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Aquaculture development and the role of the International Foundation for Science (IFS) *

by
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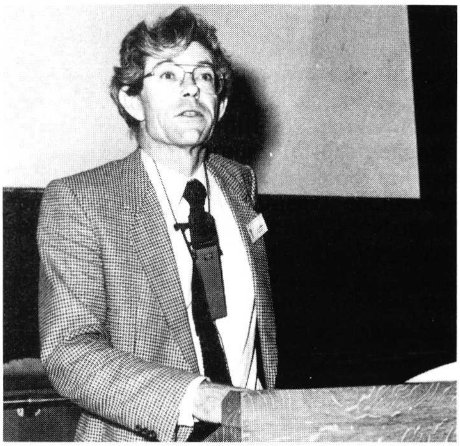

Mr. Chairman, Ladies and Gentlemen,

It is an honour as well as a pleasure to address you on this occasion. It is an honour to be invited by the distinguished **Fondation Roi Baudouin** to give this lecture and it is a pleasure to do so after having received - to quite some extent - "Carte blanche" from the **International Foundation for Science (IFS)** as to the contents of this lecture. And, with respect to these contents, I would like to ask your attention for three aspects I intend to deal with.
These aspects are :
- aquatic products as commodities in human nutrition;
- aquaculture as a disciplinary field;
- the role of IFS in aquaculture development.

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1. AQUATIC PRODUCTS AS COMMODITIES IN HUMAN NUTRITION

Animal proteins play an important role in the food supply for the human society. A main reason for this is the relatively high content of essential amino acids in these types of proteins in comparison with proteins of plant origin, which contain mostly lower amounts of essential amino acids **(Table 1)**. Therefore, animal proteins can act as vital additions to vegetable diets by improving the overall food-value of the diet. Fish (including finfish, molluscs and crustaceans) constitutes some 12 % of the total world's animal production **(Table 2)** and can be regarded as cheap in comparison to meat. Consequently low-income countries in general have a high per capita consumption ratio fish to meat, whereas this ratio is generally low in high-income countries **(Figure 1)**. Despite this fact, also fish has to be paid for, and in quite some regions in the world per capita fish consumption is strongly correlated to per capita income in the respective countries **(Figure 2 and 3)**. Total world's fish consumption has to be met by supply through capture fisheries and aquaculture **(Figure 4)**.

At present many fishery resource experts caution that the exploitation of fish stocks in many cases is stretched close to - or even over - the point of over-fishing (NEAL, 1982). Increase in fish catch does not keep pace with increased fishery effort (FAO, 1981; **Figure 5**). This explains - at least partly - nowadays emphasis on aquaculture. Aquaculture is unevenly distributed in the world, spearheaded by regions as Asia and Europe, while in Africa it is still struggling to find its "niche" in society. **Table 3** sets out present-day aquaculture, but it must be taken in mind that statistics are scarce, not always reliable and sometimes contradictory. Also the relative contribution of aquaculture to the total fish consumption varies from region to region **(Table 4)**. Obviously, there are aquaculture developed respectively developing regions and countries. Following this concept (FAO, 1985) of aquaculture developed countries (ADC's), **table 5** ranks the "top-15" countries as regards to finfish production. It is a striking fact, that these 15 countries have a fish catch, which meets - in the majority of cases even exceeds - the domestic fish consumption. Obviously, in these countries aquaculture flourishes while there is no consumptive need for more fish. Apart from this observation, another can be made e.g. that both in Asia and in Latin America fish culture production is correlated with fish consumption on a per capita basis (**Figure 6 and 7**), the latter being income-dependent as was shown in **figure 2 and 3**.

Based on the above mentioned points, two remarks must be made, as follows.

- Firstly, it seems that fish availability "paves the way" for aquaculture, most probably by making the product accepted by society, by establishing markets and market-infrastructures, etc.

- Secondly, it may be advocated that aquaculture finds its "niche" through proving itself to be a commercial viable activity rather than being a food securing activity only.

