

IMPLICATIONS OF THE JAPANESE EXPERIENCE IN AQUACULTURE
DEVELOPMENT FOR THIRTY-THREE FOOD-SHORT COUNTRIES *

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Abstract

Aquaculture development in Japan has been limited by the following factors: supply and demand, environmental suitability, technical capability, legality, experience, infrastructure, existence of leadership, economic feasibility and social welfare incentives. Similar limiting factors were examined for thirty-three food-short countries. Fifty-five aquaculture variables were tested using multiple regression analysis combined with Pearson correlation analysis. Results imply that aquaculture development in these countries are affected by the same limiting factors as in Japan. These findings are the basis for a two-dimensional aquaculture development model which may be helpful in coping with future technology transfer problems.

1. Introduction

This study is designed to devise an effective aquaculture development strategy for developing countries where there are food shortages.

The rapidly increasing popularity of aquaculture and the debates which issue from the world-wide aquaculture development scene necessitate a re-evaluation of present schemes to transfer technology related to aquaculture (13). Aquaculture has the potential for developing into an important vehicle for solving some of the employment, income, and nutrition problems in food-short countries. FAO and other UN agencies, the World Bank, the Asian Development Bank, Southeast Asian Fisheries Development Center (SEAFDC), International Center for Living Aquaculture Resource Management (ICLARM), USAID, U.S. Peace Corps, OXFAM (England), International Development Research Center in Canada (IDRC), International Foundation for Science in Sweden (ISF), Japan International Cooperation Agency (JICA), and German Volunteers are some of the organizations promoting aquaculture in developing countries (11). In addition, national development plans for aquaculture have been proposed in many developing countries (4, 6, 7). However, strategies now in use are inflexible and show a bias toward technological

aspects.

The purpose of this paper is to suggest a flexible model for revitalizing aquaculture development strategies, emphasizing the 33 food-short countries in 1973 (1). Assuming that experience in developed countries has some applications to developing countries, the history of aquaculture in Japan is reviewed. The limiting factors for aquaculture development in Japan are then tested for the 33 food-short countries. Finally, a two-dimensional aquaculture development model is developed as a key to cope with technology transfer problems.

2. Methodology

The methodology used in this study is based primarily on a combination of descriptive, correlation and multiple regression analyses. Aquaculture development in Japan is described first in order to explore limiting factors in aquaculture development and the growth pattern. The hypothesis that aquaculture activities in the 33 food-short countries are not limited by these factors described for Japan is tested using Pearson correlation and multiple regression analyses. Based on these findings, an aquaculture development model is suggested.

(1) Study area. The countries considered were Japan and the 33 food-short countries reported in 1973 (1). These include Algeria, Angola, Bangladesh, Bolivia, Cameroon, Central African Republic, Chad, Ecuador, El Salvador, Ethiopia, Gambia, Guinea, Guyana, Haiti, India, Indonesia, Iran, Iraq, Kenya, Mali, Mauritania, Niger, Nigeria, Philippines, Saudi Arabia, Senegal, Syrian Arab Republic, Tanzania, Uganda, Upper Volta, Yemen Arab Republic, Yemen Democratic, and Zaire.

(2) Data. There is an abundance of literature on Japanese aquaculture. The most useful data are Drew 1951 (2), Inaba 1964 (9), Japanese Federation of Laver and Shell Fisheries Cooperatives (IFLSFC) 1969 (10), Matsuda 1977 (12), Miyaji 1974 (15), Oshima 1973 (16) and Suisansha Fisheries Yearbook (20).

Aquaculture data for the 33 food-short countries were compiled from Bell and Canterbury 1976 (1), FAO 1974 (2); FAOa,b,c, and d, 1975 (4,5,6,7),

Pillay 1972 (17); 1973 (18) and 1976 (19) and information from the World Bank, SEAFDC, USAID, U.S. Peace Corps, OXFAM, and JICA (11).

Selected variables are summarized in Appendix Tables 1-2. Included were 1 dependent and 54 independent variables. Per capita aquaculture production in 1975 (kg) was selected as the dependent variable because most of these countries have few imports or exports of these products and this reflects consumption as well as production. The total aquaculture production in 1975, based on Pillay 1976 (19), was divided by population estimates for 1975 in the UN Demographic Yearbook 1975 (4).

Eleven basic variables are chosen as independent variables. It should be noted that data from private sectors were not readily available; thus this analysis is biased toward government activities. These 11 variables include consumer acceptability, environmental suitability, amount of papers presented at any one of the 3 FAO Symposia on Aquaculture, experience, degree of international relations, degree of political activities, average rates of return on investment (%), average rates of return on operating costs (%), and average rates of return on gross income (%).

