Economics of aquaculture feeding practices: China

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Yuan, X. 2007. Economics of aquaculture feeding practices: China. In M.R. Hasan (ed.). Economics of aquaculture feeding practices in selected Asian countries. *FAO Fisheries Technical Paper.* No. 505. Rome, FAO. 2007. pp. 65–97.

SUMMARY

This case study was conducted to assess the economic implications of adopting various feeding practices in aquaculture production in China. The case study provided a comparative analysis of three different categories of feeding practices; namely: (1) traditional; (2) semi-intensive; and (3) intensive. To minimize variation in terms of fish species being produced, a comparative analysis of the various feeding practices was undertaken for carp polyculture (silver carp, bighead carp, grass carp, crucian carp and Wuchang bream). Each feeding practice had 20 replicate farms. A total of 60 fish farms were sampled. The stratified random sampling (SRS) technique was utilized in selecting the individual farm from 10 counties in Jiangsu province.

The case study assessed the impacts of the various feeding practices in terms of: (i) gross margin; (ii) net margin/return; (iii) gross and net factor productivities; (iv) returns to land and labour; (v) break-even price coefficients; and, (vi) break-even production coefficients.

The average pond area for intensive, semi-intensive and traditional fish farm investigated under the case study was 1.27, 0.74 and 3.96 ha respectively. Profitability was the main factor for engaging in aquaculture production. The stocking strategy for semi-intensive and intensive farms was multiple stocking, while single stocking was generally practised for traditional farms. Semi-intensive farms, used a combination of commercial and farm-made feeds. Likewise, fertilizer and manure were applied in fish ponds. It was also reported that inorganic fertilizer was used in fish ponds in order to improve the water quality and plankton biomass. Intensive fish farms predominantly utilized commercial feed. On some occasions, use of farm-made feed was also reported. Fertilizer and manure were also applied in intensive farms. Commercial feed was applied in fish ponds through feeding machines while the common application of supplementary feed in intensive fish ponds was through broadcast manually.

The average production costs per ha per year ranged from US$3 839 among traditional farms to US$6 494 and US$10 967 among semi-intensive and intensive farms. In general, variable costs accounted for 99 percent of the total costs. Variable costs mainly included labour, cost of fertilizers, fingerlings, feed and others. Average variable costs per ha per year were highest among intensive farms at US$10 840 and lowest among traditional farms at US$3 812.

The average gross factor productivities (benefit cost ratio, BCR) of intensive, semi-intensive and traditional farms were computed at 1.35, 1.30 and 1.37 respectively. Net factor productivities were estimated at 0.35, 0.30 and 0.37 for intensive, semi-intensive and traditional farms, respectively. The average break-even price per kg of intensive, semi-intensive and traditional fish farms was US$0.73, US$0.79 and US$0.61 while the break-even production for intensive, semi-intensive and traditional fish farms were computed at 11 085, 6 891 and 4 132 kg/ha. All the above break even coefficients are well above the actual market prices and current levels of production of all the farms which imply financially sound aquaculture production enterprises.

The following factors are cited as constraints to the expansion in aquaculture production: lack of capital (45 percent), poor market (12 percent), limited seed availability (7 percent), and lack of technical know how (5 percent). On the other hand, the factors that would lead to an expansion in production are: better disease control (25 percent), better management (23 percent), high quality seed supply (23 percent), more feed input (22 percent), improved stocking density (25 percent), and improved water quality in pond (20 percent).

All respondents cited that the major problem was the high cost of commercial feed. There were also problems in procurement of good quality commercial feed for semi-intensive fish farms and traditional fish farms. In the case of farm-made feeds, the major problem was the high cost of making feed in their farm while there was problem of availability of supplementary feed for some semi-intensive fish farm. All the fish farms reported that the low output price was a major problem to be addressed.

By using a regression model, the relationship between production/profit and input factors were analysed, the gross margin was used as the dependent variable while training days attended, fertilizer cost, seed cost, age, labour cost, education and feed costs were used as the independent variables. The regression model identified labour cost, seed cost, feed cost and education as positively related with the dependent variable (gross income).

The general stochastic frontier production (SFP) function was used to express the relationship between inputs and output, calculating the technical efficiency (TE). The highest average technical efficiency (0.816) was reported in intensive fish farms, followed by traditional (0.8), with the lowest (0.77) in semi-intensive fish farms.