The fact that in Africa aquaculture is primarily introduced with the objectives of autoconsumption and family nutrition and scarcely with a commercialisation objective, and has hardly or not developed over the last decade underlines this second remark mentioned above (CIFA, 1983; FAO, 1985; HUISMAN, 1986a, 1986b).

Table 1.
Essential amino-acid content in different food commodities (mg/g protein).

	Meat	Fish	Wheat
Valine	50	52	42
Leucine	82	76	70
Isoleucine	52	50	42
Lysine	93	97	20
Threonine	47	45	29
Methionine + Cysteine	42	42	31
Phenylalanine + Tyrosine	86	62	79
Tryptophane	13	10	13

Table 2. World's animals production (estimate 1985)

Milk	495 million tonnes
Eggs	29 million tonnes
Meat	140 million tonnes
Fish	90 million tonnes

Table 3. World fish culture production by region and by commodity group (Estimate for 1985, after Huisman and Machiels, 1986).

Region	Finfish	Molluscs	Crustaceans	Total
	(Metric tons and percentages (%))			
Asia & Oceania	2,912,150 (72.7)	4,466,150 (84.4)	133,550 (79.1)	7,511,850 (79.3)
Latin-America	21,500 (0.5)	38,500 (0.7)	17.900 (10.6)	77,900 (0.8)
Africa	11,550 (0.3)	250 (-)	- (-)	11,800 (0.1)
North America	154,950 (3.9)	144,800 (0.7)	17,450 (10.3)	317,200 (3.3)
Europe	908,150 (22.6)	643,900 (12.2)	100 (-)	1,552,150 (16.5)
Total	4,008,300 (42.3)	5,293,600 (55.9)	169,000 (1.8)	9,470,900 (100)

Table 4. Fish consumption, fish culture production and the coverage-percentage. (after Huisman and Machiels, 1986).

Region	Fish consumption ($kg.caput^{-1}.yr^{-1}$) A	Fish production ($g.caput^{-1}.yr^{-1}$) B	%-Coverage ($\frac{B}{A}$ x 100%)
Asia & Oceania	15.8	2,248	14.2
Latin-America	9.8	208	2.1
Africa	10.5	34	0.3
North America	16.6	749	4.5
Europe	18.0	1,566	8.7

Table 5. "Top-15" of aquaculture developed countries (ADC's) (FAO, 1984).

Country	Finfish production ($g.caput^{-1}.yr^{-1}$)
Taiwan	7,181
Denmark	3,338
Philippines	3,081
Israel	3,019
Bulgaria	2,575
Hungary	2,472
Japan	2,136
Norway	1,953
Romania	1,861
Hong Kong	1,524
Yugoslavia	1,303
USSR	1,280
India	1,213
Sri Lanka	1,158
Indonesia	1,071

2. AQUACULTURE AS A DISCIPLINARY FIELD

At present aquaculture is carried out in a large variety of husbandry types and of farming systems. Within these types and systems a scala of different approaches exists, e.g.

- extensive - intensive
- small scale - large scale
- subsistence - commercial
- food crop - cash crop,

each approach having its own transition phases.
However, all these different types of aquaculture have in common "a man-controlled production of aquatic organisms", be it that the level as well as the nature of control may vary considerably. This leads to the conclusion that aquaculture in fact is animal husbandry (production of aquatic weeds being an agricultural activity).

Although fisheries and aquaculture are mostly mentioned in one row, it must be well understood that fisheries compares to aquaculture as hunting on animals compares to husbandry of animal.
In aquaculture, therefore, the most important scientific fields are :

- reproductive physiology;
- nutritional and growth physiology;
- health science.

These fields together with the applied field of engineering - what I would like to call husbandry(bio-)engineering - form the disciplinary nucleus of aquaculture.

I want to make - without trying to be complete - a few remarks confining myself to these three scientific fields, which reflect a personal view on the (future) role of these fields in aquaculture.