A preliminary analysis suggested that the last three economic variables had no significant correlation with dependent variables at the 0.05 level mainly due to insufficient data (Table 1). Therefore, we deleted these three variables from further analysis. In addition, there were interactions and overlapping among the rest of the 8 independent variables (Table 2). Thus, twenty-eight two-way interactions of these 8 variables and 15 three-way interactions are added as independent variables (Appendix Table 1).

Consumer acceptability was taken to represent the equilibrium of present supply and demand although the data in this category is insufficient. Consumer acceptability scores were adopted from Bell and Canterbury. Total scores for each country are the sum of consumer acceptability scores of 14 aquaculture species (Indian carp, channel catfish, tilapia, eel, rainbow trout, mullet, milkfish, yellowtail, Panaeus shrimp, oyster, mussels, walking catfish, macrobrachium, and blue-green algae) measured by a 4-

point scale (0: unacceptable; 1: poor potential acceptance; 2: satisfactory potential acceptance; and 3: already cultured).

For the environmental suitability variable, environmental acceptability scores were adopted from Bell and Canterbury. Each country's total score consists of the sum of environmental acceptability scores of the 14 species measured by a 12-point scale (0: no environmental acceptability, and 1.2: the highest environmental acceptability).

For technical capability, three variables were used: amount of international assistance, number of research units, and number of papers presented at any one of the 3 FAO Symposia on Aquaculture. International assistance is an external factor affecting technical capability, while research units are an internal factor. The number of papers reflects, at least roughly, the degree of research activity. International assistance to aquaculture is measured by a score of 1 if exist, 0 otherwise for each variable: aquaculture joint ventures, technical assistance to aquaculture from UN, related agencies, and so forth, during the 1967-1973 period. The number of research units is the total number of research institutions presenting papers to any one of the 3 FAO Symposia on aquaculture in Asia (17), Latin America (3) and Africa (5). Another variable is the total number of papers presented at any one of the 3 FAO Symposia. The use of numbers for these activities may not reflect the true relative importance because one project might be much larger than others. However, in this instance each project is weighted equally because sufficient data is not now available to provide a better indicator.

The degree of political activities (which represent legal structure, infrastructure and social welfare programs) takes account of government subsidies, research institutions, extension service, cooperatives, joint ventures, government farms, stocking and conservation practices, and international assistance to aquaculture.

International assistance to aquaculture, fisheries trade (imports and exports) data for 1975 with FAO Yearbook of Fisheries Statistics 1975 (8), presentation of papers at any one of the 3 FAO Regional Workshops on Aquaculture Planning in Africa (4), Asia (6) and Latin America (7) in

1975, and participation (1 if participated, 0 otherwise) to any one of the 3 FAO Symposia on Aquaculture were used to indicate interest on the part of the countries' leaders in aquaculture ("Leadership").

Experience may not be a product of long history; it may be a function of learning during a relatively short period. However, data is limited on such short-term experience. Therefore, we used historical records as a proxy for experience (1: old practice - before 1900; 2: moderately old practice - 1900-1945; 3: recent practice - after World War II; and 4: negligible practice).

Profits are a measure of economic feasibility as an incentive for the private sector. Economic feasibility is represented by average rates of return on investment (%), on operating costs (%) and on gross income (%). However, data were available for only six of the 33 countries (Central African Republic, India, Indonesia, Nigeria, Philippines and Senegal). These data were a mixture of survey results and proposed budgets, so an average of such rates of return was figured for each of these six countries.

(3) Techniques. Techniques employed are a combination of Pearson correlation, and multiple regression analyses using the SPSS system at the Woods Hole Oceanographic Computer Center. One of the serious problems of the regression analysis is multicollinearity, which means that some or all of the independent variables are very highly inter-correlated, resulting in a reduced reliability in the relative importance indicated by the partial regression coefficients. In order to eliminate the effects of multicollinearity, Pearson correlation and multiple regression analyses were combined in such a way that one selected the most important independent variable from the Pearson correlation analysis, checked the correlation coefficients between the most important variable and the rest of independent variables through Pearson correlation analysis, selected variables of low correlation coefficient ($r < .5$) with the most important variable, and analyzed a set of the most important variable and its low-correlated independent variables with the dependent variable through multiple regression analysis. If more than two independent variables were ranked as most important, the same procedure was repeated until the analysis was completed. This method was adopted as it gives the most

reliable results.

