off.

ECONOMICS AND SOCIOLOGY

The role of economics in aquaculture is to identify, analyze and express the relevant processes and tendencies (laws) governing production and distribution of fish under various farming and production conditions. These processes take place under different economic settings, social organizations, institutional frameworks and cultural backgrounds. While economic tools provide indicators to assess the relative economic performances under these various conditions, sociological analysis investigates the rationale of producers' motivations, the acceptability of innovations, or the relationships between production systems and social organizations.

At the level of the production unit, theories of production, decision analysis and mathematical programming techniques provide tools to compare the suitability of potential production systems to prevailing externalities and pre-set objectives.

At the level of the sub-sector, input-output and industrial analyses, and various methods of operations research can be applied effectively to determine development strategies for aquaculture development, or to

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9 1983; ADCP estimates.

10 For analyzing development prospects, physical production is an important criterion, and, even in live weight equivalents, the unit value of mollusks compares well to that of finfish.

assess the effects of externalities. Such analyses measure the benefits and losses associated with specific production systems or development strategies. For that purpose, relevant options, option-specific constraints to activities, and associated impacts, benefits and risks, are compared. The basic tools are those of optimization techniques in operations research. Interventions can thus be selected as best fitting given constraints and objectives. In the short run, these techniques will provide best routes for optimal resource allocation. In the long run, wider issues like international trade arrangements become critical and will need to be incorporated into the analyses.

Enough analytical tools are available at present in economic sciences to identify feasible, profitable and effective farming systems from an economic and social point of view. Although much more information should be collected for their application, sensitivity analysis may prove useful at initial stages.

Still, these methods and techniques are rarely applied to aquaculture development. Applications of economic theories are largely restricted to analyses of technological relations at producer level. Farming techniques and systems are selected primarily on technological criteria. Applications of economic theories can make significant contributions to the formulation of strategies for the development of viable, profitable and sustainable production systems. This could save a substantial part of the costs associated with current empirical or partial approaches in aquaculture development.

Applications of economics and sociology require prior ground research work. The contribution of human sciences cannot be effective if it is restricted to fragmented and short-term pre-investment analyses. The applicability of economic theories to certain socio-economic contexts have to be ascertained. Data have to be collected, through special surveys or routinely, independently of pre-investment studies, to analyze existing systems and monitor their changes in response to interventions or changes in economic conditions. Little is known about the factors and processes which have led to, or prevented, the development of aquaculture systems. A similar statement applies to the comparative economic and social advantages of alternative systems. A little more, but far from enough, is known about the future trends of markets for specific species, and about the market structure for aquaculture products, especially those supplied by the small-scale sector.

Social sciences are made up of different disciplines (economics, sociology, anthropology, ethnography, history, geography, political and institutional economy) which, historically, have developed different focuses and methodological tools in response to issues of the time. They now tend to work closer in an integrated perspective. Research on production systems is one expression of such a trend. It reflects a growing awareness of the relationships between technological developments, group economies and social organizations.

To contribute to the establishment of the scientific bases for aquaculture development in developing countries, there are three major scientific concerns that sociological research, in cooperation with other disciplines, should address:

(i) The understanding of the function played by aquaculture and other production activities in the allocation of production factors depending on social goals. For that purpose, the strategies underlying the choice of priorities and the mechanisms at work in their effective selection need to be understood. Producer strategies are often limited to profit maximization and risk minimization, but actual strategies and opportunities are considerably more complex. They aim at maximizing benefits of an overall social welfare matrix, which is the best compromise society strives to achieve, taking into account other constraints and values, such as food security, power distribution, religious and cultural preferences, ... They can be understood as strategies of social reproduction, or as efforts made by groups to maintain their identity, while undergoing changes in reaction to individual initiatives, external influences and encroachments.

(ii) A better understanding of production systems and their dynamics would enable identification of "entry points" for technological and organizational improvements (and not simply transfers) of farming systems. By "entry points", we mean system elements and modes of action through which technical and organizational dimensions of production systems could be adjusted. The approach is not simply to design innovations that are desirable, but to develop modes of action that are acceptable. From the group's or the farmer's viewpoint, the acceptance of technological innovations implies resource reallocations. The reluctance of the producer to accept them is related to trade-offs in the readjustment, and to uncertainty and risk in the change. The identification of "entry points" would help to understand patterns of development processes, from which better development strategies could be derived.

(iii) Finally, social impact assessment is a critical component of any sociological research program in aquaculture. Social impacts of external initiatives and development projects need to be assessed, using appropriate qualitative and quantitative tools developed by social sciences. The purpose would be to identify unforeseen, undesirable effects on rural communities. Such analyses will reveal and measure hidden social costs related to technological innovations and other changes.

Tables on research needs in aquaculture economics and sociology were also prepared as a means to understand trends and to derive generalizations (Annex III). The ratings indicated in the tables are very approximative owing, among other things, to the limited applications so far of economics and sociology to aquaculture development. However, some conclusions of strategic significance can be drawn, similarly to the ones presented in the previous section:

(i) little research has been conducted so far on the economic and social aspects of aquaculture development; this has seriously affected the performances of development activities and the effectiveness of research strategies;

(ii) considering the number of systems that already exist, research in economics and sociology is more important than biological research for the extension of aquaculture to new regions;

(iii) research in sociology is particularly critical for understanding the prospects and conditions for introducing aquaculture systems in new rural areas; improvement in development performances depends on the objective identification of potential producer groups and suitable farming systems, an understanding of development paths, and of the assimilation capacities of potential target groups;

(iv) a systems approach is critical for the formulation of meaningful development and research strategies; this requires research in itself (e.g., production systems, relationships between systems in intensification and diversification processes, history of aquaculture development in different economic and social contexts,...).

6. THE POTENTIAL CONTRIBUTION OF SCIENTIFIC DISCIPLINES TO AQUACULTURE

The review of potential contributions of research by scientific disciplines to aquaculture development for the forthcoming twenty-five years was the task of the second session. As compared to the first session, where research needs were analyzed horizontally by reference to the sector development, the second session aimed at identifying opportunities for potential applications of research results, including those from scientific developments that can be expected. In principle, the first section concentrated more on adaptive aspects, the second more on innovative aspects. However, some overlapping in their respective work, as well as in the reporting of their discussions, could not be avoided.

In reviewing research opportunities, Session 2 attempted to distinguish between investigations which could lead to important developments in the medium term (10 years), and those which will require more time (up to 25 years).

SOCIAL SCIENCES

Present State of Knowledge

Three areas of socio-economic and socio-cultural investigation can shed important light on the development and conduct of socio-economic research in the field of aquaculture: (i) cultural change, innovation and diffusion; (ii) farming systems research and extension; and (iii) household dynamics and the organization of production.

Many anthropological and sociological studies have been conducted on innovation and cultural diffusion, and models to predict the acceptability or rejection of these innovations have been developed. Some of the conclusions reached by these studies are: (i) innovations should be compatible with the aspirations, needs, desires, and socio-economic, political and environmental conditions of the target population; (ii) new ideas, methods, or technical innovations should be communicated clearly to the concerned population; and (iii) the target population will accept or reject a given innovation depending on whether it serves a perceived need or desire.

Similarly, numerous studies have been conducted on farming systems, household dynamics, and the organization of production. In all production systems (e.g., dryland farming, recession cultivation, irrigation, herding, fishing, ...), scientists have identified and studied factors that are also likely to be of importance in aquaculture research. Areas of investigations relevant to the socio-economics of aquaculture include:

- Social organization

  Although rural communities are often presented in the development literature as if they were internally homogeneous, again and again social science has demonstrated their internal diversity, reflecting in a local area the larger social division of labor and relations of production. The indices of segmentation are many, and may include class, ethnicity, kinship, caste, gender, occupation, and political, and religious affiliation. These are made relevant in different access to and control over the means of production (natural resources, labor and capital). In each target community, researchers will need to identify and analyze the conditions under which various attributes are made relevant in the struggle for access to strategic resources.

- Organization of production

Rural communities in the developing world are increasingly incorporated into the global economy. But, the degree of incorporation and its effects on the communities are functions of their specific histories. Hence, the situation everywhere is dynamic, and these communities are in a constant process of transition. Thus, although the overall direction is clearly towards greater commoditization, it is critical to specify the situation for each target community. In order the needs of a target population and to plan interventions that will generate equitable and sustainable development of a whole region, a detailed and dynamic study of the organization of production is vital. Aquaculture development, according to scale, will carry with it complex innovations that will require technical and organizational skills, labor inputs, and socio-economic roles that may not be present in traditional systems of production. The organization of production can be investigated from many avenues:

- Units of production, distribution, and consumption

What is the unit of production? Is it the individual, the household, a group of households, the clan, the village? Do production units differ from group to group? Do they differ within a group? How? Why? What are the units of consumption? Do they coincide with the production units? Who has authority over distribution and what are the mechanisms utilized?

- Economic activities

What economic activities exist in the area? Attention should be paid to all activities, including farming, herding, fishing, forestry, crafts, wage labor, and other non-agricultural activities. Potential competition for resource attendant on the introduction of aquacultural interventions must be specified.