2.1. Reproductive physiology

The ultimate objective of researching this field in aquaculture must be "a safe and dependable controlled reproduction to garantee seed-supply on demand".
Four different levels of control can be distinguished in view of reproduction.

a. Absence of any control of reproduction

In this case aquaculture relies on the reproductive and/or recruitment potential of natural waters. Tidal ponds (and rice-fields), which are stocked with fish concomitantly with the inflowing water, are examples of such types of aquaculture. However, catch of fry/fingerlings (culture of milkfish, eel, etc.) or of mature adults (pike, prawns) are other examples, which find their use both in developed and developing countries.

b. Control of the reproductive process

The reproductive process is controlled and triggered in nature by a wide variety of biotic and abiotic environmental factors. Manipulation of the environment ("nature building") can be applied to achieve reproduction. The "Dubisch-pond" is a wellknown example in carp farming, as is the provision of artificial nests (nesting material) in the culture of channel catfish, pikeperch, etc. These examples have in common that the manipulation of the environment only triggers final oocyte maturation, ovulation/spermiation, oviposition and fertilization. Therefore, these methods are only successful during the "normal" reproduction period.

c. Control of the time of the reproduction process

In order to achieve this level of control the reproductive cycle and its timely sequence must be known to quite an extent. This type of control asks for the understanding of regulatory mechanisms in for instance oogenesis, vitellogenesis, maturation, ovulation, and others. Only then the scope for control in time is widening. This type of research advances slowly and at present is undertaken only for a few species of commercial value. As an example the results obtained at the Wageningen Agriculture University, Department of Fish Culture and Fisheries, can serve the purpose. Since RICHTER (1976) and HOGENDOORN (1979) compiled the literature on reproduction of *Clarias gariepinus* (an African catfish species) it has been demonstrated that under conditions of elevated temperatures and long days, provided adequate feed supply, a continuous cycle progresses from pre-vitellogenic through post-vitellogenic into atretic follicles. It was furthermore demonstrated that the trigger-effect of the wet season could be replaced by hCG-injection to evoke final maturation and ovulation (EDING et al., 1982; RICHTER and VAN DEN HURK, 1982; RICHTER et al., 1985; 1986). As a result *C. gariepinus* can now be reproduced at any time throughout the year (**Figure 8**), which of course enhances the aquaculture potential of this species (HUISMAN, 1986c).

d. Control of the product of the reproductive cycle

In order to achieve this goal selective breeding has been the answer for quite some decades. More recently, sophisticated techniques have been developed for inter-specific hybridization, induction of polyploidy and "pure-line" breeding through gynogenesis (LANGHOLZ, 1986; RICHTER et al., 1986; NAGY and CSANYI, 1984).

In short, reproductive physiological research, fashioned to the needs of aquaculture must form a continuing scientific journey from descriptive research to learn the process, through experimental research to understand the process into applied research to control the process as well as the product of that process.

2.2. Nutritional and growth physiology

This type of research should emphasize on the three following points.

Firstly, it is imperative that we should enlarge the data-base as regards to our knowledge of essential nutritional requirements, both quantitatively and qualitatively, with respect to macro- as well as to micro-nutritional elements. The fact, that detailed knowledge is only available for a handfull of species - mainly carnivorous species of commercial importance in the developed and centrally-planned countries - while at present some 300 species are cultivated by man illustrates the scope for further research in this field (HALVER and TIEWS, 1979).

Secondly, the bio-chemical pathways and their efficiencies, along which nutrients are digested, metabolized, absorbed and synthetized into body constituents, should be studied as well as the regulatory mechanisms evoked by "internal" and external environmental factors. Only then the phenomenon of growth can be fully understood.

Thirdly, we should thoroughly review the composition of food organisms and of feed ingredients available for aquaculture. And especially here, strategic planning and decision-making is of utmost importance in view of whether to use such ingredients for aquacultural purposes or for other ones, like human nutrition and husbandry animal feeding (NRC, 1973, 1979).

These research lines combined toghether will yield an excellent data-base for dynamic simulation modelling of growth of the organism in particular and of aquaculture production potential in general. At present it seems, that the second line, concerning the bio-availability of nutrients, constitutes the weakest part of the chain.