3. History of Aquaculture in Japan

Japanese history reflects chronological phases in the history of aquaculture: precondition (before Edo era), phase I (Edo era: 1600-1868), phase II (1868-1945), and phase III (after World War II) (12). During the precondition period, common carp (Cyprinus carpio L.) was first raised and became popular among the nobles. During the phase I period, oyster (Ostrea gigas T.), laver (Porphyra tenera k.), fancy carp (Cyprinus carpio L.) and goldfish (Carassius auratus L.) appeared as aquaculture species. During the phase II period, salmon (Oncorhynchus spp.) and trout (Salmo gairdnerii irideus G.), eel (Anguilla japonica T. et S.), pearl (Pinctada martensii D.), "Ayu" fish (Plecoglossus altivelis T. et S.), and yellowtail (Seriola quinqueradiata T. et S.) were added. All other aquaculture species were introduced during the phase III period.

Some knowledge of methods of raising carp in ponds was apparently introduced from China by 100 A.D. (2). In 724 the Emperor Shomu emphasized the Buddhist precept against killing and changed Japanese eating habits for the next five centuries until Shinran, a new Buddhism leader in the 13th century, advocated that people might eat fish because eating fish was beyond the Buddhist precept against killing (16). During the 9th and 10th centuries, common carp were raised as pet fish among the nobles and developed as moving treasures in landscape gardening.

Despite the early introduction of fish culture into Japan, the rearing of fish was of relatively little importance and its development was modest before 1600. This is attributable to limited supply and demand, quasi-legal prohibition of eating fish, and the lack of strong interest among the countries' leaders in aquaculture development, in addition to a lack of infrastructure and experience.

During the phase I period (1600-1868), aquaculture was regarded as a potential local industry by some local lords, and they attempted to transplant various species in various parts of Japan. After much trial and error, a common carp culture settled in Niigata and Nagano prefectures, oyster at Hiroshima Bay, laver and clams (Corbi-

cula leana P.) in Tokyo Bay, and goldfish at Yamato-kooriyama. Despite the favorable climate, the development of aquaculture as a whole was slow during this period because of limited infrastructure, experience and technical capability, and a relatively low demand for the cultured species.

During the phase II period (1868-1945) the country, after long isolation, adopted some aspects of modern Western civilization with energy and enthusiasm. The government dispatched people to America and Germany to learn techniques pertaining to aquaculture (16). Salmon and trout hatcheries were built, a Fishery Section was established in 1881, many laws concerning aquaculture were legislated, and numerous related educational and research institutions were established. Corresponding to government efforts, commercial aquaculture developed among private sectors. (9,15 and 16). Eel, pearl, Ayu, and yellowtails were added as aquaculture species, due mainly to the enthusiasm of individuals.

Aquaculture production in Japan during the 1912-1975 period is shown in Figure 1. The first national aquaculture conference was held in 1913, and subsidies for aquaculture became available in 1918. Raft culture of oysters developed in 1924. The Perfectural Experiment Station Act was legislated in 1929.

A high quality of leadership toward aquaculture development in both public and private sectors played an important role. Increased experience and technical capability, as well as a favorable legal environment, encouraged the growth of aquaculture. Further more, the demand for aquaculture products increased due to rapid population growth and urbanization and to efforts to expand markets (9,16), particularly in the eel and pearl industries. By 1930 all the basic conditions for a large expansion of aquaculture had developed, and an infrastructure existed which would lead to economically sound aquaculture.

This growth was curtailed by Japan's involvement in international wars during the 1930's and 1940's. Pearls and eels were regarded as luxury goods, and were prohibited. Carp, laver and some other aquaculture species were also treated in the same way, with the exception of grass carp (*Ctenopharyngodon idellus* C. et V.) and silver carp (*Hypophthalmichthys moritrix*