1. INTRODUCTION

1.1 Aquaculture in China

Chinese aquaculture production reached 32.09 million tonnes in 2004, 65 percent of China' fishery production and 70 percent of the world's supply of farmed fish (FAO, 2006)

Chinese fish farming evolved from low output based extensive aquaculture systems in the 1970s, with no additional feed input, through to basic feeding systems, i.e. grass for grass carp and Wuchang bream (*Megalobrama amblycephala*), snails for black carp, and rice bran for crucian carp, to intensive systems using supplementary feed. As farmers realized that additional feed increased production and produced larger fish, the scale of diversification from extensive to intensive production increased. By 2004, commercial fish feed production had reached 8.8 million tonnes (production value of US$5 billion), accounting for 12.5 percent of the total feed input production in China. The annual rate of growth in feed supplements was around 17 percent per annum (Liu Qing, 2006). An added benefit for polyculture systems, was that farmers also found that food waste and feces fertilized the ponds and generated natural food organisms that benefited filter feeders.

1.2 Rationale

The combination of induced breeding, feed management and polyculture were the three contributory factors to the fast growth in Chinese aquaculture production. Feed management improved fish farm efficiency and economics by increasing production through reducing the culture period, and improving growth and meat quality. The proposed case study is expected to shed light on the economics of the various feeding practices as applied in China.

Different production practices and systems co-exist with one another depending upon the level of technology that prevails. In aquaculture production, any change in the practice of feeding (e.g. from traditional to intensive feeding practice) represents a technological innovation and this is assumed to generate increases in aquaculture production and income. On the other hand, farmers' adoption of technology such as industrially produced complete feed for aquaculture production is justified on the grounds of its financial soundness. A technology that provides reasonable financial incentives to the fish farmers will be more easily adopted than technology which does not.

1.3 Objectives

The general objective of the study is to assess the economic implications of adopting various feeding practices in aquaculture production in China.

Specifically, the country case study is aimed at:

(i) conducting a survey of feeding practices in sixty (60) aquaculture farms, twenty (20) per category;

(ii) processing and analyzing the data to arrive at a comparative analysis of the farms highlighting the following:
   a) general profile,
   b) production (including feeding) practices,
   c) production costs (fixed investment as well as maintenance and operating costs),
   d) income (gross margin and net margin/return),
   e) production problems,
   f) returns on investments (including labour, land and capital),
   g) break-even analyses (break-even price, cost, production, and sales), and
   h) suggestions/recommendations;

(iii) prepare a consolidated report of the case study based on the above information.

2. GENERAL APPROACH AND METHODOLOGY

2.1 Comparative analysis

The case study provided a comparative analysis of three (3) different categories of feeding practices; namely: (1) traditional/extensive ; (2) semi-intensive; and (3) intensive. To minimize variation in terms of fish species being produced, the comparative analysis of the various feeding practices was undertaken for carp polyculture in China.

Traditional farming refers to a feeding practice where the feed used is sourced or developed locally and is not distributed commercially. Fish farms using traditional feeding practices use farm-made aquafeed and/or supplementary diets consisting of a mixture of locally available feed ingredients. Farms with intensive feeding practices depend solely on commercially manufactured pelleted feeds while semi-intensive farms use a combination of the two.

2.2 Assessment indicators

This case study assessed the impacts of the various feeding practices in terms of: (i) gross margin; (ii) net margin/return; (iii) benefit cost ratio (BCR); (iv) returns on investment

(ROI), (v) returns to land and labour; (vi) break-even price coefficients; (vii) break-even cost coefficients; (viii) break-even production coefficients; and (ix) break-even sales coefficients. The basis of estimating the above indicators were developed based on a prepared questionnaire.

2.3 Sampling technique

The case studies included three representative feeding practices or systems for the aquaculture farms. Twenty farms were assessed as representative of each feeding system. A total of 60 fish farms were sampled. The stratified random sampling (SRS) technique was utilized in selecting the individual sample farms. The complete list was obtained from the fishery technical extension office of the Bureau of Agriculture and Fisheries. The sample farms were interviewed using a pre-agreed using questionnaire as applied in all the country case studies.

2.4 Data processing and analysis

A tabular analysis was used to develop the costs and returns for the various feeding systems observed in the study sites. The analysis identified the variable cost categories of feed, labour and management as well as fixed costs.

2.5 Scope and duration of the study

The work was undertaken between November and December, 2005. The questionnaire was tested and final adjustments were made prior to the field survey. The survey results were entered into MS Excel for analysis.

3. RESULTS AND DISCUSSION

3.1 Description of the study area

Jiangsu province is well known as a centre for pond carp polyculture. Jiangsu province is located at the lower stream of the Yangtse and Huai rivers, flowing east to the Yellow Sea. It is rich in natural water resources with inland waters comprising 1.79 million ha, including lakes (968 000 ha), rivers (608 000 ha), reservoirs (47 000 ha) and ponds (167 000 ha). Jiangsu is also well known as centre for rice and fish production. The region's fish production was 3.5 million tonnes in 2004, representing 11 percent of the total national production (Yearbook of China fishery statistic, 2005).