2.3. Health science

Also in aquaculture health science is an inter-disciplinary field, where aquaculturists, veterinarians, biologists, nutritionists as well as engineers and economists meet each other. As a consequence of the growing pig and poultry industry the conventional veterinary approach is shifting from curing an individual from disease towards disease-prevention of a population. And this is of enormous importance for aquaculture, because the ultimate goal must be health- rather than disease control. SNIESZKO (1974) stressed the importance of a health concept, in which host, pathogen and environment play an interactive role. The three entities may form the targets through which health control is substantiated. The host can be influenced genetically, by feeding, by vaccination, etc. The pathogen can be influenced by manipulation of the environment, desinfection, preventive and/or curative drugs, etc. The environment can be manipulated through water processing, changes in temperature, in dissolved gasses, etc. Be this the scope for possible action, about which knowledge should be developed, I want to emphasize two related and important fields of research e.g. :

- the relation between husbandry praxis and disease riscs, since specific husbandry types may evoke specific diseases;
- research on health parametrization.

Such research may yield knowledge suitable to develop so-called "early warning systems" for aquaculture.

3. THE ROLE OF I.F.S. IN AQUACULTURE DEVELOPMENT

This topic I have left as a last item, because is there to be added to the judgement of the Fondation Roi Baudouin, e.g. **"... pour l'originalité et l'efficacité d'une action visant à soutenir dans le tiers-monde un réseau de jeunes chercheurs participant activement au développement de leur pays, notamment dans le domaine de la nutrition".**
Obviously, there is nothing to be add to this. So, please, allow me to only elaborate somewhat more, with respect to IFS' aquaculture programme.

Since its inception in 1972, IFS-funding for aquaculture research to outstanding young scientists has nearly reached two millions US $. To place this amount of money into an aquacultural perspective it is worthwhile to mention that the total donor funding for research in aquaculture in Africa (which comprised 30 external donors) amounted to somewhat over five millions US $ in the same period (Euroconsult, 1985).

Table 6. I.F.S. Aquaculture Programme
Distribution of grantees (1974-1985).

Region	Finfish	Molluscs	Crustaceans	Total *
	(numbers and percentage (%))			
Asia & Oceania	46(47.4)	8(38.1)	18(78.3)	72(51.1)
Latin-America	25(25.7)	12(57.1)	4(17.4)	41(29.1)
Africa	26(26.9)	1(4.8)	1(4.3)	28(19.8)
Total	97(68.8)	21(14.9)	23(16.3)	141(100)

* Excluding: Seaweeds - 4 grantees in Latin-America
- 1 grantee in Asia

Amphibian - 1 grantee in Asia

Table 7. I.F.S. Aquaculture Programme
Distribution of grantees over selected research areas (1974-1985).

Research areas	Asia & Oceania	Latin-America	Africa	Total
	(numbers and percentage (%))			
Reproduction/fry supply	19 (25.7)	6(13.3)	11(39.3)	36(24.5)
Nutrition/growth	19(25.7)	12(26.7)	5(17.9)	36(24.5)
Health control	5(6.8)	3(6.7)	-	8(5.4)
Husbandry technology	31(41.8)	24(53.3)	12(42.8)	67(45.6)
Total	74(50.3)	45(30.6)	28(19.1)	147(100)

Since its inception aquaculture has been a speer-heading programme of IFS. In 1985 (IFS, 1986), 147 young scientists were or had been funded by IFS in its aquaculture programme. **Table 6** sets out a distribution of these grantees per region and per research object. Comparison of table 6 with table 3 reveals amongst others, that the relative research effort in Africa (some 20 %) is much higher than Africa's contribution to the world aquaculture production (0.1 %); that crustaceans form only 1.8 % of the global production, but account for 16 % of the IFS-funded aquaculture research. Such and other disparities are inherent to and underline the innovative character of scientific research. **Table 7** depicts the distribution of grantees per region and per selected research areas.

Husbandry technology is by far the most favourable area, followed by reproduction and nutrition, while health control is not attracting much attention, which in my option is regrettable, since this field of research is of utmost importance to the aquaculture industry. The high score of the husbandry technology research area is undoubtfully related to the fact that all grantees taken together study nearly a hundred different species.

