ALLOCATIVE EFFICIENCY IN POND FISH PRODUCTION IN DELTA STATE, NIGERIA: A PRODUCTION FUNCTION APPROACH

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Abstract

The paper examined the efficiency of resource utilisation in pond fish production in Delta State, Nigeria, using a production function approach. Data for the study were obtained from a cross section of 72 farms using a multi-stage sampling procedure. The farms had a total water surface area of 101.15 hectares. Regression results indicated that pond size, feeds, fingerlings, and labour were significant ($p < 0.05$) determinants of output in pond fish production. The index of resource-use efficiency revealed that fish farmers were not only inefficient in the allocation of productive resources, but grossly over-utilised feeds, fingerlings, fixed costs, and labour with an allocative efficiency index of 0.0025, 0.00064, –0.00017, and 0.00025 respectively. Pond size was however, under-utilised with an allocative efficiency index of 3.22. Given the under-utilisation of pond size, strategies aimed at increasing farm size will thus significantly improve efficiency of utilisation of other resources. This, in addition to enhanced access to current technical and price information by farmers, will raise output and net returns in small-scale fish farming enterprises.

Key words: resource allocation, production function analysis, allocative efficiency index, small-scale fish farming, Delta state, Nigeria

INTRODUCTION

FAO (2002) reported that an estimated 840 million people lack adequate access to food; and about 25% of these are in sub-Saharan Africa (Pinstrup-Anderson *et al.,* 1999). As the population grows and puts more pressure on natural resources, more people will probably become food insecure, lacking access to sufficient amount of safe and nutritious food for normal growth, development and an active and healthy life (Pretty, 1999). A number of countries in sub-Saharan Africa are characterised by low agricultural production, widespread economic stagnation, persistent political instability, increasing environmental damage, and severe poverty. Given this situation, it is therefore pertinent to provide the poor and hungry with a low cost and readily available strategy to increase food production using less land per caput, and less water without further damage to the environment (Pretty *et al.*, 2003).

Aquaculture, the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants, is often cited as one of the means of efficiently increasing food production in food-deficit countries. In Nigeria, total domestic fish production fluctuated between 562,972 to 524,700 metric tonnes in 1983 to year 2003; while the output of fish farming during this period was 20,476 to 52,000 metric tonnes. Fish farming accounted for between 3.64 and 9.92% of total domestic fish production in Nigeria within this period, while the bulk of production came from artisanal fishing (Table 1). Although the outlook of aquaculture production is worrisome given the growing demand for fish and the declining yield of natural fish stocks due to over-exploitation, fish farming still holds the greatest potentials to rapidly boost domestic animal protein supply in Nigeria. According to Tobor (1990), there are about 1.75 million hectares of suitable land for aquaculture in Nigeria and 25% of this will yield 656,820 tonnes of fish per year when placed under cultivation. Similarly, Welcome (1979) reported that there about 1.5 million hectares of floodplains and swampland in the Niger Delta hydro-ecological zone which are suitable for fish farming and can produce about 60,000 metric tonnes of fish per year. Furthermore, about 6,450 tonnes of fish can be produced annually from 75,000 hectares of coastal lagoons (Kapetsky, 1981).

Fish farming is an integral component of the overall agricultural production system in Delta State, Nigeria. The terrain of most part of the State, particularly the southern and central agro-ecological zones is swampy and prone to seasonal flooding. This makes a vast expanse of land in these areas unsuitable for crop farming. The prevailing hydrographic conditions therefore make fish farming a very attractive alternative production to which the abundant land and water resources in Delta State can be put (Inoni and Chukwuji, 2000). In spite of the great potentials of fish farming in the study area, factors such as low technical knowledge on the part of fish farmers and the high cost of production inputs have constrained its contribution to increased food supply and poverty reduction.