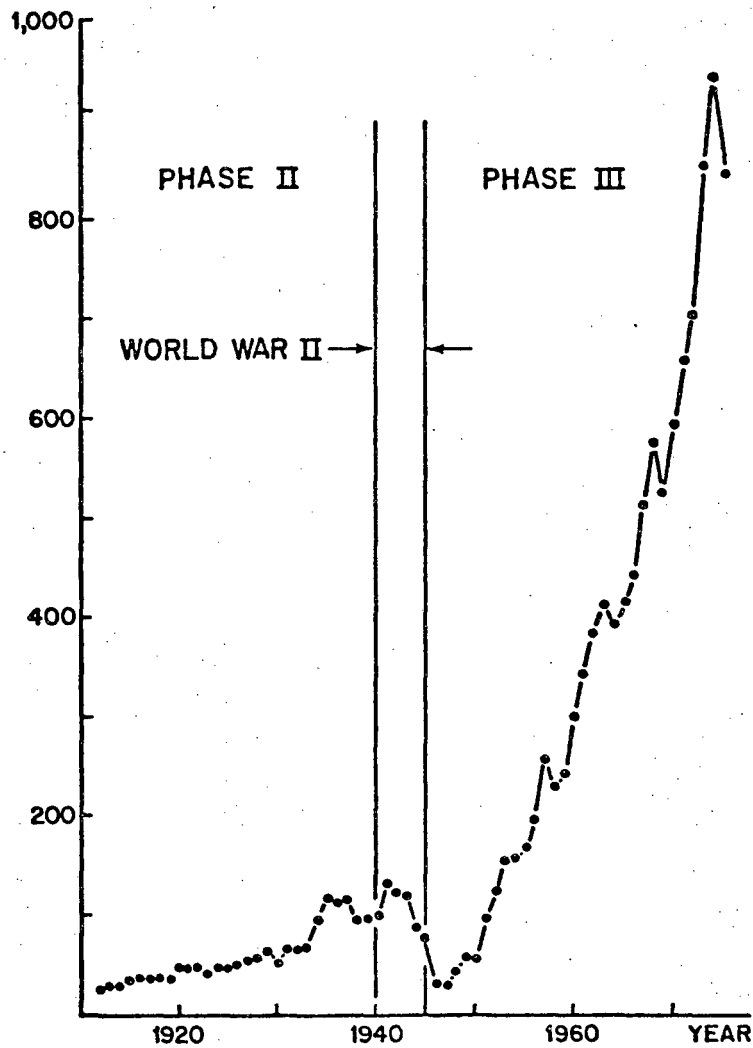
C. et V.) which constituted most of the relatively high aquaculture production during the 1941-1945 period. This is a clear example of a government's ability, through its legal powers, to wipe out all past efforts toward aquaculture development, as well as to promote its development.

Immediately after the war the aquaculture industry entered a period of recovery during the general reconstruction, and began phase III. Owing to General MacArthur's intervention, the pearl and oyster industries recovered quickly (16), and the Fisheries Agency Act was passed in 1948. Again the legal climate became favorable for aquaculture development, and the infrastructure recovered quickly. By 1960 the experience of aquaculture workers had been restored and technical capability increased rapidly. Fixed net culture developed in 1952, and artificial seedlings for laver became possible in 1958 (JFLSFC 1969). The demand for aquaculture species was also high, resulting in good profit potential. The following decades, which were characterized by economic growth, resulted in the rise of living standards and increased demand for aquaculture products, except for pearls and oysters. In 1962 the Inland Sea Fish Farming Center was established and floating net culture developed for laver, a popular magazine "Fish Culture" was first published in 1964, and a low temperature seed storing net for laver was developed in 1965.

However, the aquaculture industry has encountered environmental problems due to urbanization and water pollution as well as natural catastrophe. Abnormally warm weather (laver), typhoon, diseases (laver, goldfish, eel, yellowtail and scallops), shortage of fingerlings (yellowtail and eel), red tide (yellowtail, pearl, oyster), declines of demand (pearl and oyster) and reclamation (laver) have been some of the limiting factors for aquaculture development following the war. Thus, Japanese aquaculture production as a whole does not show a smooth growth curve; instead, it follows a modified combination of the Sigmoid curve and the J-shaped growth curve.

In 1973, the Japanese Diet dealt with issues pertaining to pollution and on July 1, 1977, the Japanese government declared a 200-mile economic zone. There now exists a new climate favorable for aquaculture.

Figure 1. Aquaculture Production in Japan during the 1912-1975 Period (Unit: 1,000t)



Sources: Ministry of Agriculture and Forestry, Fisheries Statistics of Japan 1975, 1977(14) and Suisansha, Fisheries Yearbook 1968, 1968; 1971, 1971; and 1976, 1976(20).

In summary, throughout the history of Japan, aquaculture development has been limited by supply and demand, environmental suitability, technical capability, legality, experience, infrastructure, existence of leadership, economic feasibility and social welfare incentives. Aquaculture has not followed a smooth growth curve.