Fish is an important source of animal protein within the Province. The percentage contribution of aquaculture to agriculture ranges from eight percent to 52 percent in the 65 counties. Carp is the most important species produced in Jiangsu, but other high value species are also cultured. The most common culture model is polyculture. The major cultured species include grass carp *(Ctenopharyngodon idella)* , silver carp (*Hypophthalmichthys molitrix*), bighead carp *(Aristichthys nobilis)*, black carp *(Mylopharyngodon piceus)*, Wuchang bream *(Megalobrama amblycephala)*, common carp *(Cyprinus carpio)* and crucian carp *(Carassius auratus)*. The grass carp, black carp, Wuchang bream, common carp and crucian carp are the major users of fish feed, and silver carp and bighead carp are the major filtering feed fishes. In 2004, the freshwater culture area was 634 000 ha, and carp production in Jiangsu province was 2 million tonnes, which accounted for 28 percent of the national carp production. (Anon., 2006b)

The case study was undertaken in 10 counties where fish culture is significant. Table 1 illustrates the importance of aquaculture production in each county, along with the average income per farmer. The income range in 2005 was from 3 839 Yuan (US$487) to 8 002 Yuan[1] (US$1 016) per farmer per annum.

[1] US1.00 = 7.87 Yuan

60 farms were selected using the stratified random sampling technique. Table 2 shows the sample size from each county. The farms in the survey covered 39 villages. The location of the surveyed farms were scattered from the north, middle and south of Jiangsu, representing a range of feed management in carp farming (Figure 1).

TABLE 1
Fishery production value, its contribution to agriculture and average income by 10 surveyed counties in 2005

County	Total fishery production value		Contribution to agriculture production (%)	Average income of agri-farmer	
	CNY(10^9)	US$($10^9$)		CNY/year	US$/year
1. Dong Tai	1.50	0.191	8.0	5 665	719.82
2. Gao You	1.66	0.211	34.9	4 938	627.45
3. Hai An	2.50	0.318	52.1	5 300	673.44
4. Li Yang	0.76	0.097	36.0	5 331	677.38
5. Su Qian	3.87	0.492	16.3	3 839	487.80
6. Wu Jiang	13.9	1.766	47.6	8 760	1 113.09
7. Xi Shan	0.14	0.018	13.5	8 002	1 016.77
8. Yan Cheng	9.50	1.207	18.5	4 893	621.73
9. Yang Zhou	3.68	0.468	26.4	5 215	662.64
10. Yi Xing	0.88	0.112	26.0	7 010	890.72

TABLE 2
Number and percent of respondents sampled by location

County	Number	%
1. Dong Tai	15	25
2. Gao You	1	2
3. Hai An	8	13
4. Li Yang	8	13
5. Su Qian	5	8
6. Wu Jiang	8	13
7. Xi Shan	2	3
8. Yan Cheng	4	7
9. Yang Zhou	3	5
10. Yi Xing	6	10
Total	**60**	**100**

3.2 Description of the respondents

Of the 60 farmers in the survey, 91.7 percent were male and 8.3 percent female (Table 3).

The average age of all respondents was 49.7 years (Table 4). The average age of the intensive, semi-intensive and traditional farm respondents was 49 years, 49 years and 52 years respectively.

The average household size of all respondents (Table 4) was 4.4. Semi-intensive farmers had the smallest household size of 3.7, traditional and intensive the largest, 4.7and 4.8 respectively.

The average fish farming experience (Table 4) was 12.7 years, with intensive fish farms reporting the longest experiences in fish farming of 13.7 years.

FIGURE 1
Map of China and sample location in Jiangsu province

TABLE 3
Profile of respondents by category

Category	Gender of respondents			
	No. of male	%	No. of female	%
Intensive farms	17	85	3	15.0
Semi-intensive farms	18	90	2	10.0
Traditional farms	20	100	0	0.0
All farms	55	92	5	8.3

TABLE 4
Average age, household size, and years in fish farming by category

Category	Age	Household size	Years in farming
Intensive farms	48.75	4.8	13.70
Semi-intensive farms	48.85	3.7	12.15
Traditional farms	51.6	4.7	12.35
All farms	49.73	4.40	12.73

Of the all respondents, 92 percent were married and 8 percent were single. Whilst most traditional farmers were married (85 percent), a larger number were unmarried relative to the other groups (Table 5).

TABLE 5
Marital status by category

Marital status	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Married	19	95	19	95	17	85	55	92
Single	1	5	1	5	3	15	5	8
Total	20	100	20	100	20	100	60	100

All the respondents have a relatively high education background. Most of the respondents completed primary (38 percent) and secondary school education (42 percent) (Table 6). Twenty percent of the respondents completed high school and 5 percent were able to complete their college education. By the feeding categories, intensive and semi-intensive fish farming respondents were more highly educated

with 45 percent and 40 percent having completed secondary education and 20 percent having completed high school respectively.