Furthermore, the efficiency or inefficiency of utilisation of available resources for fish farming has remained an unanswered question in the quest for increased pond fish production in Delta State in particular, and Nigeria in general. An efficient method of production is that which utilises the least quantity of resources in order to produce a given quantity of output. A productionprocess that uses more physical resources than an alternative method in producing a unit of output is thus said to be technically inefficient. However, since economic efficiency embodies both technical and allocative efficiencies, once the issues of technical inefficiency have been removed the question of choosing between the set of technically efficient alternative methods of production, allocative efficiency, comes to fore. According to Oh and Kim (1980), allocative efficiency is the ratio between total costs of producing a unit of output using actual factor proportions in a technically efficient manner, and total costs of producing a unit of output using optimal factor proportions in a technically efficient manner. However, a farm using a technically efficient input combination may not be producing optimally depending on the prevailing factor prices. Thus, the allocatively efficient level of production is where the farm operates at the least-cost combination of inputs. According to Yotopoulos and Lau (1973), a firm is allocatively efficient if it was able to equate the value of marginal product (MVP) of each resource employed to the unit cost of that resource; in other words, if it maximises profit. Therefore allocative efficiency measure, quantifies how near an enterprise is to using the optimal combination of production inputs when the goal is maximum profit (Richetti and Reis, 2003).

Although a number of studies have been carried out on efficiency in livestock and crops production in Nigeria, most of such studies dwelled on technical efficiency with only a few dealing with the critical issue of allocative efficiency (Okoruwa *et al*., 2001; Agbamu and Fabusoro, 2001; Ajibefun *et al*., 2002; Ojo, 2003; Ogunyinka and Ajibefun, 2004). In the fisheries sector in Nigeria, and particularly the fish farming sub-sector in Delta State, the quantitative determination of allocative efficiency has not been the focus of recent studies. Given the foregoing scenario, the study intends to determine resource-use efficiency in pond fish production in Delta State, Nigeria using production function approach. A determination of allocative efficiency in pond fish production will facilitate investment decision-making in the fish farming business, as well as give an indication of optimal input combinations necessary to obtain maximum returns from the scarce resources employed.

RESEARCH METHODS

Area of study

Delta State which is one of the 36 States that comprise the Federal Republic of Nigeria is the location of study. Delta State lies approximately between longitude 5^0 00´ E and 6^0 45´E of the Greenwich Meridian, and latitude 5^0 00´N and 6^0 30´ N of the Equator. It is one of Nigeria's extremely southern states, that covers an area of 17,698 km^2 with a population of 2.57 million people. (National Population Commission, 1993; Delta State Agricultural Statistics and Information, 2000). The State is predominantly rural, and is traversed by flowing streams and rivers that empty into the western coast of the Niger Delta. The vegetation of the area ranges from mangrove swamps along the coast to freshwater swamp forests, and a derived savannah in the northern extremities. The prevailing climatic and hydrographic conditions favour a fishery and an agricultural economy. In fact, agriculture and fishing are the major occupations of the people of Delta State, Nigeria.

Sampling method and data collection

Data used to estimate allocative efficiency in pond fish production were collected as primary data from a cross-section of fish farmers with the aid of questionnaire that was administered to the respondents. This was complemented by oral interviews in some cases. Data collected include social characteristics of the fish farmers, types and quantity of inputs used, pond size, output of fish, input and output prices, fish sales, production period, fish species cultured, and labour utilisation during the 2004/2005 production year. The survey was conducted between September and December, 2005.

Multi-stage random sampling technique was used to obtain the data. Firstly, the State was stratified into the three agricultural zones of Delta North, Delta Central and Delta South from which three (3) local government areas (LGAs) each were randomly selected to give a total of 9 LGAs used for the study. The nine (9) LGAs were Aniocha South, Oshimili South and Ika South in Delta North; Ughelli South, Ughelli North and Udu in Delta Central; and Isoko North, Isoko South and Warri South in Delta South agricultural zone. Secondly, 24 fish farms were chosen randomly from the 3 agricultural zones to give a total sample of 72 pond fish farmers from which relevant data were obtained. The sample size represents about 31% of the 232 functional fish farms in the State in the 2004/2005 production season. The 72 farms have a total water surface area of 101.15 hectares (Table 2).

Model specification and estimation

The following power production function was specified in order to determine the effects of predetermined variables on the value of pond fish production, as well as the efficiency of resources used:

$$OPT = \beta\left(PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}\right) \qquad (1)$$

where:

OPT = the output of fish harvested (kg),
PND = pond size in fish was grown (ha),
FDS = the quantity of feed resources utilised (kg),
FNG = the volume of fish seeds stocked,

LBR = labour input utilised in man-days,
FXD = the expenses on fixed inputs (N,=), proxied by the annual depreciation using straight line method
β = the intercept
δ_i = the function coefficients
e = the stochastic error.