4. Analysis of the Material for the 33 Food-Short Countries

(1) Preliminary Results

Pearson correlation analysis with per capita aquaculture production in 1975 reveals several significantly correlated independent variables ($S = 0.001$): consumer acceptability, amount of international assistance, number of research units, number of papers, degree of international relations, degree of political activities, and experience; and one less significant variable ($S = 0.033$), environmental suitability (Table 1). The high correlation among these independent variables results in multicollinearity problems (Table 2).

Among these independent variables, consumer acceptability is the only one subject to changes in demand. Although the data include species which are not now consumed in the 33 food-short countries, consumer acceptability is highly correlated with per capita production. Consumer acceptability is likely to reflect present consumption patterns in such a way that the higher the present per capita consumption, the larger the consumer acceptability. Because external trade is negligible at present, per capita consumption and per capita production can be interchanged. Further, consumer acceptability is significantly correlated with 7 other independent variables ($r > .7$): international assistance, number of research units, degree of political activities, and experience. Since international assistance, number of research units, and degree of political activities are highly production oriented variables, it is possible that effects of these variables on production are transformed into effects on consumer acceptability. Experience, or a past history in aquaculture, certainly affects consumer acceptability because consumer taste and preference are products of their past.

Despite the importance of environmental suitability for aquaculture production in general, it was not highly correlated with per capita production. This might result from inadequate data. In fact, most of the selected species for the environmental suitability contribute neither to present aquaculture production nor to consumption. Although, environmental suitability value is positively correlated with the values for consumer acceptability, international assistance, and degree of international relations there is no obvious explanation for this. It maybe that an environment suitable for selected species maybe of a general enough type to attract the interest of international agencies. Nevertheless, improvement of data on environmental suitability is essential for future analysis.

Among technical capability variables, the amount of international assistance has the highest correlation with per capita production. International assistance is intended to provide technology for these countries to increase per capita production in response to critical nutrition problems. The largest recipient of international assistance to aquaculture during the 1967-1973 period was the Philippines, which recorded the highest per capita aquaculture production in 1975 (2.94 kg). Further, the amount of international assistance is correlated with all other seven independent variables. In particular, high correlations are observed with the number of research units, degree of international relations, degree of political activities, and experience. High correlation with experience is explained by the fact that one main purpose of technical assistance projects has been to improve existing aquaculture management. Therefore, most international assistance has been practiced in Bangladesh, India, Indonesia and the Philippines where aquaculture is an ancient practice. Thus, all these high correlations are reasonable.

The next highest correlation with per capita production was .7864 with the number of research units. This high correlation is partly attributable to one inclusion of the Philippines where there are seven research units (the highest) and the highest per capita production. Although most of these research units have been supported by international assistance, internal activities are partially also important for production. Internal research activities provide fingerlings where they

Table 1. Pearson Correlation with Per Capita Aquaculture Production in 1975 for the Thirty-Three Food-Shortages Countries

Categories	Independent Aquaculture Variables (Indicators)	Correlation Coefficient (r)	Cases	Significance
Supply and Demand	1. Consumer acceptability scores	.7653	27	.001
Environmental Suitability	2. Environmental suitability scores	.3965	29	.033
Technical capability	3. Amount of international assistance	.7881	33	.001
	4. Number of research units	.7864	33	.001
	5. Number of papers	.5540	33	.001
Existence of leadership	6. Degree of international relations	.5550	33	.001
Legality-infrastructure-social welfare	7. Degree of political activities	.6172	33	.001
Experience	8. Experience	-.6553	33	.001
Economic feasibility	9. Average rates of return on investment	.6762	6	.140
	10. Average rates of return on op. costs.	-.4594	6	.359
	11. Average rates of return on gross income	-.4849	6	.326

Table 2. Correlation Matrix for the Eight Basic Independent Variables

	CA	ES	IA	RU	P	DIR	DPA	E
Consumer acceptability (CA)	1.0	.52	.76	.80	.60	.68	.80	-.74
Environmental suitability (ES)	.52	1.0	.55	.47	.42	.61	.47	-.40
Amount of international assistance (IA)	.76	.55	1.0	.80	.65	.73	.76	-.78
Number of research units (RU)	.80	.46	.80	1.0	.88	.70	.85	-.73
Number of papers (P)	.60	.42	.65	.88	1.0	.61	.76	-.59
Degree of international relations (DIR)	.68	.61	.73	.70	.61	1.0	.75	-.72
Degree of political activities (DPA)	.80	.47	.75	.85	.76	.75	1.0	-.80
Experience (E)	-.74	-.40	-.78	-.73	-.59	-.72	-.80	1.0