Farmers with both longer farming experience and higher education, had a greater probability for adopting intensive feeding systems. This may be also explained by better understanding of aquaculture technology and management strategies among the intensive fish farmers.

TABLE 6
Education attainment by category

Education	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Primary	6	30	7	35	10	50	23	38
Secondary	9	45	8	40	8	40	25	42
High school	4	20	4	20	1	5	9	15
College	1	5	1	5	1	5	3	5
Total	20	100	20	100	20	100	60	100

Sixty two percent reported that fish farming was their main occupation (Table 7), with a further 27 percent of farmers describing agriculture as their main occupation. Ten percent of the respondents in the intensive fish farming category claimed that fish trading was their main occupation. Intensive farmers also reported a greater knowledge of economic conditions and market information.

TABLE 7
Main occupation by category

Occupation	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Fish farming	13	65	12	60	12	60	37	62
Fishing	2	10	0	0	1	5	3	5
Fish trading	2	10	0	0	0	0	2	3
Agriculture	2	10	7	35	7	35	16	27
Carpenter	1	5	0	0	0	0	1	2
Others	0	0	1	5	0	0	1	2
Total	20	100	20	100	20	100	60	100

3.3 General profile of the farm

The average total pond area of intensive, semi-intensive and traditional fish farm was 2.7, 2.65 and 6.23 ha respectively. The intensive fish farm had fewer ponds (2.9), while semi-intensive and traditional fish farms had a larger number (4.5 and 4.85). The average pond area for intensive, semi-intensive and extensive fish farms was 1.27, 0.74 and 3.96 ha respectively. The average pond water depth of all categories in the rainy season was 2.42 m, and 1.92 m in the dry season (Table 8).

The traditional fish farms had the largest ponds in all three categories, whilst intensive fish farms had the smallest pond size, while the semi-intensive were somewhere between the two. Ponds with an area of 1 ha were perceived by the respondents as optimal area for culture management, with larger areas difficult to manage.

Twenty seven percent of respondents were single owner occupiers (Table 9). Seven percent were multiple owner occupiers. Sixty five percent of the respondents reported singly leased ponds. These respondents identified fish farming as a promising business opportunity. Forty one percent of the lessees were in the intensive sector where income expectations were greater. However, a not insignificant number were also in the semi-intensive (31 percent) and traditional sectors (28 percent).

TABLE 8
Total number, total area, average area of ponds and average water depth by category of respondents

Item	Intensive	Semi-intensive	Traditional	All categories
Total no. of ponds	2.90	4.50	4.85	4.083
Total area of ponds (ha)	2.70	2.65	6.23	3.86
Average area of ponds (ha)	1.27	0.74	3.96	1.87
Average water depth (m)				
Rainy season	2.27	2.50	2.49	2.42
Dry season	1.88	1.89	2.01	1.92

TABLE 9
Ownership structure by category of respondents

Type of ownership	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Single ownership	4	20	5	25	7	35	16	27
Multiple ownership	0	0	3	15	1	5	4	7
Singly leased	16	80	12	60	11	55	39	65
Jointly leased	0	0	0	0	1	5	1	2
Total	20	100	20	100	20	100	60	100

The average pond lease was 5.78 years. Intensive fish farms had longer lease durations, 6.8 years, while semi-intensive and traditional fish farms had shorter lease durations, 5.2 years. The respondents stated that longer lease periods of 5–7 years were sufficient to invest, plan and maintain (Table 10).

TABLE 10
Ownership, number of lessees and duration for jointly leased farms by category of respondents

Item	Intensive	Semi-intensive	Traditional	All categories
Number of owners (multiple ownership)	-	2	2	2
Number of lessees (jointly leased)	0	0	1	1
Duration of lease (months)	82	62	62	69

Seventy seven percent of the respondents used the ponds exclusively for fish farming (Table 11), while 23 percent used the ponds for other integrated activities including duck and chicken farming as well as other livestock.

TABLE 11
Pond utilization by category of respondents

Pond utilization	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Fish culture	17	85	14	70	15	75	46	77
Multipurpose	3	15	6	30	5	25	14	23
Total	20	100	20	100	20	100	60	100

The average number of full time farm workers was 2.12 (Table 12). Intensive fish farms had less full time labour (1.75), while semi-intensive and traditional fish farms had higher labour levels (2.5 and 2.1 respectively). The respondents said that the higher labour activity in semi-intensive and traditional fish farms was a direct result of using labour for feed collection. This labour comprised family members, including children. Among family members, the wife took care of daily management, feeding and domestic activities, while the husband was responsible for marketing and technical matters.