However, the determination of allocative efficiency in pond fish production can only be derived from certain physical parameters of the power production function specified in equation (1). These are the marginal physical product (MP), the per unit price of fish, and per unit cost of each input utilised. The marginal physical products with respect to each of the inputs in equation (1) are given as follows:

$$MP_{pnd} = \frac{\partial OPT}{\partial PND} = \frac{\partial\left(\beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}\right)}{\partial PND} = \frac{\delta_1 \beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}}{PND} = \frac{\delta_1 OPT}{PND} \tag{1a}$$

$$MP_{fds} = \frac{\partial OPT}{\partial FDS} = \frac{\partial\left(\beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}\right)}{\partial FDS} = \frac{\delta_2 \beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}}{FDS} = \frac{\delta_2 OPT}{FDS} \tag{1b}$$

$$MP_{fng} = \frac{\partial OPT}{\partial FNG} = \frac{\partial\left(\beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}\right)}{\partial FNG} = \frac{\delta_3 \beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}}{FNG} = \frac{\delta_3 OPT}{FNG} \tag{1c}$$

$$MP_{lbr} = \frac{\partial OPT}{\partial LBR} = \frac{\partial\left(\beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}\right)}{\partial LBR} = \frac{\delta_5 \beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}}{LBR} = \frac{\delta_5 OPT}{LBR} \tag{1d}$$

$$MP_{fxd} = \frac{\partial OPT}{\partial FXD} = \frac{\partial\left(\beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}\right)}{\partial FXD} = \frac{\delta_6 \beta\, PND^{\delta_1} FDS^{\delta_2} FNG^{\delta_3} LBR^{\delta_4} FXD^{\delta_5} e^{\mu}}{FXD} = \frac{\delta_6 OPT}{FXD} \tag{1e}$$

Therefore allocative efficiency of resources employed in pond fish production can be expressed as follows:

$$AL_{ef} = \frac{MP_{x_i} * p_{opt}}{p_{x_i}} \tag{2}$$

But, $MP_{x_i} * p_{opt} = MVP$, and $p_{x_i} = MFC$; therefore allocative efficiency,

$$AL_{ef} = \frac{MVP}{MFC} = \frac{Value\, of\ Marginal\ Product}{Marginal\ Factor\ Cost} \tag{2a}$$

where:

AL_{ef} = an index of allocative efficiency in pond fish culture.
MP_{x_i} = the marginal physical product of the ith input. It is the change in output due to a per unit change in the specified input. It is obtained as the first derivative of the production function, equation (1).
p_{opt} = is the price per unit of fish, and it is obtained by dividing total revenue by the quantity of fish produced.
p_{x_i} = the cost per unit of the ith input employed in the production process. It is obtained by dividing

the total cost of the i^th input by the quantity of such input utilised.

For the respective inputs in equation (1), the allocative efficiency is given as:

$$AL_{ef} = \frac{\left(\delta_1 OPD / PND\right) * p_{opt}}{p_{pnd}}$$
$$AL_{ef} = \frac{\left(\delta_2 OPD / FDS\right) * p_{opt}}{p_{fds}}$$
$$AL_{ef} = \frac{\left(\delta_3 OPD / FNG\right) * p_{opt}}{p_{fng}}$$
$$AL_{ef} = \frac{\left(\delta_5 OPD / LBR\right) * p_{opt}}{p_{lbr}}$$
$$AL_{ef} = \frac{\left(\delta_5 OPD / FXD\right) * p_{opt}}{p_{fxd}} \quad (3)$$

A given resource is optimally allocated when there is no divergence between its MVP and its MFC. According to Agbamu and Fabusoro (2001), Oladeebo *et al*. (2006) and Fasasi (2006), three scenerios can be observed;

(a) $\frac{MVP_{x_i}}{MFC_{x_i}} = 1,$

indicates that resource X_i is optimally utilised

(b) $\frac{MVP_{x_i}}{MFC_{x_i}} < 1,$

indicates that resource X_i is over-utilised

(c) $\frac{MVP_{x_i}}{MFC_{x_i}} > 1,$

indicates that resource X_i is under-utilised.