A considerable part of the research input is devoted to - what I like to call - "aquaculture candidate identification" research. This broad diversification can be argued from a number of reasons, e.g. market preferences, avoiding of riscs of introduction of exotic species, suitability of the species as a research model, over-exploitation of the natural stock, enlargement of the aquaculture data-base, etc. However, apart from these pro's there are also con's; aquaculture candidate identification asks for answers to specific, often identical, questions (easy reproduction, efficient feed conversion, etc.), which leads to more or less identical research projects. Broad species diversification also leads to an exponential growth of research requirements which are difficult to meet in view of limited resources. It is my personal view that the aquaculture industry would be more efficiently enhanced by limiting diversifications somewhat more in favour of specialization.

However, what is mentioned so far in this chapter, is mentioned from an aquacultural point of view and I am well aware that IFS does not stand for aquaculture, but for SCIENCE in aquaculture ! Normally a project is "a means to an end" : to a problem solution, to a production increase, to an innovative action, or other. For IFS a project is a means to educate the project-executor. There is an old Dutch proverb, saying "the job teaches its master", and that's exactly what IFS is aiming at : the scientist, not the project. There is of course some tension here; the candidate-grantee is selected on the basis of - amongst others - his/her research project proposal and his/her output is judged, based on its contribution to science, in this case aquaculture science. This tension is inherent to the target IFS has set, and - let us be frank here - speaks for the courage in and the originality of the programme.

The person-tuned approach, together with the fact that the funded research is to be carried out in the home country, makes IFS unique in the entire donor-world. IFS has now over 1000 grantees, can draw upon the expertise and experience of some 500 unpaid scientific advisors, is - as a non-political organization - supported by 10 governments and at present 82 member organizations. This successful result must be contributed to its approach and its execution. Still, in assessing these results main focus should be on the persons involved.

In this year alone, I have counted $\pm$ 30 scientific publications, published in high standard, double-referee journals, symposium-proceedings, etc., which were made possible by the IFS aquaculture programme, and I am sure I overlooked quite a number. From own experience I know that IFS-grantees became acknowledged members in the national and international scientific community, they became senior scientists, regional training programme managers, University professors and Deans of Faculty. In this way the global task-force to enhance aquaculture is considerably enlarged, as is the aquaculture data-base, due to their results.

Mr. Chairman, ladies and gentlemen, I am aware that I have approached IFS's role from a quantitative point of view. All along the history of Science it is often tried to assess Science qualitatively, and as far as I know it's been always in vain. I may quote here one of my former teachers, who said "quality is difficult to discuss, it is only recognized". May I conclude by expressing my wish that what I have said here will form a means to assess and appreciate the role of IFS, both quantitatively and qualitatively, in Science in general and in Aquaculture Science in particular.
Thank you.

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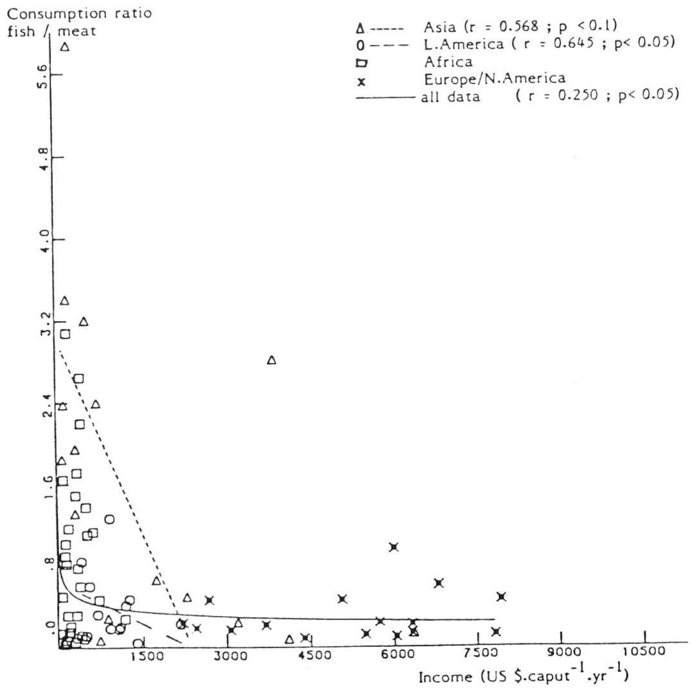

Fig. 1. Fish/meat consumption ratio vs. income (after Huisman and Machiels, 1986).