are not easily available, advice, better aquaculture management, and support through extension services. Research activities might affect total production directly and per capita production indirectly. For example, in India where total aquaculture production, supported by the same number of research units as in the Philippines, is the highest (494,000t), per capita production in 1975 was relatively small (.825Kg) because of India's huge population. Further, the number of research units is highly correlated with number of papers, degree of international relations, degree of political activities and experience. The direct correlations among these variables are obvious. However, these correlations could be directly or indirectly affected by the following logic: the longer the experience, the higher the consumer acceptability, which in turn leads to larger total production, and more active political and research activities. As political and research activities increase, international relations become more important.

Number of papers presented at international meetings had the least correlation with per capita production because of its indirect effects. Number of papers has a high correlation with degree of political activities. The logic behind this is that the more active the political activities, the more active the research activities, which in turn leads to larger number of papers.

Degree of international relations is correlated with per capita production, but only a little. The high correlation with degree of political activities is because external incentives have enhanced internal activities.

Degree of political activities and experience are also correlated with per capita production. High correlation between degree of political activities and experience is reasonable because historical experience has influenced aquaculture activities internally.

Despite the fact that most data on independent variables is limited to government activities, significant correlations with the dependent variable, per capita production, imply that the role of government in per capita aquaculture production is important.

(2) Results

Results from the multiple regression analysis, combined with Pearson correlation analysis, are summarized in Table 3.

After eliminating multicollinearity problems, the final results indicate that a three-way interaction of the consumer acceptability, amount of international assistance, and the number of papers presented at any one of the 3 FAO Symposia on Aquaculture has the most significant relationship to per capita aquaculture production in 1975. The square of multiple correlation (R^2) is .85794 which implies that the result is highly reliable. The regression coefficient is large ($B = 2443$) so that the impact of the interaction of these three limiting factors on per capita aquaculture production would be large.

Despite relatively high correlations with per capita production, the final result does not include any direct effect of the 8 basic independent variables, because of high interactions and/or overlap among these. Since the result is mechanically determined by regression analysis, assuming linearity, we could not simply say that other variables are insignificant. Instead, if this interaction variable is deleted from the data, we could expect a completely different second best answer which might be some other combination.

In summary, per capita aquaculture production in these 33 food-short countries is limited by consumer acceptability, environmental suitability, amount of international assistance, number of research units, number of papers presented to any one of the 3 FAO Symposia on aquaculture, degree of international relations, degree of political activities, and experience. These limiting factors interact with and/or overlap each other and can explain per capita aquaculture production up to the point that the square of multiple correlation (R^2) reaches .85794, based on our present data. These results for the 33 food-short countries imply that aquaculture development is also limited by one or a combination of the same factors as prevail in Japan.

5. Discussion

The evaluation of economic feasibility for the thirty-three food-short countries has suffered from insufficient and/or inadequate data for economic variables in these countries. There

Table 3 Emperical Results

** Significant at the 0.01 level

$$Y' = 3.812 \times 10^{-2} + 2443 X_1 X_2 X_3$$

where Y' is an estimated per capita aquaculture production in 1975 (kg), X_1 is the consumer acceptability, X_2 is the amount of international assistance, X_3 is the number of papers; Pearson correlation coefficient between Y (per capita aquaculture production in 1975) and $X_1 X_2 X_3$ is .92625 in which 33 countries are included; F value for regression coefficient (B) is 187.2187**; multiple correlation coefficient (R) is .92625; R^2 is .85794; and F value for multiple correlation coefficient (R) is 187.2187.**

is much room for the improvement of data. Nevertheless, economic feasibility seems to be critical in these countries. According to FAO (4), failures of some of the ill-conceived programs in the past have continued to remain a major constraint in convincing farmers and investors of the economic viability of aquaculture. There are indeed problems of increasing input costs, exploitation of middlemen, perishable products and remoteness of production areas from the market, which directly affect the economic feasibility.

Based on the previous analyses, together with the importance of economic feasibility, we could assume that aquaculture development measured by per capita production in these food-short countries is limited by one or combinations of nine factors in any given circumstance: supply and demand, environmental suitability, technical capability, legality, experience, existence of leadership, infrastructure, economic feasibility and social welfare incentives which interact with one another. Assuming that the Japanese experience is also applicable to a growth model in these countries, a hypothetical aquaculture development model could be posited. The model consists of functional and growth dimensions.