In order to estimate the regression coefficients using the Ordinary Least Squares (OLS) technique, equation (1) was linearised by logarithmic transformation to;

$$\ln OPT = \xi + \delta_1 \ln PND + \delta_2 \ln FDS + \delta_3 \ln FNG + \\ + \delta_4 \ln LBR + \delta_5 \ln FXD \quad (4)$$

where the variables are as defined earlier in equation (1), and $\xi = \ln \beta$. Regression results were obtained using Pc Give version 9.10 (Hendry and Doornik, 1996).

RESULTS AND DISCUSSION

Regression results

The results of the regression analysis of factors influencing output in pond fish production in Delta State, Nigeria are shown in Table 3. The estimated regression fits the data well with an adjusted R^2 coefficient of 0.70. Also, the size and signs of the regression coefficients are in consonance with *a priori* expectations. The results indicate that pond size, feed, fingerlings, and labour exert a statistically significant effect on fish output in the study area. While the influence of labour was negative, the impact of the other variables was positive. The results compare with those of Islam (1987), Islam and Dewan (1986), Khan (1986), and Inoni and Chukwuji (2000) who found pond size, stocking density, fertilizer, labour and age of pond as significant factors affecting fish yield.

The positive and significant effect of pond size, feeds and fish seeds imply that there is a direct relation between these variables and fish yield. That is, as pond size increases given other inputs, fish output will increase. The pond is one critical variable upon which output in fish farming depends. Therefore, if other inputs are available to expand production, the farmer will have to expand the size of his ponds if existing ponds are stocked to their optimum capacity. The positive impact of pond size on fish production found in the study may be attributed to farmers response in this regard. The response of fish yield to pond size was quite high as a 10 percentage increase in pond size will result in a 3% increase in fish output.

In order for fish to reach marketable size in good time, an adequate feeding regime must be adopted. Thus as the quantity and quality of feed utilised increase, fish production is bound to increase, other things being equal. There has been a growing increase in the use of home-mixed fish feed in Delta State, particularly among fish farmers who grow highly priced species such as *Heterobranchus spp., Gymnarchus spp.* and a hybrid between *Heterobranchus* and clarias species. The need to sustain the specialised market niche and to meet the increasing local demand may be implicated for the direct relationship between fish feeds and output. Like pond size, the elasticity of output with respect to fish feed is high as a 10% increase in feed utilisation will raise fish yield by 5%.

Fish fingerlings was another independent variable that exerted a positive and statistically significant influence on pond fish production. Improving yield in fish farming requires the stocking of fast growing fingerlings of economically viable fish species, if the farmer must realise his objective of maximising revenue and profit. Thus the positive response of fish production to increased fingerlings utilisation may be attributable to farmers' goal to realise optimal benefits from the resources employed in production. As indicated in Table 3, a 10% increase in stocking density will cause fish yield to rise by 3.8%, and this is very high by every standard. Since increased stocking density may not necessarily translate into increased fish yield, its effect must have been reinforced by adequate feeding regime and efficient management. Comparable results were found by Hatch *et al* (1995), Khan (1986), and Merola and Pagan-Font (1988).

The contribution of labour in pond fish production is accentuated by the regression results. Although unlike other factor inputs its influence is negative and highly statistically significant as an increase in labour utilisation will cause a reduction in fish output. The implication of the result is that optimum levels of labour utilisation under the current scale of pond fish production in Delta State have been reached. Therefore further additions to labour will exert a depressing effect on fish yield. The inverse relationship between labour and fish output found in the study may be attributed to this situation. Similar findings were reported by Inoni and Chukwuji (2000) and Nyrkowski (1988).

Allocative efficiency estimates

The results of the estimates of allocative efficiency in pond fish production are shown in Table 4. However, the estimation of resource-use efficiency required the determination of parameters such as marginal physical product (MPP), marginal factor cost (MFC), and marginal value product (MVP). The marginal factor cost of each input was determined as the average farm cost of an input per unit output, according to Chukwuji et al. (2006).