The average number of part-time workers was 2.14. Traditional fish farms had less part time labour than the other two categories. Part time labour was usually used for stocking, guarding, feeding and routine pond management. The average number of casual workers was 9.16. The main casual responsibilities were for harvesting.

TABLE 12
Average number of labourers employed by category of respondents

Item	Intensive	Semi-intensive	Traditional	All categories
	(Average)	(Average)	(Average)	(Average)
Full-time labour (No.)	1.75	2.50	2.10	2.12
Part-time labour (No.)	2.08	3.00	1.33	2.14
Casual labour (No.)	6.14	12.33	9.00	9.16
Total	3.33	5.94	4.14	4.47

Eighty percent of the respondents reported that fish farming was undertaken for commercial reasons (Table 13). The proximity to water and close access to fish culture was cited as the second main reason for undertaking fish farming. Own consumption was not perceived as a major reason for fish farming.

TABLE 13
Main factors considered in undertaking fish farming by category of respondents

Factor	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Commercial	16	80	14	70	17	85	47	78
Own consumption	1	5	0	0	1	5	2	3
Access to fish culture technology	2	10	3	15	1	5	6	10
Feed availability	1	5	3	15	0	0	4	7
Seed availability	0	0	0	0	1	5	1	2
Others	0	0	0	0	0	0	0	0
Total	20	100	20	100	20	100	60	100

3.4 Farm production practices

3.4.1 Stocking strategies

Polyculture was the only stocking model used by all the farmers. The stocked species included silver carp, bighead carp, grass carp, crucian carp and Wuchang bream. Intensive fish farms adopted multi-harvest and multi-stocking strategies to operate the pond more efficiently.

The culture period for all fish farms was estimated at 301 days. Culture periods for traditional, semi-intensive and intensive farms were 291 days, 324 days and 286 days respectively. It was reported that shorter culture periods, within these cycles enabled farmers to recover financial investments on a continuous basis during the year (Table 14).

TABLE 14
Average culture period (days) for polyculture practice by species and by category of respondents

Type of species	Intensive	Semi-intensive	Traditional	All categories
Silver carp	282	318	280	292
Bighead carp	317	338	289	320
Grass carp	294	325	281	300
Black carp	277	335	299	301
Crucian carp	288	270	269	278
Wuchang bream	286	356	296	318
All species	291	324	286	301

The study revealed that all traditional fish farms applied a single stocking strategy. Eighty percent and 20 percent of intensive fish farms and semi-intensive fish farms applied single stocking, and multiple stocking strategies, correspondingly (Table 15).

TABLE 15
Stocking strategy by category of respondents

Item	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Single stocking	16	80	16	80	20	100	52	87
Multiple stocking	4	20	4	20	0	0	8	13
Total	20	100	20	100	20	100	60	100
Number of stocking (for multiple stocking)								
2x per year	3	75	3	75	0	0	6	75
3x per year	1	25	1	25	0	0	2	25
Total	4	100	4	100	0	0	8	100

Silver carp and bighead carp were the main species stocked in traditional ponds. Black carp would also be stocked if there were snails in the pond. Grass carp, Wuchang bream, crucian carp and black carp were the main species stocked in intensive and semi-intensive farms. However, there were large differences in species mix from one site to the next. The species compositions were usually determined by local market preferences and preferred culture technique.

Fish farmers would usually stock over-winter fingerlings (yearlings) in the pond, and would add fish seed as proceeds from sales generated surplus cash. Some farmers stocked fry in ponds to produce fish yearlings for the next fish production year.

Multi-harvesting was carried out in intensive farms. Fish fingerlings of different sizes were stocked in ponds. The bigger fish were harvested after two to three months growth in the pond, while the others were harvested after 4–6 months. The remainders were retained as over-winter fingerlings for the next production circle.

The biomass in fish ponds was always maintained at high levels in intensive fish farms (Table 16). Moreover, pumps and aerators were applied to keep good water quality and high dissolved oxygen.

TABLE 16
Fingerling stocking density (No./ha/year) and ratio (%) by type of species and by category of respondents

Species	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
1. Silver carp	15 653	31.8	5 652	16.3	7 285	26.6	9 530	25.7
2. Bighead carp	2 393	4.9	2 160	6.2	1 365	5.0	1 973	5.3
3. Grass carp	10 678	21.7	5 323	15.4	4 553	16.6	6 851	18.5
4. Black carp	752	1.5	541	1.6	441	1.6	578	1.6
5. Crucian carp	14 604	29.6	16 966	48.9	11 039	40.3	14203	38.3
6. Wuchang bream	3 145	6.4	2 604	7.5	2 689	9.8	2 813	7.6
7. Other fishes	2 068	4.2	1 414	4.1	53	0.2	1 178	3.2
Total	49 295	100	34 661	100	27 424	100	37 126	25.7

The average stocking rate (by species) for intensive fish farms was 49 295 pieces per ha per year; 34 661 pieces per ha per year for semi-intensive fish farms; and 27 424 pieces per ha per year for traditional fish farms (Table 16). Intensive fish farms had the highest stocking rate, and traditional fish farms had the lowest stocking rate. The higher stocking rate in intensive fish farms was due to multiple stocking, mixed-age and multi-harvest practices. This type of stocking rate normally allows for a harvest frequency of 2–3 times during the stocking season. This balance regulates market supply and improves the economic returns.