What are the farming systems in the area? Close attention should be paid to the range of crops grown, the division of labor and the economic roles of women and children, methods of cultivation, the availability of credit -both formal and informal, and whether livestock production is integrated with farming activities. What is the likelihood that aquaculture might compete with present land, water or fishery resource uses?

What farm practices, including farming cycles, are followed?

What is the nature of the marketing system?

What are the incentives and constraints on productivity?

Will aquaculture production conflict with other economic activities, especially agricultural practices? Can it be integrated with animal and plant production?

If fishing is a prominent economic activity in the area, who are the fishermen ethnically and in class terms? Is fishing a year-round or seasonal occupation? Are the fishermen also farmers? How does planting and harvesting affect time of fishing?

Will aquaculture compete with capture fishing? To whose benefit?

- Inter- and intra-household differential access to resources of land (and water and fishery resources), labor and capital

Researchers will quantify household resources in land (and other natural resources), livestock and other forms of capital, and will anticipate the impact of differential access to resources of introducing new technologies. As resources are researched, it is important to remember that households are highly differentiated internally. It is, therefore, critical to ascertain which household member(s) have which kind of control over which resources, and which members perform which kinds and amount of labor. Also, what is the likelihood that the introduction of the new technology will increase gender inequalities, elitism, and social stratification.

- Land/water tenure and use

Land/water tenure and use rights have been shown to be the framework within which traditional fishing, farming and herding activities operate. As such, they often play key roles in determining the propensity among producers for technology adoption and in conditioning economic efficiency of innovations. Thus, the land/water tenure and use should be undertaken in any aquaculture development effort. Some of the questions it raises are:

Who owns and controls land and water uses?

Who has access to land and water resources of different kinds?

What are the conditions under which this access is maintained?

What impact do present land and water tenure systems have on agricultural productivity?

Is there a correlation between access to land and water, and crop selection?

Will new tenure systems come into direct conflicts with traditional ones? If so, how will that affect project sustainability? Is there anything that can be done at the planning stage to avoid or minimize conflict?

- Division of labor by gender, age and status

A comprehensive understanding of the local economy necessitates a thorough examination of existing division of labor. Often planners fail to take the traditional division of labor and the role of women and children into consideration. For example, although it is well documented that women are the primary food producers in much of Africa, food production projects are too often designed and implemented almost exclusively in terms of male heads of households. Men receive the land, technical and agricultural inputs, and credit. Women may receive little but increased burdens and dependency on men. This increased dependency might have negative nutritional and health implications since women's reduced ability to dispose of household resources is likely to affect the quality and quantity of food available for them and their children.

- Labor availability, strategies and migration
- Household decision-making

Since households are the ultimate implementors of development projects, the process by which household decisions are made should be an important component of the research portofolio. Household decisions are conditioned by issues such as household composition, labor availability, access to resources (including political and social resources), income and education.

- Marketing and rural-urban exchange

SHORTCOMINGS

Little systematic investigation of the issues discussed above has been conducted specifically in the context of aquaculture development. Although several of the factors relevant in other production and farming systems are likely to be pertinent in aquacultural research and development, it is naive to assume they will carry the same weight. Critical issues are likely to differ between countries where aquaculture is a new and unfamiliar activity, those where it is of minor importance, and others where it is already important but of a different scale. The introduction of aquaculture or its intensification is likely to involve profound technical and institutional changes, and implies new adaptive strategies on the part of the new users. For example, conflicts over ownership rights and use of newly introduced resources (in the absence of adequate institutional arrangements to regulate and resolve them) are likely to take different forms and expressions.

These and other issues have to be re-examined and re-analyzed in the context of the broader issue of rights over the fishery resources and the uses of aquatic environments. Accordingly, all likely relevant issues have to be re-identified and reformulated in the light of new opportunities for aquaculture development and new needs for exploited ecosystems management.

Future Plans

To correct the wide gap in our knowledge of aquaculture and socio-economics, the following reviews and investigations are suggested.

- Immediate actions
  - Review the state-of-the-art in the socio-economics of aquaculture. This would include a compilation of existing literature, including the relevant knowledge derived from other production activities and their historical developments, a partially annotated bibliography (annotations of works that are specifically relevant to aquaculture research and development), and would identify the present gap in knowledge;
  - A draft copy of the paper would be used as a background document for a seminar to be attended by relevant experts; the purpose of the meeting would be to discuss preliminary findings and conclusions, to prepare a preliminary field research strategy, and to formulate a field research agenda.

- Long-term research

This meeting referred to above would produce a framework for:

- Initiating field research on identified topics in selected regions;
- Data analysis and interpretation of research results;
- Formulation of principles, guidelines and scenarios for socio-economically sound development of small-scale aquaculture.

ECONOMICS

The economics of aquaculture is primarily an applied discipline, involving the application of various sub-disciplines in economics and commerce to the field of aquaculture. It is also a fairly recent development and, so far, few scientific analyses have been undertaken.

Economics can be used to analyze both sector development and single projects. In addition, cost-benefit analysis of research projects relating to aquaculture may be undertaken.

Theoretical Economics

Investigations on (i) optimal feeding and harvesting in aquaculture, (ii) optimal rotation, (iii) polyculture, and (iv) the issue of property and use rights, will be important.

In the last years, a number of theoretical analyses of optimal feeding, harvesting and rotation have been undertaken. In most instances, it appears optimal to harvest all fish at the same time. This is in contrast to the practice of continuous harvesting over some period of time. Problems related to continual harvesting and feeding have not yet found their solution in literature. The same relates to polyculture. This is a matter of joint production (cf. multispecies resources exploitation in fisheries), but the analysis needs to be extended to the context of aquaculture.

The issue of property or use rights, and conflicting uses of aquatic environments, varies widely from culture system to culture system. While exclusive (individual or collective) property rights exist for some systems, others resemble the open and free access situation in capture fisheries. This is particularly true for certain open systems, such as ocean-ranching (e.g., salmon). Even where exclusive rights exist for aquaculture, conflicts for the use of the aquatic environments remain.

In the same way as for fisheries, the implications of property and use rights systems on the development and performances of aquaculture, and the conditions for their emergence, need to be researched. The problems relate to the tenure (e.g., the physical support of privileges), the contents of the rights, and the mechanisms for their allocation. Issues related to the sharing of exclusive (individual or collective/communal) use rights and public ownership need to be analyzed.

Applied Economics

In this field, research should be promoted in the following areas:

- The development of aquaculture:

Essentially, this would be an economic analysis of the development of aquaculture (economic history). The primary purpose would be to identify the factors that have been of critical importance in the development (successful and unsuccessful) of aquaculture (different systems in different socio-economic contexts).

This development is likely to be similar to what has been experienced in agriculture. It is important to understand the underlying factors that are critical. These include designation of tenure systems and the availability of inputs, in particular credit, as aquaculture represents a delayed-output production process. Furthermore, in pre-capitalist societies, markets for inputs and outputs may need to be developed, which will imply institutional and cultural changes.

In this context, the objectives of aquaculture development must also be considered. Some developing countries are focusing on aquaculture as a means for increasing export earnings; some for increasing domestic food supplies; and others for creating employment opportunities. These policies are not always clearly thought out, and pursuit of one policy (e.g., export earnings) may be damaging for other national objectives (e.g., domestic food supply). Furthermore, the true social costs of a policy may be overlooked. Economic analyses of alternative food policies are important.

- Production Economics

Aquaculture systems are traditionally classified in extensive, semi-intensive or intensive systems, usually on the basis of the usage of certain inputs such as feed and fertilizer (see PP 4 &7). From an economic viewpoint, this may not be a meaningful definition.

Economic criteria for the classification of aquaculture systems - e.g., investment costs per unit of production capacity, or labor/capital ratio - should be established and economic analysis undertaken on this basis. In particular, the following factors need to be analyzed:

- production efficiency (cost of production), including economies of scale;
- productivity;
- substitution between factors of production;

- externalities.

In general, economic analyses in the field of aquaculture would consist of the following elements:

- market analysis,
- market structure,
- institutions,
- production economics,
- investment analysis,
- financial analysis.

An economic analysis of aquaculture development will always start with a market analysis, as an actual or perceived demand is a precondition for successful development. While market supplies from capture fisheries are limited by nature, this is commonly not the case for aquaculture where market demand may be the limiting factor for development. In other words, where supply is limited by nature and demand is continuing to increase, this will result in an increase in the real price of the product and create a potential for aquaculture development. But whether aquaculture will affect market price is likely to vary from product to product.

PHYSIOLOGY

In research on aquaculture physiology, a useful distinction should be made between programs aiming at improving husbandry techniques and those, conducted on a few species models, aiming at acquiring the basic knowledge needed for the design of future applications. The latter includes the development of research tools (e.g., tissue culture techniques for investigations in pathology). These considerations should be kept in mind when considering the following lists which are more general frameworks than comprehensive inventories. Within the justification for short- and long-term research, priority of each item must be modulated, depending on the types of farming systems, their development stages and the importance of commercial production of the species.