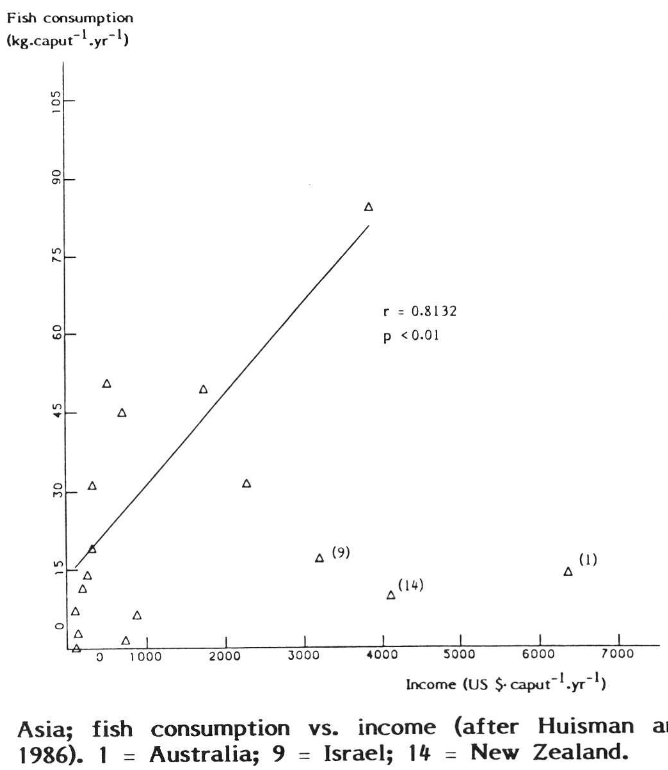

Fig. 2. Asia; fish consumption vs. income (after Huisman and Machiels, 1986). 1 = Australia; 9 = Israel; 14 = New Zealand.

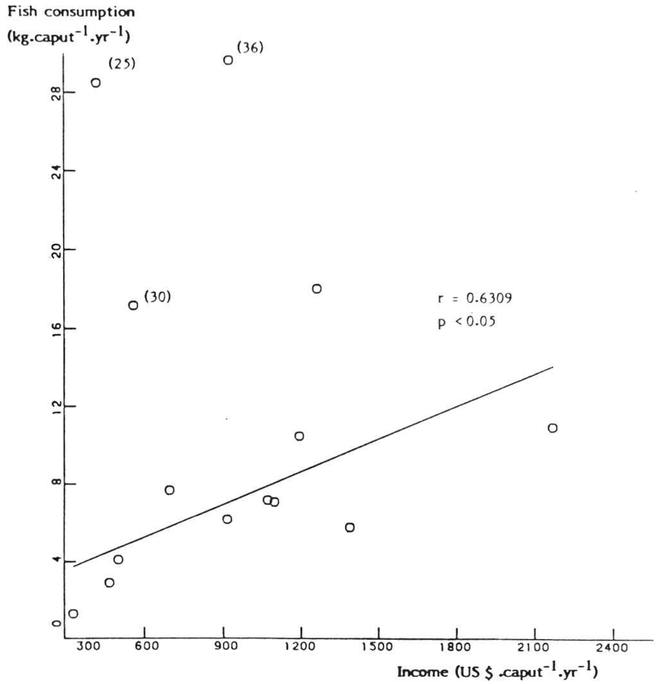

Fig. 3. Latin-America; fish consumption vs. income (after Huisman and Machiels, 1986). 25 = Chile; 30 = Equador; 36 = Peru.