Seventy eight percent of respondents reported applying modular stocking[2] in carp farms (Table 17). Fish farmers utilized modular stocking to change the major fish in

[2] Modular stocking is a method to improve the pond production efficiency. This enables the pond operator to stock and harvest the fish continuously. Farmers stock fingerlings in pond for about one month, then shift to another pond for grow-out.

polyculture ponds. Other farmers did not use this practice due to the limited pond area and lack of capital to buy fingerlings.

TABLE 17
Modular stocking by category of respondents

Response	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Yes	14	70	17	85	16	80	47	78
No	6	30	3	15	4	20	13	22
Total	20	100	20	100	20	100	60	100

In terms of cost on fingerling stocking, traditional fish farms cultured more filter feeding species, i.e. silver carp and bighead carp (31 percent of stocking cost). Intensive fish farms spent more feed dependent species i.e. grass carp, Wuchang bream, black carp and crucian carp (75 percent). The semi-intensive fish farms cultured both filter feeders and feed dependent species depending on farmers' economic wealth and seed availability in the area (Table 18).

TABLE 18
Cost of fingerling stocking by species and by category of respondents (US$/ha, percent)

Species	Intensive		Semi-intensive		Traditional		All categories	
	Total cost	%	Total cost	%	Total cost	%	Total cost	%
1. Silver carp	442	10.4	615	20.9	415	23.0	491	16.4
2. Bighead carp	364	8.6	237	8.0	141	7.8	247	8.2
3. Grass carp	1705	40.2	968	32.9	574	31.8	1082	36.1
4. Black carp	351	8.3	224	7.6	109	6.0	228	7.6
5. Crucian carp	861	20.3	648	22.0	353	19.6	621	20.7
6.Wuchang bream	264	6.2	175	5.9	134	7.4	191	6.4
7. Other fishes	257	6.1	79	2.7	77	4.3	138	4.6
Total	4243	100	2946	100	1802	100	2997	100

Mixed age stocking provides a sound basis for multi-harvesting. The larger fish grows faster and needs more feed. While the small fish needs less feed and grows slower. The bigger fish are harvested when they reach marketable size (e.g. after 2–3 months). The small fish will reach market size at a much later stage (e.g. 4–8 months). This common multi-harvest practice in intensive fish farming enables the farmers to generate income continuously and address short term cash flow deficiencies during the production process.

3.4.2 Fertilization and feeding practice

Type of fertilizers and feed

Fertilizers

Forty eight percent of the respondents reported applying fertilizer in on-growing fish ponds (Table 20). Sixty five percent of intensive fish farmers used fertilizer to improve water quality. In traditional fish farms, 75 percent fish farmer reported that they did not use fertilizer for on-growing fish ponds. However, they did use fertilizer on grass land to produce more green grass as fish feed. Twenty five percent of fish farmers reported that they applied fertilizer to improve natural food organisms in ponds. Fertilizers/ compost comprised cow manure/dung, chicken/poultry manure, pig manure, and inorganic fertilizers such as TSP, and urea.

TABLE 19
Average stocking weight and length by species and category of respondents

Item	Intensive	Semi-intensive	Traditional	All categories
Silver carp				
Weight (g)	213.80	107.50	110.26	143.85
Size (cm)	15.69	12.34	10.79	12.94
Bighead carp				
Weight (g)	159.60	147.00	201.00	169.20
Size (cm)	15.70	13.60	11.80	13.70
Grass carp				
Weight (g)	236.09	122.06	58.58	138.91
Size (cm)	15.39	10.00	9.00	11.46
Black carp				
Weight (g)	433.81	365.00	425.00	407.94
Size (cm)	21.37	20.69	19.83	20.63
Crucian carp				
Weight (g)	60.70	23.20	40.00	41.30
Size (cm)	7.36	7.20	5.71	6.76
Wuchang bream				
Weight (g)	167.50	117.50	52.00	112.33
Size (cm)	14.00	10.63	8.60	11.08

TABLE 20
Use of fertilizer for on-growing by category of respondents

Response	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Yes	13	65	11	55	5	25	29	48
No	7	35	9	45	15	75	31	52
Total	20	100	20	100	20	100	60	100