Reproductive Biology

In aquaculture, controls of reproduction are developed in response to different purposes depending on the farming systems under consideration.

- Conservation and enhancement of natural reproduction (habitat management):
  - protection of natural spawning grounds;
  - preparation of artificial spawning grounds.
- Control of spawning (by inhibition or by stimulation):
  - age at first sexual maturity: this control can have different purposes: early reproduction for fry production, or delayed reproduction to spare growth potential, ...;
  - reproduction cycles: production of eggs at any season, synchronization (to maximize the synchronous production of homogeneous fry), or inhibition (in order to maximize growth).
- Gamete and egg conservation and cryo-preservation.
- Sex control (in gonochoric as well as in hermaphroditic species).
- Control of embryonic development.
  - assessment of ecophysiological requirements: e.g., egg quality control.
- Control of larval rearing:
  - assessment of ecophysiological and nutritional requirements of larvae.

Scientific knowledge in different fields is required to reach the above objectives. To the extent that such knowledge is not available, basic investigations may have to be undertaken. They fall under broad scientific topics:

- Reproduction cycles:
  - precise determination of their chronology (seasonal or not) and the determinism of the successive gametogenetic steps, in relation with changes in the environment.
- Role of external factors driving the reproduction cycles:
  - physical and chemical factors: temperature, photoperiod, salinity, ...
  - social factors: pheromones.
- Role of internal factors:
  - reproductive hormones: regulation of their secretion, mechanisms of action;
  - metabolic hormones;
  - nutritional factors;
  - mechanisms of gonadal and sexual differentiation.
- Gamete physiology:
  - scientific basis for gametic preservation and cryo-preservation.
- Embryonic and larval physiology.

Although the priority of these research topics differ from species to species according to farming systems they are part of, the role and the mechanisms of action of external factors present a particular and broad interest, since they may lead to the development of non-sophisticated tools for controlling reproduction cycles. Potential applications of this research topic have been underestimated in the past.

Genetics

According to farming systems, their development stages and the species involved, investigations in this field are undertaken in response to different purposes:

- Selection of appropriate founding populations for domestication.
- Domestication and improvement of commercial traits:
  - growth,
  - reproduction: age at first reproduction, seasonality, tolerance to environmental variations,
  - resistance to stress and diseases, ...
- Sex control:
  - production of monosex stocks,
  - production of sterile progenies: the development of appropriate tools to reach this goal is likely to become increasingly important to prevent interbreeding with wild populations and preserve genetic and species diversity.

As for reproductive biology, the development of these capacities will depend on the acquisition of basic knowledge in different fields:

- Population genetics, using either protein, mitochondrial, or genomic DNA polymorphism (characterizing species, strains, founding populations, ...).
- Quantitative genetics:
  - evaluation of variability and heritability of relevant traits;
  - setting up selection protocols.
- Chromosomal stock manipulation:
  - hybridization for obtaining sterile progenies, or for sex control, ...
  - gynogenesis for the production of homozygous strains, among others,
  - polyploidization.
- Gene transfer:

- introduction of particularly interesting genes (e.g., growth enhancement) in given species.

Nutrition

When planning research in nutrition, three considerations deserve particular attention.

– Nutrient requirements and availability

Nutrient availability has to be considered in the context of culture systems, taking into account the potential qualitative and quantitative contribution of the ecosystem itself. Of the 40 or so essential nutrients required by fish (including crustaceans), precise knowledge on the quantitative requirements is available for only a few tropical species. There is, thus, an overall lack of basic knowledge on the quantitative (and possibly qualitative) nutrient needs of most warm-water species. The use of novel, but specific, biochemical criteria for assessing nutrient requirements, as well as the nutritional status of cultivated organisms, can contribute effectively to this area of investigations. Methodologies are also available for assessing the nutrient bio-availability of feedstuffs: digestibility, biological value of proteins, serum or tissue nutrient or enzyme concentrations/activities.

The assessment of nutrient needs and bio-availability under different culture systems requires the development of specific methodologies that take account of micro (or macro) nutrients directly or indirectly provided to cultivated species. The role of micro-organisms needs to be quantified precisely inasmuch as they are capable of providing micro-nutrients, or of increasing their availability.

– Interactions between nutrition and other physiological functions

Investigations on fish nutrition have so far aimed at increasing productivity (quantity) by optimizing animal diets under intensive farming conditions. Recent works are, however, demonstrating the importance of nutrition on other biological processes. Basic investigations on the interrelationships between nutrition and reproductive performances, health (immune response), flesh quality, ... are timely.

– Feed formulation and processing

An overall knowledge on the nutritional value of feed ingredients locally available and affordable for the cultivation of local species is an important factor for the development of intermediate and controlled systems. Information on digestibility value, biological value of proteins, essential amino-acid profiles, anti-nutritional factors, ... for specific aquatic organisms under known abiotic conditions are needed for the formulation of "least-cost" feeds. Research on this area should also aim at minimizing the negative effects of self-pollution in controlled systems, as well as in open or natural environments.

Given this general background, short or long-term needs on nutrition research encompass the assessment of:

(i) essential nutrient requirements (qualitative and quantitative) of species of local commercial interest, using proven methodologies;

(ii) nutrient availabilities under intermediate and controlled farming systems; this requires, at the outset, the development of precise methods for measuring the contribution of natural trophic inputs;

(iii) nutritional value of indigenous plant and animal feedstuffs.

Simultaneously, a world-wide database on feedstuff composition in relation to nutritional requirements of major commercial species raised under known abiotic conditions should be established. This work would lead to comparative analyses of nutrient needs and utilization (digestive and metabolic) of different species under comparable environment conditions. Potential energy values of different substrates (proteins, carbohydrates and fats) could be compared as well. Existing husbandry techniques could be assessed by referring to ideal feeding strategies. While optimizing productivity in quantitative terms, more attention should be paid to the manipulation of quality through nutritional means.

Research is also needed on techniques for conserving feeds and preventing deterioration. At the same time, indigenous feed industries, aware of the importance of preserving the water quality from the effects of digestive and metabolic wastes (P, N) for the future of this activity, should be promoted.

Pathology

Fish pathology comprises the set of basic and specific responses by the fish host, and the aetiologies of the agents or agencies provoking them.

	Non infectious	
		Virology
Pathology =	Infectious aetiologies	Bacteriology
		Parasitology
		Histopathology
	Host responses	Molecular responses
		Immune Responses

These must be studied in the context of the farming stresses imposed on still basically wild animals, and the environment and changes in it, all of which enhance pathogen capability. They must also be studied with a view to control either by modifying the environment or stock, or else treatment with drugs, or prophylaxis via vaccines.

- Contribution to date

Knowledge of pathology is intrinsic to any domestication and intensification of culture. Thus, as species come into culture, empirical knowledge develops which then gradually forms a corpus of clinical pathology. The next stage is experimental models to allow basic responses to be categorized and a holistic pathology to emerge leading to rational control.

Currently, this process has developed reasonably successfully for salmonids, temperate carps, tilapias and yellowtails. Major deficiencies exist in relation to tropical carps, tropical marine finfish, crustaceans, and molluscs. This applies as much to the empirical base as to underlying basic pathology, and equally to the taxonomy and biology of their pathogens, and their control.

Such studies have the extra dimension of importance in that there may be great patho-ecological and environmental risks to development, associated with transformation of such agents, and also with the marketing of aquaculture products. A further dimension, still insufficiently recognized in developing countries but which will have profound public health and even political as well as export marketing significance, is the environmental pollution resulting from disease treatment, especially by antibiotics.

Public health hazards associated with fish culture is a separate, but closely related, area which has to come high in priorities for innovative research. Molluscs, crustaceans and finfishes, all present problems for the producer country which must be addressed if export markets are to be gained and retained. It must be addressed as well by importing countries. The risk is particularly great for species, such as bivalve molluscs, which are commonly consumed live, since they are traded and eventually brought back live in the aquatic environments of importing countries. Since detecting and controlling the distribution of asymptomatic carriers is problematic, there is a need for production and certification of disease free seed stocks for domestic use and international transfer.

Research needs and opportunities

(i) Short-term:

- description of the clinical pathology of tropical prawn, mollusc, and finfish species;
- development of appropriate tissue cultures for tropical species as above;
- development of monoclonal antibody technology;
- development of nutritional pathology, particularly for fish meal substituted diets.

(ii) Long-term

- development of disease resistant strains of key species;
- development of comprehensive monitoring schemes of fish health and clinical monitoring system,
- development of specific pathogen free cryo-preserved gene pools of gametes for transportation instead of adults, and to preserve the wild stock gene pools,
- development of environmentally safe drugs,
- development of bio-engineered vaccines, against parasites and viruses,
- understanding, and exploitation, of the "specific" defense mechanisms of crustaceans and molluscs.

FISH BEHAVIOR AND ETHOLOGY [11]

Selection of animals with a behavior adapted to cultivation conditions is an important element in the process of domestication and, in aquaculture, many cultivated strains are still basically wild.