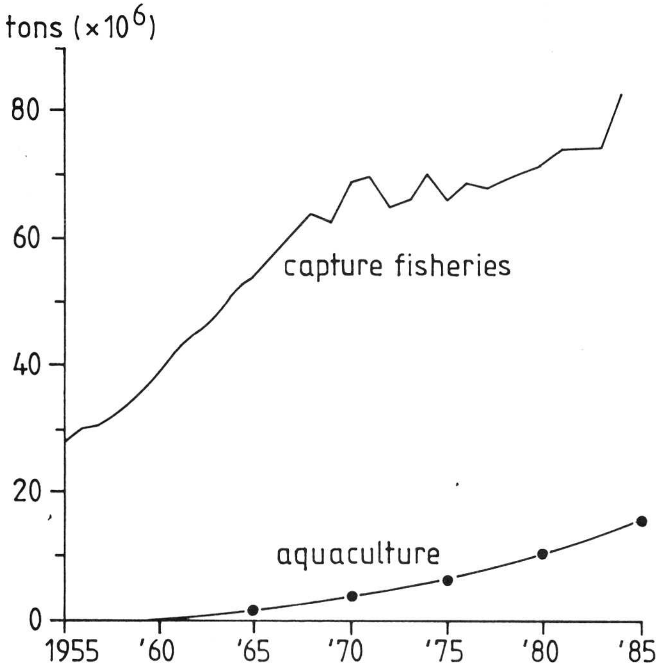

Fig. 4. Total world fish production.

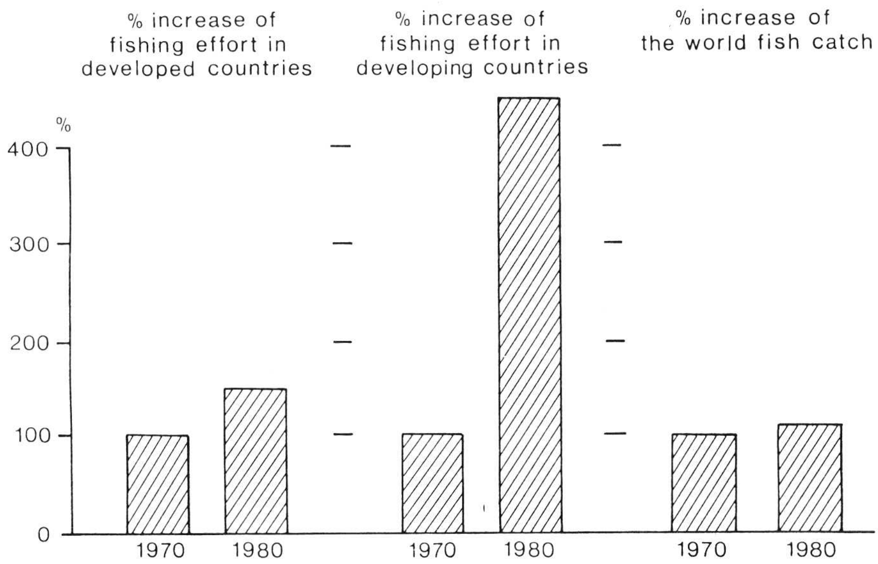

Fig. 5. Increase in fishing effort (power of the fishing fleet in HP) and resulting catch.