TABLE 21
Average application quantity (kg/ha/year) of inorganic and organic fertilizers by type of fertilizers and category of respondents

Type of fertilizer	Intensive	Semi-intensive	Traditional	All categories
A. Inorganic				
1. Urea (nitrogen)	147	188	11	136
2. TSP (phosphate)	277	450	173	290
3. MP (potash)	-	-	-	-
4. DAP (potash)	-	-	-	-
5. Others	225	-	-	225
All inorganic	649	638	183	651
B. Organic				
1. Dung	-	-		-
2. Compost	2 503	3 330	2 719	2 808
3. Others, specify	-	-		-
All organic	2 503	3 330	2 719	2 808
All fertilizers	3 152	3 968	2 902	3 459

TSP = triple super phosphate; MP = muriate of potash; DAP = di-ammonium phosphate

TABLE 22
Frequency of fertilizer use by type of fertilizer and category of respondents

Type of fertilizer/frequency	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
A. Cow manure								
Daily	1	50	0	-	0	-	1	50
Irregular	1	50	0	-	0	-	1	50
Total	2	100	-	-	-	-	2	100
B. Poultry/chicken manure								
Daily	0	0	1	25	1	50	2	15
Weekly	1	14	0	0	0	0	1	8
Monthly	1	14	0	0	0	0	1	8
Irregular	5	71	3	75	1	50	9	69
Total	7	100	4	100	2	100	13	100
C. Pig manure								
Daily	0	0	0	0	1	33	1	8
Weekly	0	0	0	0	1	33	1	8
Bi-weekly	0	0	2	29	0	0	2	17
Irregular	2	100	5	71	1	33	8	67
Total	2	100	7	100	3	100	12	100
D. Urea (nitrogen)								
Never	0	0	0	0	0	-	0	0
Daily	0	0	1	33	0	-	1	13
Weekly	2	40	0	0	0	-	2	25
Irregular	3	60	2	67	0	-	5	62
Total	5	100	3	100	0	-	8	100
Type of fertilizer/frequency	**Intensive**		**Semi-intensive**		**Traditional**		**All categories**	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
E. TSP (phosphate)								
Bi-weekly	1	33	0	0	0	-	1	25
Irregular	2	67	1	100	0	-	3	75
Total	3	100	1	100	0	-	4	100
F. Others								
Daily	0	0	1	100	0	-	1	33
Irregular	2	100	0	0	0	-	2	67
Total	2	100	1	100	0	-	3	100

Urea and TSP were reportedly used in fish ponds because of their lower costs. Cow, chicken and pig manure were commonly used as compost by all groups of farmers. However, an additional new compound fertilizer (commercially know as FeiShuiBao, the common ingredients include microorganism fertilizer, plant nutritional parts, organic nitrogen and phosphorus, trace elements, amino acids, vitamin complex, and inositol, etc.) was used by intensive fish farmers to improve the water quality in ponds.

Fertilizers were commonly applied weekly, biweekly or irregularly (Table 22). Most of the organic fertilizer was used as base manure (Figures 2 and 3), and inorganic fertilizer was used as additional inputs during the growing period.

Feed

Feed included industrial commercial fish feed, compound feed and farm made fish feed. The crude protein varied from 25.0 percent to 30.6 percent. Intensive fish farms were dependent on pellet fish feed during the grow-out period. The average content of protein was 30.6 percent for intensive fish farms, and 25.0 percent for semi-intensive fish farms. The feed applied by intensive fish farms used to have higher crude protein content. Higher protein feeds were more expensive. Only fewer semi-intensive fish farms reported the use of farm made aquafeed, due to the high cost of operation and fixed investment. This practice is becoming increasingly unpopular among fish farmers (Table 24).

Supplementary feeds were also applied in all farming systems and included rice bran, wheat, oil cake, soybean cake, green grasses, waste water, snail meat and worm meal depending on the local availability. Traditional fish farms applied more supplementary feed for fish i.e. rice bran, oil cake and grasses to improve the fish production. (Figures 4 and 5).

Feeding strategy, frequency and application method

Intensive feeding was common among intensive fish farmers (75 percent), while semi-intensive and traditional feeding were common among semi-intensive and traditional fish farmers (Table 25).

The most common application method for pellet feed was through broadcasting over the pond, especially among semi-intensive and traditional fish farms. This method used more labour in feed management (30 percent in semi-intensive and 25 percent in traditional fish farms). Feeding machines were used in feeding (75 percent reporting using feeding machine) in intensive fish farms (Figure 6). Supplementary feeds were applied through the broadcast method particularly when using rice bran and wheat. Green grasses were normally placed in a feeding frame in the fish pond. In case when the farmer feed the summer-fingerlings, they use feeding tray to prevent the big fish to take the feed. The trays are placed upside down in water, the mesh size allows the fingerlings to swim inside the tray, but the big one can not (Figure 7).