Animals living under artificial conditions exhibit different behaviors in reaction to the suitability of the cultivation environment. Schematically, one can distinguish:

(i) "normal" behavior, when the cultivated animals appear to be "feeling at ease";

(ii) "abnormal" behavior, when the animals have to adapt to certain stresses; and

(iii) "avoidance" behaviors, in situation under which the animal's well-being is seriously affected.

Objective, if possible quantitative, criteria are needed, particularly for confined farming systems, to distinguish between the different "types" of behavior, since they can provide clues on the suitability of the layout of production facilities and the overall conception of production systems.

The study of behaviors characteristic of certain biological activities or functions, e.g., schooling, reproduction, feeding, social, ... can also contribute to the improvement of current husbandry practices, as well as to the understanding of more basic phenomena, such as:

(i) feeding strategies with respect to frequency, mode of supply, temperature regimes during feeding;

(ii) social dominance and individual or sex hierarchy;

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11 In the absence of specialists in that field in the Working Party, the terminology, typology and characterization used in this section may not meet the standards of the discipline.

(iii) crowding effects, prediction of fish movements and behaviors;

(iv) herding of fish stocks - e.g., fish attraction to feeding or harvesting devices.

ECOLOGY

Although, in general, the potential contribution of ecology is inversely related to the degree of intensification of farming systems, even in controlled systems, production performances depend on the capacity to optimize certain configurations between the stock and its physical and chemical environment. Therefore, the understanding and monitoring of ecological processes that are characteristic of aquaculture systems, as well as their interactions with, and feedbacks from, their environment (including the impacts of other uses of the same environments) are important for improving the relationships between the stock and its habitat. At the same time, they are of paramount importance for the sustainability of aquaculture. Because aquaculture is carried in a fluid medium, production performances of individual farmers are considerably more exposed to environment spillovers than in agriculture.

In applications to aquaculture, ecological investigations address basically to four goals, namely:

(i) production enhancement and optimization of populations released in open systems;

(ii) environment monitoring, and stock and products protection against exogeneous disturbances;

(iii) minimization of environmental impacts of aquaculture;

(iv) compatibility and integration of aquaculture systems with competing uses of environmental resources.

According to major farming systems, the dominant research topics are:

(i) in open systems:

- the prospects of, and the conditions for, enhancing recruitment;
- the assessment of the "carrying capacity" of open ecosystems -i.e., the evaluation of density-dependent effects on the optimization of the grow out phase in relation to the stocking densities (e.g., in shellfish and seaweed culture);
- habitat manipulations, as a way to enhance the concentration and/or the production of cultivated and wild populations (e.g., role of artificial reefs and shelters);

(ii) in intermediate systems:

- enhancement of primary and secondary productivity through the use of fertilizers, the input of agriculture offal and by-products of other industries, and the manipulation of the balance between primary and secondary productions (for optimum fish production (e.g., through the balance between herbivorous and carnivorous fish);

(iii) in all systems based on natural water resources:

- the monitoring of, and protection against, exogenous disturbances: agricultural, industrial and urban wastes; red tides; "climatic" changes;

(iv) in all systems:

- the environmental impacts of aquaculture systems: eutrophication and abnormal plankton blooms; release of antibiotics and toxics; impacts on wild stocks and fisheries of harvests of natural fry for aquaculture purposes ("fishery aquaculture"); mangrove felling and land reclamation for aquaculture development; introduction or escapement of non-indigenous species, parasites and pathogens and modifications of wild communities (species and genetic composition);
- compatibility and integration of aquaculture systems with other direct or indirect uses of environmental resources.

The prospects of open aquaculture deserve more attention. Furthermore, their development requires research on the population dynamics of stock enhancement, a topic which has not received attention matched to its importance. Recent developments in marine ecology theory, based on a re-examination of the mass of observations accumulated by marine research[12], suggests that the absolute abundance of marine populations is limited primarily by spatial processes - such as the dispersion of eggs and larvae by the oceanic circulation taking place during the early stages of the life cycle - and not by trophic constraints affecting adult stocks. The high yields (per unit area or volume) achieved in shellfish or seaweed culture are empirical evidence supporting the theory. Thus, from an ecological viewpoint, the production of several species could be considerably increased through recruitment enhancement programs. If the theory proves valid - this requires specific scientific investigations -, there would be new opportunities for developing fish production in marine and freshwater ecosystems. For this purpose, investigating the dynamics of early stages of fish populations to be enhanced (and the regulation of access to exploitation) are critical. They have generally been overlooked by approaches concentrating on the production and release of fingerlings.

Priority areas in ecological research in support of aquaculture development include:

(i) modeling of physiological (e.g., gametogenesis), trophic (nutrition, starvation) and spatial (advection, dispersion) processes in the recruitment success of wild populations;

(ii) assessment of density-dependent effects on the growth and mortality rates of stocks in open and intermediate systems;

(iii) modeling (quantitative and qualitative) of energy transfer in ecologically structured microcosms, such as ponds (intermediate systems);

(iv) modeling of energy transfer and structural system variability in artificial microcosms, such as larval rearing systems;

(v) analysis of fluxes and effects of organic aquaculture wastes on surrounding environments and feed-backs on production; this topic should include bio-purification microcosms and the re-use of organic matter;

(vi) the dynamics of red tides and other possible noxious effects of aquaculture wastes.

Investigations on the understanding of basic ecological processes, should go with the development of the methodological tool-box, notably with respect to:

(i) adaptation and development of mathematical models and numerical techniques;

(ii) improvement and development of in situ measuring techniques;

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12 See in particular: Sinclair, M.M., 1988 - "Marine populations. An Essay on Population Regulation and Speciation". Washington Sea Grant Program. Univ. Washington Press, Seattle: 252 p.

(iii) improvement of sampling techniques;

(iv) selection of adequate descriptors.

BIO-TECHNOLOGIES

Biotechnology is in a period of rapid development and is expected to have decisive influence in many fields, including aquaculture. Prediction of potential contributions is hazardous since the development of biotechnology itself involves quantum jumps. Investments in research and development in biotechnology are high and risky, and require groups of highly trained personnel, expensive equipment and costly safety measures. Normally, only highly profitable activities can justify such investments. Therefore, it is essentially from controlled and large-scale systems that demand for biotechnology will come.

In general, biotechnology is expected to contribute to the growing of animals and plants, in the farming processes, in the production of feeds and in the development of pharmaceuticals. As example of expected contributions of biotechnology to aquaculture, one can mention:

- Genetics:

disease resistance: identification of genes responsible for immune reactions, and amplification or transfer in desired fish species;

growth: amplification of growth hormone gene in major commercial species.

- Product quality:
  - genetics of characters responsible for special qualities, and transfer and amplification in cultivated species;
  - in seaweeds, genetic improvement of commercially important species through protoplast isolation, protoplast fusion and direct introduction of synthetic DNA fragments, and regeneration of improved plants.
- Feed technology:
  - bio-conversion of low value, but largely available, plant material (soybean, lupin, etc.): new yeast and bacteria enriched in S-amino acids and lysine can be developed through genetic engineering to secure feed for controlled aquaculture systems;
  - detoxification of inhibitors and noxious compounds through fermentative processes;
  - single cell protein may become economical for production of additives rich in S-amino acids, lysine and growth factors (fatty acids, vitamins, ...);
  - fermentation (ensilation) of plant material in small-scale fish-farming to preserve feed and improve feeding rations, through tailor-making of special yeasts and bacteria that can be propagated in traditional ways by farmers.
- Medication:
  - vaccine production by cell cultures, ... will expand to many bacterial diseases, and will probably also make vaccines available against virus infections;
  - biological production of degradable (environmentally acceptable) pesticides, antibiotics and antiparasite agents;
  - diagnostic means to detect disease agents and stress indicators, based on monoclonal antibodies.
- Industrial applications:
  - some competition with natural microphytes from tissue and cell culture for production of biologically active chemicals can be expected but, in the phycocolloids industry as well as in the cultivation of seaweeds for food, traditional cultivation will probably continue to dominate.

Two great challenges to research and development in biotechnology for aquaculture are biological purification to reduce pollution and bio-conversion of waste (sewage) into fish feed of good quality and the development of improved, tailor-made microorganisms and safe, efficient processes. The long-term goal of research and development is to provide fish farmers with highly developed organisms, complete feed material, efficient and proven technology, and high quality products, integrated in farming systems that are environmentally sustainable. For that purpose, biotechnology is an imperative.

7. RESEARCH CAPACITIES IN DEVELOPING COUNTRIES

PAST RESEARCH STRATEGIES

Past research made some positive contributions to the development of tropical aquaculture, notably in the field of carp and shrimp hatchery technology, in the biological bases for the cultivation of commercially important species, or in husbandry practices. The private sector has been a major source of funding for the development of intensive systems (shrimp, salmon), and important developments have been born out by private research - e.g., production of red tilapia fingerlings, micro-encapasulated feeds for larvae rearing, bacterins for disease prevention, ...

However, globally, research is not contributing as it could to the development of tropical aquaculture. An overall experience was missing. More importantly, research agendas are characterized by the same short-comings as development approaches: their scope is too narrow.