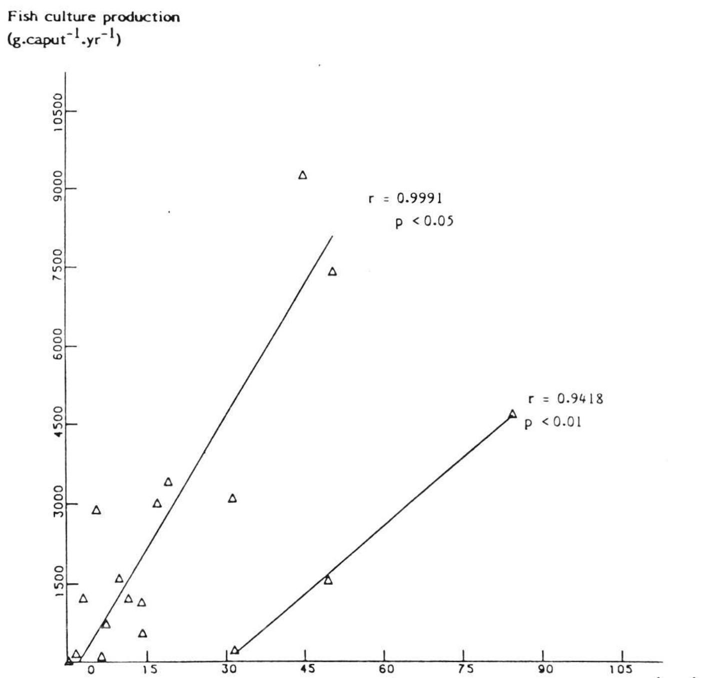

Fig. 6. Asia; fish culture production vs. fish consumption for low-and-high-income countries (after Huisman and Machiels, 1986).

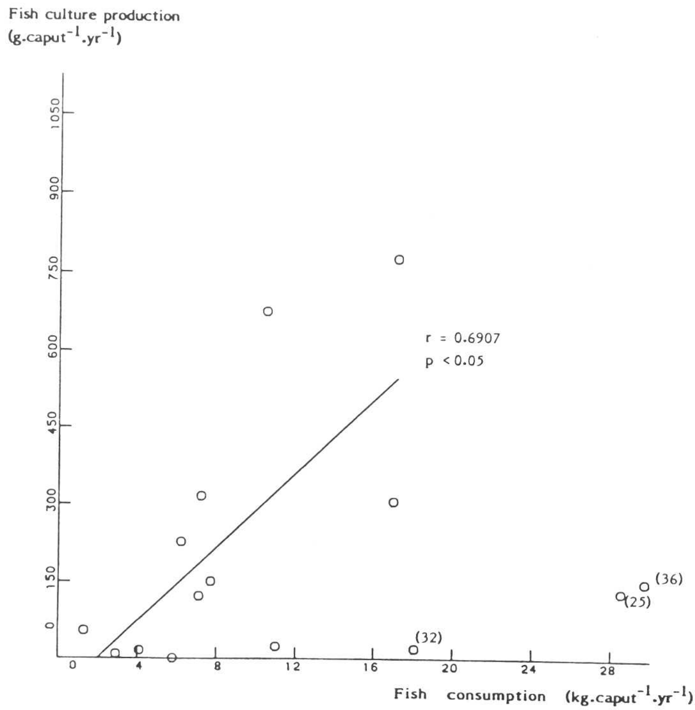

Fig. 7. Latin-America; fish culture production vs. fish consumption (after Huisman and Machiels, 1986). 25 = Chile; 32 = Honduras; 36 = Peru.

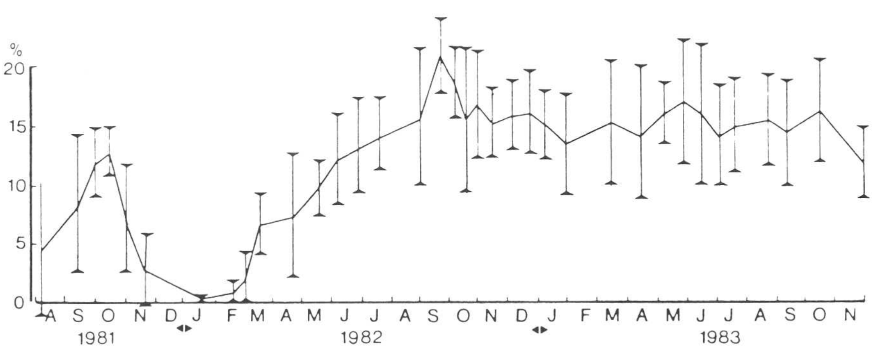

Fig. 8. Egg production as a percentage of female body weight of *C. gariepinus* transferred from outdoor ponds into the hatchery in July 1981 (after Janssen, 1985).