The functional dimension emphasizes the importance of the existence of leadership as a lubrication function, infrastructure as a transportation function, social welfare as an incentive for the public sector, and of economic feasibility as an incentive for the private sector. Supply and demand, environmental suitability, technical capability, legality and experience become crucial as basic limiting factors for aquaculture development only when leadership exists, and infrastructure, economic feasibility and social welfare incentives are sound and adequate.

The growth dimension is regarded as a combination of the Sigmoid shaped growth curve in the long run and the J-shaped growth curve in the short run which occurred in aquaculture development in Japan. If each limiting factor is removed, the growth curve should be a perfect combination of these two curves. However, each limiting factor may become so critical that despite increasing efforts the growth curve would stagnate as in India or decline as in Indonesia (18 and 19). Aquaculture could even be eliminated. For example, regardless of an early introduction of aquacultural methods, aquaculture activity is negligible in Guyana, Iran, Iraq, Niger, Saudi Arabia, Syrian Arab Republic, and Upper Volta (3 and 5). Another classic example is the abandoned ponds built by colonial governments in many parts of Africa (5). Modern versions of this disintegration could result from disease and competition, urbanization and pollution, as occurs in Japan (12).

6. Summary and Conclusions

In any given circumstance, aquaculture development in Japan has been limited by one or a combination of the following factors: supply and demand, environmental suitability, technical

capability, legality, experience, infrastructure, existence of leadership, economic feasibility and social welfare incentives. The results for the 33 food-short countries indicate that present per capita aquaculture production as an indicator for aquaculture development is a function of an interaction of the consumer acceptability, amount of international assistance and the number of papers presented at any one of the FAO Symposia on aquaculture; and all the other basic independent variables could also be used, with a declining degree of correlation. These results imply that aquaculture development in these countries is also limited by one or a combination of the same sort of factors as prevail in Japan. One possible development from our analyses could be a hypothetical aquaculture development model to cope with technology transfer problems in these food short-countries. This model would imply the following:

- i) Until industry reaches the "take off" stage, the growth of aquaculture is a slow, step-by-step process.
- ii) The elimination of any one of the limiting factors will contribute to the growth of aquaculture, but not much.
- iii) Nevertheless, the best way to develop aquaculture is to eliminate the limiting factors one by one.

Although further research is needed for the improvement of data, economic feasibility, experience, social welfare, links among limiting factors and methodology, the proposed two-dimensional aquaculture development model -- function and growth -- is likely to be adequate to predict when, how, and why aquaculture can develop in any given circumstance or place.

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Appendix Table 1: Aquaculture Variables Used

Item	Variables
1	Consumer acceptability*
2	Environmental suitability*
3	Amount of international assistance on aquaculture: 1967-73*
4	Number of research units concerning aquaculture in 1975*
5	Number of papers presented at the 3FAO Symposia on Aquaculture in Asia, Africa and Latin America*
6	Degree of international relations on aquaculture*
7	Degree of political activities*
8	Aquaculture experience*
9	Average rates of return on investment (%)*
10	Average rates of return on operating costs (%)*
11	Average rates of return on gross income (%)*
12	Item 1 x Item 2
13	Item 1 x Item 3
14	Item 1 x Item 4
15	Item 1 x Item 5
16	Item 1 x Item 6
17	Item 1 x Item 7
18	Item 1 x Item 8
19	Item 2 x Item 3
20	Item 2 x Item 4
21	Item 2 x Item 5
22	Item 2 x Item 6
23	Item 2 x Item 7
24	Item 2 x Item 8
25	Item 3 x Item 4
26	Item 3 x Item 5
27	Item 3 x Item 6
28	Item 3 x Item 7
29	Item 3 x Item 8
30	Item 4 x Item 5
31	Item 4 x Item 6
32	Item 4 x Item 7
33	Item 4 x Item 8
34	Item 5 x Item 6
35	Item 5 x Item 7
36	Item 5 x Item 8
37	Item 6 x Item 7
38	Item 6 x Item 8
39	Item 7 x Item 8
40	Item 1 x Item 3 x Item 4
41	Item 1 x Item 3 x Item 5
42	Item 1 x Item 3 x Item 6
43	Item 1 x Item 3 x Item 7
44	Item 1 x Item 3 x Item 8
45	Item 3 x Item 4 x Item 5
46	Item 3 x Item 4 x Item 6
47	Item 3 x Item 4 x Item 7
48	Item 3 x Item 4 x Item 8
49	Item 4 x Item 5 x Item 6
50	Item 4 x Item 5 x Item 7
51	Item 4 x Item 5 x Item 8
52	Item 5 x Item 6 x Item 7
53	Item 5 x Item 6 x Item 8
54	Item 6 x Item 7 x Item 8
55	Per capita aquaculture production in 1975 (Kg)**

* Basic independent variables.