Investigations concentrated almost exclusively on zoology and technology. Emphasis was put on intensification and the development of new, inyensive systems, when open and intermediate systems production largely predominate in developing countries. Technological solutions were seen as the way to promote development and achieve economic profitability. Economic and social dimensions of production systems and their effects on the assimilation of technological innovations were overlooked. Research agendas were not structured in multi-disciplinary programs, with contents defined from analyses of local prospects of farming and production systems. Such analyses would have shown the critical importance of research in economics and sociology for the formulation of appropriate development strategies, especially in developing countries. Locally-suitable systems would have been better identified, and conditions for their assimilation or intensification within the socio-economic fabric governing production better appreciated.

Concentrated on the fish, the approach neglected not only the farm and the farmer, but also the environment. The current significance of open systems - e.g., in coastal areas - is not fully realized, nor are the conditions for their development. Development actions concentrated on the production and release of juveniles, while the regulatory mechanisms of fish populations and the regulation of access to their exploitation did not receive adequate attention.

This technologically driven development strategy led naturally to a subordination of research to development. Investigations were often undertaken in response to short term funding opportunities, sometimes for the immediate support of development actions. Scarce funds are available for innovative research. A corpus of knowledge has not been built. The lack of innovative research has affected the relevance of development strategies, as well as the scope and quality of investigations. If innovative research in zoology is relatively less important for the transfer and adaptation of existing systems to other areas, the lack of innovative research in biology and physiology will check the development of commercially established systems. New needs and new opportunities will not be anticipated.

PRESENT STATE OF RESEARCH IN DEVELOPING COUNTRIES

In discussing the present state of research, the Working Party noted that research capacities differ significantly between, and also within, regions. Therefore, generalizations are necessarily affected by exceptions. Also, several of the identified gaps are not restricted to developing countries, an indication that everywhere the management of research is complex.

In national administrations in charge of research, the specific requirements of the different kinds of research, or the differences between research and development, are not always properly appreciated. This affects research effectiveness and accountability. For example, in a number of public institutions, mechanisms derived from basic research are used to plan and fund investigations which are essentially applied in nature. For such investigations, economic mechanisms (i.e., the funding of separate projects on the basis of expected economic returns) would be more effective. More attention is given commonly to budget spending than to the effective impact of investigations.

Research management requires special focus. This covers matters such as the selection of priority areas and budget allocation, the mounting of multi-disciplinary programs, the design of research protocols, program and staff evaluation according to procedures matched to the nature of investigations, the cooperation with research users.

Research programs are seldom holistic. The formulation and implementation of multi-disciplinary programs would require the cooperation of different research units in the same institutions, or of sectoral research institutes and universities. Mechanisms are required for that purpose.

This does not mean that the task is simple. The complexity of linking scientific research to commercial production, taking Africa as an example, was given. The first difficulty comes with the identification of constraints inhibiting development. Then comes the integration of the required inputs from various disciplines, both applied and basic. The lack of researchers with sufficient technical knowledge of the array of scientific disciplines of potential interest, and professional understanding of farming systems, is a shortcoming in all regions. Finally, mechanisms required for integrating the inputs of different institutions with recognized competencies and facilities are frequently lacking. But because the task is complex, a rigorous and professional approach is a condition of success.

A majority of research institutions lack long-term financial support from governments to implement comprehensive research strategies and innovative investigations. Opportunistic changes in research focus are common. Distribution of expenses is imbalanced. Salary and professional and support staffing are often grossly inadequate. Operating funds are insufficient, while capital outlay and equipment are more attainable from government and donor agencies allocations.

The difficulties faced by researchers contribute to declines in efficiency and motivation in program implementation. In many countries, low salaries compel highly qualified personnel to take up complementary appointments, sometimes outside aquaculture and research. Researchers move early to more rewarding or more challenging responsibilities outside research, or emigrate. Lack of competition among scientists, resulting from insufficiently selective procedures in the evaluation of programs and that of the staff, leads to decline in scientific dynamism and innovation.

The problem of the quality and relevance of training and education of researchers was also highlighted. It requires efforts at both national and regional levels. Technical skills need to be enhanced through training in research methodologies. Education systems and curriculae of academic and research institutions require revision to produce skilled scientific manpower. However, the scientific environment is even more critical for the development of scientific capacities. Flexibility in selecting and mounting programs, organizational ability to develop cooperative investigations, staff and program evaluation procedures, the conduct of a minimum amount of innovative research, scientific backstopping, contacts with foreign research teams, scientific competition,... are vital for the professional development of junior researchers.

Funding by aid agencies suffers from similar shortcomings. Emphasis is often put on the provision of hardware, disciplinary research and training -not infrequently related to specific interests of particular research institutes in donor countries. Comparatively, institution building and the promotion of human resources receive less attention. In regions where research budgets are tight, external aid sometimes creates distortions for a comprehensive approach. This, plus the lack of continuity in funding, contribute to maintain imbalances in research agendas. When external aid is a major source of funds, the short duration of projects has negative effects. They open opportunities which increase staff versatility: research programs can be terminated before being completed.

Nevertheless, the example of agriculture shows that research of good quality is feasible in developing countries. The International Rice Research Institute, the Rubber Research Institute, or the Palm Oil Research Institute were cited as examples of institutions which, given adequate conditions and means, have achieved scientific excellence with an impact on development. Innovative research requires security in funding, matched to the time scale of investigations, and adequate autonomy for selecting innovative programs (with proper confrontation of views with the scientific community and the potential users of the research). Today, these conditions are exceptionally met in aquaculture research in developing countries.

DISPARITIES IN THE DISTRIBUTION OF KNOWLEDGE

As with respect to the development of aquaculture systems, marked regional differences exist in the basic knowledge and techniques available for aquaculture development. Without effective regional and inter-regional cooperation, this may result in geographic disparities of interests and incentives, which may in turn impede the flow of knowledge required for a steady development of aquaculture in all developing countries.

Redundancy in research programs needs to be minimized in order to use in a more efficient manner the very limited research potential available, while stimulating its strengthening through the conduct of more advanced investigations. Lack of opportunities for researchers to present their findings and views, and lack of scientific competition, are causes of fragmentation of investigations, duplication of efforts, and low incentives.

Venues for research communications (scientific meetings, workshops, scientific publications) are not equally available to all countries. Scientists from developing countries will benefit from evaluation of their research outcomes using international standards of evaluation. This requires the strengthening of regional mechanisms for scientific cooperation. Larger participation of young scientists from developing countries in international gatherings, or the active involvement of scientists from such nations in the preparation and implementation of scientific programs in collaboration with counterparts from developed nations, require stronger support from governments and aid agencies. Scientific journals of international standard have probably to be created in certain regions.

THE USE OF RESEARCH

The communication gap between public sectoral research institutes, universities, and the production sector is a major weakness affecting both the use of, and the demand for, research.

Information dissemination does not always reflect the needs of different audiences for the various kinds of research. For direct users of adaptive research, information should be published as technical reports to national administrations and industry, training and extension manuals, educational materials. For that purpose, local languages should be used.

The transfer of technical innovations, through extension work, is often top-down, with little active participation of fishers and farmers in the conduct of that function. Conditions of assimilation are not systematically taken into account, and a positive attitude of users towards innovations is not promoted. The extension function itself should be an object of research. The long-term objective should be to give the production sector the lead in mobilizing and adapting technological innovations.

Farm demonstrations can be useful in showing the viability of technologies developed through research. However, demonstrations carried out in public agencies lose part of their signification since they are not conducted under the economic constraints of commercial production. Research institutes may be inclined to underscore non-technical constraints. When there is a confusion between research and development, and evaluation procedures are lacking, it is more difficult to stop "demonstrations" which have failed. Important aspects such as access to capital, risk, tenure systems, can be ignored. Consequently, the feasibility and profitability of new techniques should preferably be validated within commercial farms.

With the industry, mechanisms through which representatives of farmer associations and researchers could collectively review opportunities for technical innovations, select and finance jointly applied research projects to be implemented in public institutes, and evaluate the findings, are not common, or not sufficiently active. This may require the strengthening of industry associations. Shortcomings in communication are a major cause in the low use of, and interest for, research findings, insufficient appreciation by research of the problems confronting the sector, and of mutual misunderstandings. The responsibility is not on the side of research only. Better use of research is a shared duty.

Systematic procedures for monitoring and assessing development and research performances are not the rule. Explicit research strategies, tailored on development policies based on socio-economic analyses of the sector, would provide benchmarks for evaluation. Participation of all parties concerned in open evaluations would facilitate the emergence of a common understanding of existing constraints and opportunities, and the adoption of common strategies.

INSTITUTIONS

As already noted, governments and aid agencies gave less attention to institution building and the promotion of human resources than to the provision of facilities and hardware. At national level, the spreading of scarce resources between institutions and the low priority assigned to innovative research have played against the emergence of centers of excellence.