Estimates of allocative efficiency of production resources employed in fish farming were 3.22, 0.0025, 0.00064, –0.00017, and 0.00025 respectively for pond size, feed resources, fingerlings, labour, and fixed costs. The indices indicate that apart from pond size which was under-utilised, all other resources were over-utilised implying sub-optimal resource allocation in fish farming in Delta State, Nigeria. Inadequate, and timely access to production credit by many farmers may be responsible for the under-utilisation of pond size in the production process. This condition is accentuated by the use of home-mixed feed of comparatively less nutritive value by majority of the farmers sampled. Table 4 further showed that labour, fingerlings and feed resources were over-utilised in fish production. Family labour is a readily available pool of labour to draw from whenever the need arises. There is thus, the tendency to over-utilise it in an operation of this scale (Agbamu and Fabusoro, 2001; Akanni and Adeokun, 2004). The gross inefficiency and over-utilisation of labour found in the study may be attributed to this condition. Comparable results of the over-utilisation of labour in small-scale agricultural production and processing in Nigeria, have been reported by Olarinde and Kuponiyi (2004), Akanni and Adeokun (2004), Oladeebo *et al*. (2006). Technical knowledge amongst fish farmers in Delta State, Nigeria is somewhat low. This situation may have led to over-stocking pond space with slow-growing, economically less-viable fish species, coupled with undue dependence on home-mixed fish rations, of comparatively less nutritive value. There is no doubt that this situation may have contributed to the gross over-utilisation of productive resources in the farms.

Therefore, in order for fish farmers to achieve optimal allocation in the use of productive resources, inputs such as labour, feeds, and fingerlings may have to be reduced, while more pond space should be put to use. This, in addition to improved managerial ability and the stocking of economically viable fish species, will raise output and consequently net returns in the fish farming business.

CONCLUSION

The study examined the efficiency of resource utilisation in pond fish production in Delta State, Nigeria. The results indicated that there was gross inefficiency in the allocation of productive resources among fish farmers in the study area. Apart from pond size which had allocative efficiency index of 3.22, inputs such as feeds, fingerlings, labour, and fixed costs were over-utilised. While the relatively low technical know-how of fish farmers may be implicated for the over-utilisation of some inputs, their relative abundance may also have contributed. Therefore in order to achieve optimality in resource allocation, there is the need to reduce the quantity of such inputs employed in fish production, as this will raise the productivity of resources, increase output, and consequently improve revenue and net returns.

Although the results of the study have shown that fish farmers were inefficient in the application of productive resources, the low output prices and the imperfect condition of input markets in the study area may have hampered efficient utilisation of production inputs. In order to improve efficiency in resource allocation in pond fish production therefore, access to current technical and price information is needed by farmers, and the Delta State government should facilitate this as a matter of policy.

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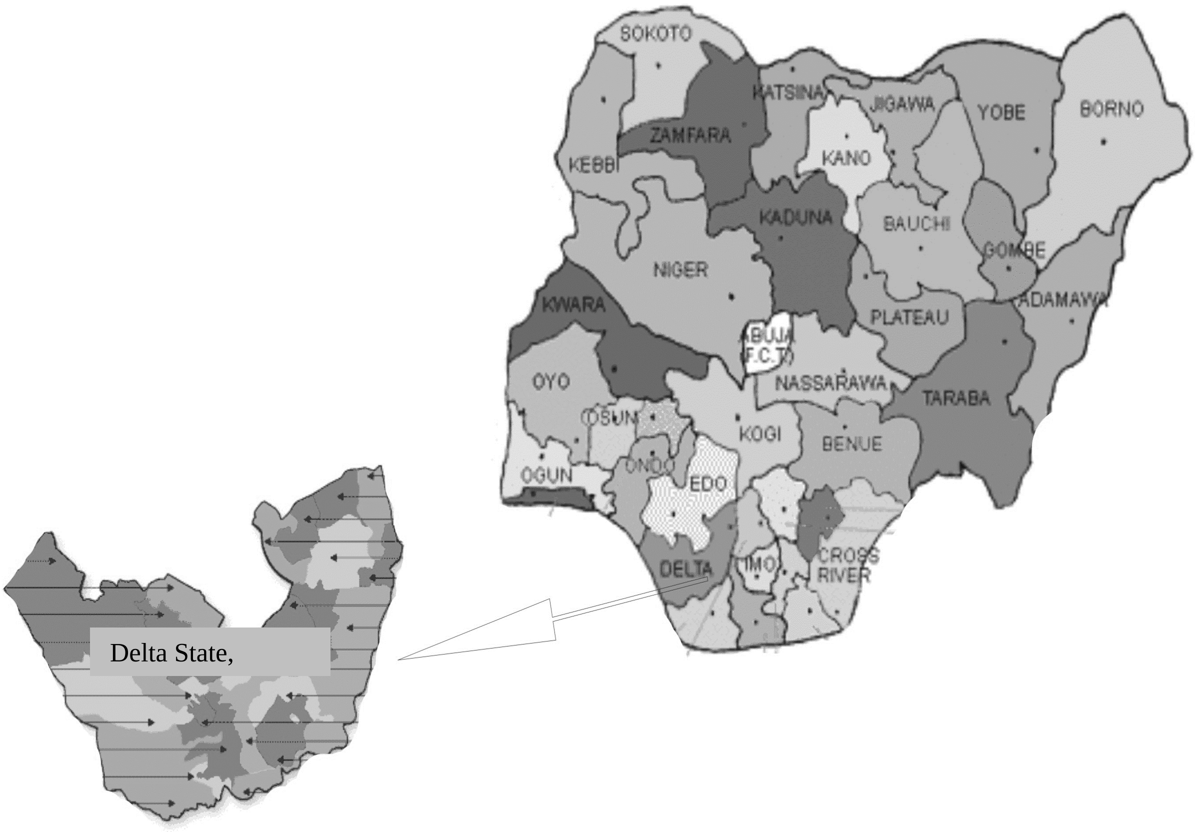
Figure 1: Map of Nigeria, showing Delta State, the location of the study