** Dependent variables.

Appendix Table 2: Data Matrix for the Thirty-Three Food-Short Countries

	Consumer Acceptability*	Environmental Suitability*	Amount of Int. assistance: 1967-73*	No. of research units in 1975*	No. of Papers	Degree of international relations*	Degree of Political Activities	Experience*	Ave. rate of return on investment(%)*	Ave. rate of return on operating costs (%)*	Ave. rate of return on investment (%)*	Per capita aqua- culture production in 1975 (Kg)**
Algeria	9	8.0	0	0	0	0.0	0	4	n.a.	n.a.	n.a.	0
Angola	16	10.2	0	0	0	0.0	0	4	n.a.	n.a.	n.a.	0
Bangladesh	31	11.8	4	1	0	2.0	2	1	n.a.	n.a.	n.a.	0.995
Bolivia	23	4.4	0	1	1	0.0	2	2	n.a.	n.a.	n.a.	0.248
Cameroon	23	12.8	4	1	1	1.0	4	3	n.a.	n.a.	n.a.	0.007
Central Afr.Rep.	n.a.	5.0	2	2	5	3.0	3	2	174.7	196.8	58.8	0.023
Chad	17	5.0	0	0	0	1.0	0	4	n.a.	n.a.	n.a.	0
Ecuador	22	13.2	2	2	4	3.5	4	2	n.a.	n.a.	n.a.	0.147
El Salvador	27	13.5	1	2	2	3.0	5	3	n.a.	n.a.	n.a.	0.301
Ethiopia	17	11.3	0	1	1	1.0	3	4	n.a.	n.a.	n.a.	0
Gambia	n.a.	n.a.	0	0	0	1.5	0	4	n.a.	n.a.	n.a.	0
Guinea	16	13.0	0	0	0	0.0	0	4	n.a.	n.a.	n.a.	0
Guyana	n.a.	n.a.	1	0	0	2.0	1	3	n.a.	n.a.	n.a.	0
Haiti	18	12.1	0	0	0	0.0	0	4	n.a.	n.a.	n.a.	0
India	33	13.0	5	7	11	3.0	7	1	20.8	152.6	49.3	0.825
Indonesia	35	12.0	4	3	1	4.0	4	1	35.7	93.2	45.0	1.101
Iran	9	10.9	2	0	0	1.0	0	3	n.a.	n.a.	n.a.	0
Iraq	10	7.0	2	0	0	1.0	0	3	n.a.	n.a.	n.a.	0
Kenya	16	13.8	2	1	0	3.0	3	2	n.a.	n.a.	n.a.	0.029
Mali	16	5.0	0	0	0	1.5	0	4	n.a.	n.a.	n.a.	0
Mauritania	n.a.	n.a.	0	0	0	0.0	0	4	n.a.	n.a.	n.a.	0
Niger	16	7.0	1	0	0	1.0	2	3	n.a.	n.a.	n.a.	0
Nigeria	22	13.0	3	2	6	3.0	4	2	7.7	22.0	18.0	1.191
Philippines	37	13.0	7	7	6	4.0	7	1	371.6	149.8	46.3	2.940
Saudi Arabia	11	4.8	0	0	0	0.0	0	3	n.a.	n.a.	n.a.	0
Senegal	n.a.	n.a.	2	1	1	2.0	5	3	14.9	1650.0	93.0	0.046
Syrian Arab Rep.	10	6.0	0	0	0	0.0	1	3	n.a.	n.a.	n.a.	0
Tanzania	18	13.0	2	2	3	4.0	4	2	n.a.	n.a.	n.a.	0.098
Uganda	17	5.0	2	1	2	2.0	4	3	n.a.	n.a.	n.a.	0.060
Upper Volta	17	5.0	0	1	1	0.0	0	3	n.a.	n.a.	n.a.	0
Yemen Arab Rep.	9	4.8	0	0	0	0.0	0	4	n.a.	n.a.	n.a.	0
Yemen Dem.	n.a.	4.8	0	0	0	0.0	1	4	n.a.	n.a.	n.a.	0
Zaire	17	5.0	1	1	1	1.0	4	2	n.a.	n.a.	n.a.	0.201

*Basic independent variables

**Dependent variables