Integration of talents and efforts can be facilitated by establishing national entities responsible for mobilizing the resources and raising awareness at the planning level for the necessary budgets. In countries with clear sector and research policies, research often works more effectively and is less dependent on foreign aid. But, if not equipped with adequate mechanisms for ensuring regular evaluation of programs, scientific competition, and adequate autonomy for selecting innovative research programs, there is a risk for unique governmental sectoral research institutions to become overwhelmed by bureaucracies, at the detriment of their innovative capacities.

National programs involving different research institutions active in aquaculture research can be a solution against dispersion, provided that coordination is organized in partnership between teams actively engaged in research. Seed money to stimulate cooperation can also be extremely important.

Since it is at national level that most investigations are carried out, and at that level that research findings are translated into actual development, strengthening national capacities should be the ultimate goal of institution building. However, national research capabilities cannot be strengthened through efforts deployed at country level only. National means and international aid will not be sufficient, notably in regions where countries are small (e.g., island states). Moreover, everywhere, scientific progress depends critically on international cooperation.

The experience of regional programs and networks was discussed taking Asia and Latin America as examples. Individual networks, such as the Asian Fisheries Society, can play a very useful role in improving research protocols, and facilitating exchange of information and personal contacts between scientists, both within the region and outside. The International Foundation of Science (IFS) was also mentioned as an example of an effective mechanism through which international aid assists junior scientists by providing scientific backstopping of senior scientists on a voluntary basis.

Institution networks have had impacts but, often, they have been difficult to maintain when external aid terminated. This does not imply that the mechanism is not useful. On the contrary. It is one of the most efficient way to stimulate national capabilities and the progressive achievement of collective self-reliance.

But, conditions of success have generally not been fulfilled. First, formal mechanisms are required and they do not exist in all regions. Second, the building of institutions for regional cooperation in research is a particularly long endeavor. So far, this kind of aid did not have a high priority in the agendas of donor agencies. Because their outputs are diffuse and perceived only on the long run, governments and aid agencies do not always appreciate their usefulness. They have not been able to match the time requirement for achieving self-reliance.

Networks of scientists are presently a more resilient mechanism. One reason is that their cost is low. Another one is that research personnel is directly involved in their activities, which is an important element of motivation. However, since their field of activity is restricted to single disciplines and their means are modest, they are insufficient to give the momentum and implement the comprehensive research programs which are required for tropical aquaculture development.

At present, only few regional research bodies and some regional and inter-tropical networks of scientists are active. In several tropical regions, cooperation in aquaculture research is not dynamic.

To strengthen national capabilities through international cooperation, it is useful to distinguish between the building up of regional institutions and the promotion of scientific excellence:

(i) for promoting regional cooperation between national research institutions, formal structures, preferably distinct from development and management bodies, are required; their major duties would be to assess research priorities, to conduct joint research programs on topics of regional significance, and to provide common services (information, publications, meetings); initially, activities would concentrate on research topics of adaptive nature, but they can be expected to extend progressively towards innovative research as national capabilities develop; even if external support is required for a relatively long period, the cost of such bodies would be relatively low since most of the work and participation to regional activities would be at national cost;

(ii) for stimulating innovative research in national institutions, a specific action is needed; this could be done through the implementation of a few multi-disciplinary, targeted programs of strategic significance for tropical aquaculture (see # 5.1); such programs would be conducted in cooperation between national institutions in developing countries, as well as with research centers in developed countries working on tropical aquaculture; because national capabilities in the fields of innovative research are very limited, nucleus research teams would be needed to serve as catalysts for each program; such core teams should not act simply as coordinators (secretariats) of institution networks, but be actively involved in research programs since this conditions their credibility and supportive capability in research.

Given the diversity of farming systems, disciplines, species and regional development which characterizes aquaculture, such medium-term programs should be selected to cover the most important research issues of tropical aquaculture development, and be implemented, in a decentralized but inter-connected (inter-regional) way, in tropical regions to reflect geographic differences in opportunities and needs. In this way, both cooperation between developing regions and between Southern and Northern institutions could be stimulated.

It was, however, recognized that these types of arrangements and activities depend on adequate funding. So far, such commitments have been extremely difficult to mobilize. CGIAR was mentioned as the example of an arrangement which has ensured continuity in funding, autonomy in programming and emphasis on innovative research, all conditions which, to day, are dramatically missing in aquaculture research in developing countries.

8. WAYS AND MEANS OF OVERCOMING GEOGRAPHIC DISPARITIES IN KNOWLEDGE

CONDITIONS FOR EFFICIENT TARGETED RESEARCH

In setting the tone for a wide ranging discussion based on the specific requirements and status discussions of the previous days, Professor E.A. Huisman, Convenor of Session 2, emphasized that the present situation is very deficient in all respects. Unless major structural changes are made in the organization and funding of tropical aquaculture research, there will be no way in which research could make an important, or in some areas crucial, contribution to the progress of tropical aquaculture. The statement applies primarily to the situation in developing countries, but also to centres of tropical aquaculture research in certain developed countries.

Research in aquaculture in developing countries is currently too thinly spread and underfunded for excellence. In certain developed countries, it was in the past too dependent on cross-subsidy from other sources. These are no longer available in the tight science funding framework now extant on all sides. Historically, full costs were rarely available in this area of research.

Only very few institutes or universities in some developing countries and some specialized centres in certain developed countries have established programs in innovative research. Largely, the former do not enjoy the means nor the conditions that it requires. The Centre for Cellular and Molecular Biology in India, or the Marine Sciences Institute in the Philippines, demonstrate, for example, what standards can be aspired in terms of innovative, targeted research.

In view of development needs, adaptive research is quite rightly the priority in most developing country institutions. It is crucially important, but currently its standards, value for money, and applicability can often be called into question. In many institutions, the minimum amount of scientific research that is ultimately vital for the quality of investigations, both innovative and adaptive, is not conducted. Bilateral support is very valuable but, unless institutional development is carried out at the same time, experience shows that the needed improvements would not be possible.

The conditions which must be met to allow targeted innovative research to become efficient are those basic to organization of all science, namely:

(i) scientific leadership,

(ii) adequate procedures for program selection and staff evaluation,

(iii) well-trained scientists, familiar with the requirements of the scientific methods,

(iv) cooperation with the national and international scientific community,

(v) suitable facilities,

(vi) adequate funding,

(vii) protection from short-term, administrative or political interferences.

In addition, aquaculture research is affected by specific constraints and shortcomings:

(i) lack of comprehensiveness and relevance of research agendas;

(ii) lack of target definition and focusing;

(iii) the great ignorance from which we are starting, and the very wide range of high-calibre scientists required to make a serious impression;

(iv) the discontinuous need for different skills and disciplines, leading very easily to fossilization of research bodies outliving their usefulness;

(v) lack of persons with aquaculture training and professional experience in the higher levels of management of research;

(vi) shortage of highly competent, skilled manpower, at Ph.D. level, in the disciplines required to make meaningful contributions at regional level;

(vii) insufficient standards in national programs in, but not only, developing countries.

INSTITUTIONAL REQUIREMENTS

Improvement of research capabilities in the developing world can only be made in the context of national institutions, and the economic and social realities of the countries, and must be led by the local potentials. It is, therefore, vital to encourage national independence in this respect. The resolution of the problems preventing good scientific research depends on the provision of funding and a framework for using existing means and capabilities. For that purpose, international cooperation is essential.

Concern was expressed at the nature of the structures and mechanisms to be established. Firstly, it was unanimously agreed that an international centre was inappropriate. Even formal institutes in the Asian, African and Latin American sectors will present difficulties in avoiding fragmentation of research agendas in addition to their high cost.

The Working Party stressed that any scheme should simultaneously make the best use of existing manpower and expertise, and stimulate the development of advanced research capacities in developing countries. Human resources are likely to be a very limiting factor, if high calibre scientists are to be involved with the framework. Since the establishment of the regional research networks are dependent on their inputs, the participation of specialized research centers in Northern countries is important. Some of them are currently under grave threat. This situation must be addressed by national governments concerned.

At the same time, the scheme should aim at becoming redundant, which will be achieved when developing countries have attained individually and collectively an adequate level of self-reliance. The promotion of national capacities is, therefore, essential.

Emphasis was placed, from all sources, on the importance of networks, for example the COPRAQ[13] network of EIFAC[14], or the Asian Fisheries Society. It was considered that seed money to set up such networks, to which regional scientists felt that they were making a personal contribution, and which was demonstrably "theirs", had great merit. However, scientist networks will not be sufficient. If research is to make an effective contribution to aquaculture development, a few comprehensive targeted scientific programs have to be implemented. For that purpose, advanced teams in developing and developed countries have to be mobilized to work together. Indeed, this might prove a uniquely useful route to strengthen research capacities in developing countries, to promote equality of standards, and to make a proper use of existing expertise. But structures and funds are required to implement cooperative programs that are

13 COPRAQ: Cooperative Program for Aquaculture.

14 EIFAC: FAO European Inland Fisheries and Aquaculture Committee.

dynamic, relevant and comprehensive. Fellowships are needed to offer developing countries scientists opportunities to work together with research teams in Northern institutes, and to support two-ways exchanges in research, training and teaching to cement collaborative programs.