Tab. 1: Domestic fish production in Nigeria by sectors (metric tonnes)

Year	Domestic fish production	Coastal/Brackish Water	Inland Lakes/Rivers	Aquaculture (fish farming)	Aquaculture as % of domestic production
1983	562 972	376 984	146 267	20 476	3.64
1984	406 665	246 784	112 219	22 012	5.41
1985	242 525	140 873	60 510	15 000	6.18
1986	307 059	160 169	106 967	14 881	4.85
1987	289 108	145 755	103 232	15 221	5.26
1988	348 996	185 181	112 443	15 764	4.52
1989	362 706	171 332	132 112	25 607	7.06
1990	316 360	170 459	115 044	7 297	2.31
1991	343 352	168 221	123 045	15 840	4.61
1992	343 078	184 407	995 36	19 770	5.76
1993	255 523	106 276	949 00	18 703	7.32
1994	283 193	124 117	110 484	18 104	6.39
1995	371 053	159 201	161 754	20 755	5.59
1996	355 934	138 274	170 926	19 490	5.48
1997	413 187.6	175 126	185 096	25 265	6.11
1998	483 482.27	219 073	213 996	20 458	4.23
1999	479 663	239 228	187 558	21 738	4.53
2000	467 098	236 801	181 268	25 720	5.51
2001	474 000	209 000	181 000	47 000	9.92
2002	504 000	218 000	195 000	50 000	9.92
2003	524 700	229 100	201 700	52 000	9.91

n.a. = not available

Source: Federal Department of Fisheries; Fisheries Statistics of Nigeria, 1990, 2000; FAO Yearbook of Fisheries Statistics 2004

Tab. 2: Size and number of ponds in sampled farms

Item	Total size
Land area (ha)	128.05
Water surface area (ha)	101.15
Number of ponds	222
Number of fish farms	72

* Computed from survey data, 2005

Tab. 3: Regression results of determinants of output in pond fish production

Variable	Estimated coefficient	t-statistic	p-value
Pond size	0.302	4.99	0.000**
Feed resources	0.489	3.28	0.002**
Fingerlings	0.382	2.35	0.022*
Labour	–0.430	–3.43	0.001**
Fixed costs	0.068	0.835	0.407

F-statistic = 34.88; D-W statistic = 1.64; Adjusted R-squared = 0.70; n = 72
*significant at ($p < 0.05$); ** significant at ($p < 0.001$)
Source: author's calculation

Tab. 4: Indices of allocative efficiency of resources utilised in pond fish production

Variable	Marginal Physical Product(MPP)	Marginal Value Product (MVP) (₦)	Marginal Factor Cost (MFC) (₦)	Allocative Efficiency	Remark
Pond size	3.92	1168.16	362.48	3.22	Under-utilisation
Feed resources	0.00031	0.0924	37.45	0.0025	Over-utilisation
Fingerlings	0.00014	0.0417	65.4	0.00064	Over-utilisation
Labour	–0.00016	–0.0477	280	–0.00017	Over-utilisation
Fixed costs	0.000062	0.0185	72.65	0.00025	Over-utilisation

* Computed from survey data, 2005

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