FIGURE 2
Fermented manures are commonly used in fish ponds in China

FIGURE 3
Terrestrial grasses are submerged as fertilizer

3.5 Comparative analysis of farm production costs

3.5.1 Fixed costs

Farm fixed costs include the costs of buildings, truck/pickup, aerator, pumps, feeding machine and others. Pumps and aerators are fixed investment common to all farm categories. Feeding machines were common in intensive fish farms but not used in semi-intensive and traditional systems. The fixed cost per ha of intensive, semi-intensive and traditional fish farm was US$126, US$52 and US$27 respectively (Table 27). Intensive fish farms have the highest average fixed investment relative to semi-intensive and traditional farms. Table 27 shows buildings and aerator as the most significant fixed cost item, with average investments of US$468 and 171 respectively.

TABLE 23
Average proximate composition (% dry matter basis) feeds by type and category of respondents

Type of feed/average proximate composition	Intensive	Semi-intensive	Traditional	All categories
A. Industrially manufactured pelleted fish feed				
1. Moisture	12.4	12.5	-	12.4
2. Crude protein	30.6	25.0	-	27.8
3. Crude lipid	2.8	2.5	-	2.6
4. Ash	15.3	15.5	-	15.4
5. Crude fibre	12.3	14.5	-	13.4
6. NFE[1]	26.6	30.0	-	28.3
Type of feed/average proximate composition	**Intensive**	**Semi-intensive**	**Traditional**	**All categories**
B. Pelleted fish feed produced by cottage feed plant				
1. Moisture	12.0	-	-	12.0
2. Crude protein	24.8	27.3	-	26.1
3. Crude lipid	3.0	-	-	3.0
4. Ash	14.0	-	-	14.0
5. Crude fibre	9.0	-	-	9.0
6. NFE	37.2	-	-	37.2
C. Farm-made aquafeed				
1. Moisture	-	12.0	-	12.0
2. Crude protein	-	30.0	-	30.0
3. Crude lipid	-	-	-	-
4. Ash	-	15.0	-	15.0
5. Crude fibre	-	4.0	-	4.0
6. NFE	-	-	-	-

[1]Nitrogen free extract= 100 - (moisture+ crude protein + crude lipid +ash +crude fibre); "-" refer to data not available

TABLE 24
Average quantity (kg/ha/year) of feed by type and category of respondents

Type of feed		Intensive	Semi-intensive	Traditional	All categories
A.	**Commercially manufactured pellet**	14 202	3 621	-	5 941
B.	**Farm (home)-made pellet**	-	430	75	168
C.	**Supplementary feed**				
	1. Rice bran	428	863	450	580
	2. Wheat bran/flour	1 118	570	576	754
	3. Oil cakes	1 028	1 124	719	957
	4. Soybean meal	150	75		75
	5. Aquatic plants/green grass	2 700	9 744	3 728	5 390
	6. Slaughter house waste	-	281	195	159
	7. Snail meat	600	993	420	671
	8. Worm meal	-	75	38	38

TABLE 25
Feeding strategy by category of respondents

Item	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Feeding strategy								
Well planned and well practised (regular)	15	75	8	40	10	50	33	55
Well planned but not well practised (occasional)	4	20	6	30	3	15	13	22
Not well planned and practised (irregular)	1	5	6	30	7	35	14	23
Total	20	100	20	100	20	100	60	100

FIGURE 4
Farmer simply mix supplementary feed before feeding

FIGURE 5
Water lamina as feed for grass carp juveniles

FIGURE 6
Auto-feeders are common in intensive fish farms in China

Courtesy of Mohammad R. Hasan

FIGURE 7
Feeding trays are used in modular grow-out pond for fingerlings feeding

3.5.2 Variable costs

Cost of labour

Labour is used for pre-stocking, stocking/release and post stocking. Intensive farms use more labour than the other farming systems (461 man days/ha/year) (Table 28). Semi-intensive and traditional fish farms had fewer labourers (357 and 311 man days/ha respectively). The major differences were accounted for by hired labour, amounting to 304, 209 and 153 man days/ha for intensive, semi-intensive and traditional fish farms. Intensive fish farms had almost double the quantity of hired labour as compared with traditional fish farms.

The average annual labour costs incurred by intensive, semi-intensive and traditional fish farms were US$2 064, US$1 644 and US$1 417 respectively (Table 29).

Cost of fertilizers

The costs of inorganic fertilizer for intensive, semi-intensive and traditional fish farms were estimated at US$1 334/ha/year, US$81/ha/year, and US$20/ha/year, respectively (Table 30). Intensive fish farms have the highest cost in inorganic fertilizer, since they applied specialized fertilizer to improve the water quality.