The WHO scheme was mentioned as a possible model for harnessing the world's resources for enhancement of the scientific and technical research productivity, and feeding into the national systems. Essentially this involves a small secretariat attached to the international set-up and responsible for the formulation of international programs implemented in cooperation between national research centers.

This scheme provides flexibility to respond to the important regional differences in terms of research needs and opportunities, and avoids the problem of single institute centralization and risk of fossilization. It also provides a possible framework whereby the developed and developing world can work together in addressing important research issues. It gives the flexibility to turn resource on or off on a reasonable time scale, as one area becomes more or less important. It interdigitates with specialist networks to produce funding policies in high significance strategic areas, which would establish target oriented research groups, with a defined life span.

In the case of aquaculture research, however, a small secretariat would not be sufficient. In certain developing regions, institution networking alone cannot work since there are just too few institutes actively engaged in innovative research. If the scheme is to promote institution building and the development of human resources, and not only achieving scientific excellence, a special, even if only catalytic, scientific input is required until a sufficient number of national teams have emerged and a satisfactory level of collective self-reliance is reached.

In the present situation of tropical aquaculture research, institutional arrangements have to fulfill a number of partly contradictory requirements:

(i) activities should aim at achieving high scientific standards while addressing in a comprehensive manner sets of scientific issues of strategic significance for the development of tropical aquaculture research; this calls for the implementation of a few comprehensive programs targeting on major strategic development issues, rather than for the building of centers; geographic differences in research needs and opportunities should be accommodated and scientific cooperation with national institutions facilitated; if such programs were inter-connected, they could jointly cover the various disciplines and major research issues of tropical aquaculture development;

(ii) activities should strengthen national capabilities and the progressive emergence of centers of excellence in developing regions, while making the best use of existing expertise and competencies; this calls for programs implemented through networks of advanced scientific teams in developing and developed countries;

(iii) at the same time, because national expertise is not sufficiently developed, core teams are needed; in addition to providing scientific secretariat services, they should be directly engaged in research investigations; this is an important condition for their ability to provide support and for their scientific credibility; they would have a direct responsibility for transferring methodologies to research institutions in developing countries and promoting the emergence of national teams of excellence in those countries;

(iv) activities should be flexible to respond to needs for temporal shifts in topic and discipline emphasis, something critical in this field and not very obviously achieved in other sectors of international collaboration; this is another argument in favor of zonal programs, rather than centres.

(v) finally, such programs would have a defined life - e.g., 10-15 years, with monitoring and periodic evaluation in terms of scientific excellence, impacts on sector development, and promotion of national scientific capacities.

In addition to the conduct of research in such fields, one important mandate of such programs would be to develop and disseminate to national research centers new scientific methodologies and approaches, and train scientific personnel in their application.

It is also important that the networking information technology and the collaborative output costs (e.g., organization and participation to workshops, dissemination of information - e.g., on scientific methodologies, training) are properly supported.

With respect to programming responsibilities, topics needed to be chosen through some form of donor, recipient countries and independent scientist interaction. The best compromise would possibly be through boards in which donor agencies and participating countries will take decisions on policy and budget matters, and scientific committees where scientists of internationally recognized standards from developing and developed countries will provide guidance on program relevance and excellence. Such advice would be directly useful to donor agencies and participating countries to evaluate program priorities.

Any facilities, centres or resource bases, which were to have a full time regional or zonal rather than a national remit, should be free from particular national influences. Such a need should be reflected in the status of programs and of the staff directly employed by them.

POSSIBLE FRAMEWORK FOR INTER-REGIONAL COOPERATION IN TROPICAL AQUACULTURE RESEARCH

The purpose of these programs would be to provide, for their subsequent transfer to national institutions, the scientific base in the context of available or developmentally likely methodology in the next decade. Each program would concentrate on the key research issues and the various relevant disciplines (ecology, biology and physiology, technology, economics, sociology, institutions) underlying major opportunities for aquaculture development in tropical areas. Assuming that aid agencies give priority to small-scale systems of production, three development-oriented packages deserve a special attention:

- the intensification of freshwater fish pond aquaculture systems;
- the initiation of small-scale aquaculture in new areas;
- the prospects and conditions of open aquaculture development.

At the same time, such programs would reflect regional disparities in needs and opportunities. The first program should focus on Asiatic aquaculture systems: because those are economically the most developed, they are those which will benefit most from scientific investigations in the biology, physiology and ecology of commercially-dominant tropical species. The other two programs would constitute a major thrust for the development of aquaculture in Africa and Latin America; at least, they would indicate objectively what are their prospects and, if opportunities exist, determine the conditions for their take-off. In addition, the three programmes would have the requirement to interdigitate, and transfer information and expertise, to ensure a homogeneous approach, and to take advantage of information gained and expertise available in one geographic area, which is relevant in another. This would be one responsibility of the core scientific staff.

Contemporaneously, the framework would sustain collaborative research programs implemented through networks of research laboratories in developing countries and developed countries, and support both innovative research and training on disciplinary issues identified as major components of the main programs. For example, environmental impact methodology, disease studies, population genetics, population dynamics of early stages, cryo-preservation or gene banks, are of immediate concern and require both scientific answers and the development of third world capabilities.

This sketch will be part of a more general framework. It has to be matched with complementary activities equally needed in the field of fisheries research and fishery ecosystem conservation. But if the scenario is feasible, it will at last represent an interlocking and relevant strategy, involving national research institutions, international development organizations and bilateral donor agencies. It will promote N/S cooperation in research, but also collaboration between developing regions. It will address the economic and social aspects of aquaculture development which have been left largely unattended, and will take into account the needs for awareness of environmental impact and sustainability. Finally, it should also provide a basis for the generation of information of scientific validity to counter developmental impetuses which do not fall in with such requirements. If the international community can take up the challenge, we may well for the first time put people, fish resources and environment together for rational exploitation in a sensitive and sustainable fashion.

Annex I
ORIGINAL DRAFT AGENDAS

SESSION 1

Tuesday, 5 September

1 - Presentation of participants

2 - Introduction of SIFR

3 - Adoption of agenda

4 - Definition of terms

5 - Importance of fish and the role of aquaculture

6 - Criteria for classifying aquaculture systems

7 - Classification of world aquaculture systems

Wednesday, 6 September

8 - Constraints affecting aquaculture development

9 - System specific research and priorities in relation to development stages

10 - Systems approach to aquaculture development

Thursday, 7 September

11 - Review of past research strategies

12 - Strategies to improve research capabilities

13 - Strategies to improve the use of research results

Friday, 8 September

14 - Institutional arrangements

15 - Adoption of the report

SESSION 2

Monday, 10 September

Tuesday, 11 September

1 - The contribution of scientific disciplines to aquaculture

- Sociology
- Economics

- Ecology
- Biology:
  - Reproduction
  - Genetics
  - Nutrition
  - Pathology
  - Ethology
- Biotechnology
- Farming systems

Wednesday, 12 September

2 - Possible disparities in the distribution of knowledge

3 - Conditions for efficient targeted research

Thursday, 13 September

4 - Ways and means to overcome geographic disparities in knowledge

5 - Adoption of the report

Annex II
List Of Participants

SESSION 1

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R. Pullin (ICLARM)
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SESSION 2

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* Dr. V.R.P. Sinha was unable to attend the meeting, but contributed to its work by providing a note on the agenda items.

Annex III
Research Needs (tables)

The tables presented in this annex have been prepared during the first session of the Working Party. Their purpose was to analyze how research needs (disciplines and topics) change with farming and production systems, as well as with their stages of development (startup and mature).

When reading these tables, the following remarks are important:

(i) the attribution of an order of importance is only qualitative; significant differences subsist between species groups falling within the same system category; it is difficult, for example, to distinguish in such tables between open systems relying on the artificial production of juveniles (e.g., salmon ranching), and systems where fry is collected in the wild (e.g., in shellfish culture);

(ii) the distinction between short-term and long-term research must not be interpreted in terms of relative urgency - i.e., that they could be undertaken in sequence; since the time scale of their investigations differs, certain long-term investigations need to be initiated now; in addition, in certain disciplines, there are both short- and long-term opportunities for research.

(iii) the interpretation of the tables requires professional experience of both the production systems and the disciplines under consideration.

Therefore, these tables do not provide criteria applicable to particular countries or regions. Rather, they illustrate an approach, based on the concept of production system, which could be used by countries to analyze their own research priorities (see text).

Table 1. Matrix of the major biological research disciplines vs. the major categories of aquaculture production systems

DISCIPLINES	MAJOR CATEGORIES OF PRODUCTION SYSTEMS: OPEN (EXTENSIVE) — SEA		COASTAL AREAS		INLAND WATERS		INTERMEDIATE (1/2 INTENSIVE) — WATER-BASED		LAND-BASED		INTENSIVE (CONTROLLED) — FEEDLOT	
	startup	mature	startup	mature	startup	mature	startup	mature	startup	mature	startup	mature
ETHOLOGY	1 L	3 L	0/2 -/L	0/2 -/L	1 L	2 L	1 L	1 L	1 L	1 L	1 L	2 L
ENVIRONMENTAL SCIENCES	1 L	3 L	3 L	3 L	3 L	3 L	1 L	2 L	1 L	2 L	3 L	3 L
POPULATION ECOLOGY	3 L	3 L	1 L	2 L	3 L	2 L	1 S	1 L	1 S	1 L	1 S	1 S
FARMING SYSTEMS	0 -	0 -	1 S	2 S	2 S	1 S	3 S	2 S	3 S	2 S	3 L	2 L
GENETICS	2 L	3 L	2 L	3 L	2 L	2 L	3 L	3 L	3 L	3 L	3 L	3 L
REPRODUCTIVE BIOLOGY	3 S	1 S	3 S	3 S	2 L	1 L	2 L	1 L	2 L	1 L	2 S	1 S
NUTRITIONAL BIOLOGY	0 -	0 -	0 -	2 S	1 L	1 S	3 S	2 L	3 S	2 L	3 L	3 L
PATHOLOGY	0 -	0 -	1 S	3 L	1 L	2 L	2 L	2 L	2 L	2 L	3 L	3 L
ENGINEERING	0 -	0 -	1 L	2 S	1 S	1 S	1 S	1 S	1 S	1 S	2 L	2 S

- = not relevant; 0 = not important; 1 = some effect; 2 = strong effect; 3 = limiting; S = short term (up to 10 years); L = long term (up to 25 years)

Table 2. Matrix of the major aquaculture commodity groups vs. biological research disciplines, for the three major categories of aquaculture production systems

COMMODITY GROUPS	PATHOLOGY			ENVIRONMENTAL ENGINEERING SCIENCE			ETHOLOGY			POPULATION ECOLOGY			FARMING SYSTEMS			GENETICS			REPRODUCTION BIOLOGY			NUTRITIONAL BIOLOGY					
	O	I	C	O	I	C	O	I	C	O	I	C	O	I	C	O	I	C	O	I	C	O	I	C	O	I	C
seaweeds	?	2	-	-	-	-	-	-	1[a]	1	3	3	3	3	3[a]	2	2	2[a]	1	1	2[a]	2	2	2[a]	1	2	3
molluscs	3	3	-	0	0	-	3	3	-	1	2	-	3[b]	3[b]	-	3	2	-	1	1	-	3	3	-	1	2	-
crustaceans	1	2	3	2	2	2	3	2	1	1	3	3	3	3	3	2/3[c]	2/3[c]	2/3[c]	1	2	3	1	2	3	1	2	3
finfishes	2	2	3	2	2	1	3	2	1	1	3	3	3	3	3	2/3[c]	2/3[c]	2/3[c]	1	3	3	1	2	3	1	2	3

O = open; I = intermediate; C = controlled; - = not relevant; 0 = no importance; 1 = slight importance; 2 = important; 3 = limiting. This table refers to grow out systems, not to hatcheries and nurseries, which are usually controlled, some time intermediate (semi-intensive), the major exception being the seed collected from the wild.

a. Applies to intensive culture in closed systems.
b. Applies to population genetics research on wild/transplanted stocks.
c. Reflects a need for further research on some species (e.g. Latin American freshwater and many marine finfish and crustaceans) as against an already large body of knowledge on other species.

Table 3. Research needs in economics by major categories of production systems

	MAJOR CATEGORIES OF PRODUCTION SYSTEMS											
	OPEN WATERS (EXTENSIVE)				INTERMEDIATE (SEMI-INTENSIVE)				CONTROLLED (INTENSIVE)			
ECONOMIC PROCESS / FUNCTION	INLAND WATERS		WATER-BASED		LAND-BASED		FEEDLOT		SEA		COASTAL AREAS	
	startup	mature	startup	mature	startup	mature	startup	mature	startup	mature	startup	mature
PRODUCTION												
Output (resource supply)	1SL	2SL	3S	3L	3S	3L	3S	3L	3S	3L	1S	2L
Output (transformed supply)	1SL	2SL	2S	3L	2S	3L	2S	2L	2S	2L	1S	1L
Factor Demand (resource)	0SL	1S	2S	3L	3S	3L	3S	3L	3S	3L	1S	3L
Factor Demand (transformed)	0SL	1SL	2S	3L	2S	2L	2S	3L	2S	3L	1S	1L
Inputs Combination	1L	2SL	1S	3L	1S	3L	2S	3L	2S	3L	1L	3L
Competition	0L	1L	2S	3L	3S	3SL	3S	3SL	3S	3SL		
Alternative*	1L	2L	1S	2SL	2SL	2SL	3SL	3SL	3SL	3SL	2S	3L
DISTRIBUTION												
Output Resource Demand	1L	2L	2SL	3SL	2SL	3SL	2SL	3SL	2SL	3SL	1S	2L
Output Transformed Demand	1L	2L	2L	3L	2L	3SL	2SL	3SL	2SL	3SL	1S	1L
Output Storage	1L	2S	2S	3SL	3S	3SL	2S	3SL	2S	3SL	1S	1L
Output Transport	1L	2S	2SL	3SL	3SL	3SL	2SL	3SL	2SL	3SL	1S	1L
APPROPRIATION												
Consumption	2S	2SL	3S	3L	3S	3L	3S	3L	3S	3L	1S	2L
Income/value Distribution	3SL	3SL	3SL	3SL	3SL	3SL	3SL	3SL	3SL	3SL	2S	3L
Capital Growth Evaluation	2-	3L	3L	3SL	3SL	3SL	3SL	3SL	3SL	3SL	2S	3L

0 = not important; 1 = little importance; 2 = important; 3 = very important; S = short term (up to 10 years); L = long term (up to 25 years)

*Innovation, adaptation and transfer.

Table 4. Research needs relative to major economic processes by major categories of socioeconomic organizations

ECONOMIC PROCESS/FUNCTION	Major Categories of Socio-Economic Organizations		
	Subsistence	Semi-commercial	Commercial
PRODUCTION			
- Market Demand	1 L Ql Qq	2 S	3 SL Ql
- Input Combination	1 L Ql Qq	3 L	2 L Ql
- Output Supply	1 S Ql Qq	3 SL	3 SL Qq Ql
- Industry Behavior and Performance	-	3 Ql	3 SL Ql
DISTRIBUTION			
- Output Demand	0 -	2 SL Ql Qq	3 L QQ Ql
- Output Storage	1 S Ql	1 L Ql	3 L Ql
APPROPRIATION			
Output Consumption	2 L Qq	3 SL Qq	3 SL Qq
- Surplus Distribution	2 S Ql Qq	3 SL Qq Ql	3 SL QL Qq
- Capital Growth/Loss	-	3 L Ql Qq	3 SL Qq

0 = not relevant; 1 = little importance; 2 = important; 3 = very important; S = short term (10 years); L = long term (up to 25 years); Ql = Qualitative; Qq = Quantitative

Table 5. Research needs in social science by topics and major systems of aquaculture production

SOCIOLOGICAL ISSUES/FACTORS	MAJOR CATEGORIES OF PRODUCTION SYSTEMS											
	OPEN WATERS (EXTENSIVE)						INTERMEDIATE (SEMI-INTENSIVE)				CONTROLLED (INTENSIVE)	
	SEA		COASTAL AREAS		INLAND WATERS		WATER-BASED		LAND-BASED		FEEDLOT	
	startup	mature	startup	mature	startup	mature	startup	mature	startup	mature	startup	mature
I) RESOURCE STATUS												
(TENURE SYSTEMS)												
- Use rights	1	3	1	3	1	3	3	3	3	3	3	3
- Management (collective)	1	3	1	3	1	3	1	2	1	3	1	0
- Conflicts	1	3	2	3	3	3	1	1	2	2	0	0
II) HUMAN RESOURCES												
- POPULATION/DEMOGRAPHY												
. Size	0	0	1	1	3	3	3	3	3	3	1	1
. Work Force Composition	2	3	2	3	2	3	3	3	2	2	3	3
- Age												
- Gender												
- Skills/Education												
. Migration												
- Outmigration												
- Immigration												
. Ethnicity												

Table 5. (continued)

- SOCIAL STRUCTURE								
. Gender Division of Labor	3	3	3					
. Age Classes								
. Social Classes								
. Power Structure								
- SOCIAL INSTITUTIONS								
. Kindship/Lineage								
. Family/Household								
. Organization								
- Cooperatives								
- Communal								
III) SOCIAL RELATIONSHIPS/PRODUCT								
- Legal: Ownership								
- Technical								
- Econ. Appropriation/Revenue								
- Decision Making in Product.								
IV) EXCHANGE/COMMERCIAL SYSTEM								
- Traders-Producers Relation.								
- Processing								
- Modes of Value Tranfer								
- Consumption Alterns/Prefs.								
V) PRODUCTION/FARMING SYSTEMS								
- All Items Above								
- Competition Among Activities								
- Social/Econ. Strategies								
VI) POLICIES								
- Government/Donors								
- Credit								
- Institutional/Legal								

0 = not important; 1 = slight importance; 2 = important; 3 = very important

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