Food Supply Values and Their Factors of Three Pond Aquaculture Ecosystems: A Case Study of Shanghai

Zhengyong YANG*, **Xinzheng ZHANG**, **Zhenfang HAN**, **Keyong TANG**

College of Economics and Management, Shanghai Ocean University, Shanghai 201306, China

Abstract Studies on food supply values, the basis of eco-service values, and their factors of different pond aquaculture ecosystems are helpful to explain the influences of the inputted factors and their variations among these ecosystems and provide information for stakeholders to adjust their decisions and behaviors to increase their total eco-service values. On the basis of continued records from 2011 to 2012 of 18 ponds of three pond aquaculture ecosystems, namely Litopenaeus vannamei, Macrobrachium nippponensis and carp fresh water pond aquaculture ecosystems in Qingpu, Fengxian, and Jiading, three suburban districts of Shang, this paper analyzed the costs, returns, net food supply values and their regional and temporal fluctuations. The results showed that: (1) the net food supply values of the three ecosystems are 143252.4, 135883.7, and 52623.1Yuan/Ha in 2011 correspondently, with the Litopenaeus vannamei pond aquaculture ecosystem (LVPAE) ranking highest and the carp pond aquaculture ecosystem (CPAE) lowest among them, and the trend was same in 2012, but the values decreased than that of 2011 with the rate of 30.0% (LVPAE), 38.0 % (Macrobrachium nippponensis pond aquaculture ecosystem, MNPAE) and 13.7 % (CPAE). (2) The dominant factors of the net food supply values of these ecosystems are the produce price and variable costs; fry and feed costs are the main variable factors producing the noticeable difference among the ecosystems. (3) The cost – benefit ratio of per unit product of the CPAE, LVPAE and MNPAE changed from 27.5%, 91.7%, 129.0% in 2011 to 23.0%, 73.8% and 63.8% in 2012, with the CPAE ranked lowest among them in both years. (4) For all the three ecosystems, their net food supply values may not always change in same trends with their net eco-service values, if stakeholders want to keep a balance between these two types of values, MNPAE should be encouraged in these districts.

Key words Pond aquaculture, Food supply value, Eco-service value, Cost – benefit analysis

1 Introduction

Aquaculture ecosystems can provide not only food supply service, but air conditioning, temperature adjustment, biodiversity protection and culture recreation services for human beings[1-3]. Food supply service is the basis of these services. In fact, aquaculture contribute over 70% of the total aquatic production of China, and aquaculture production of China occupies about 2/3 of total aquaculture production of the world[4]. Pond Aquaculture ecosystems are the main aquaculture ecosystems in China. Fish farmers' incentive to maximize net food supply value not only directly dominates the value itself, but also impact eco-service values of pond aquaculture ecosystems by changing their structures. Studies on food supply values and their factors of different pond aquaculture ecosystems are helpful to explain the influences of the inputted factors and their variations among these ecosystems and provide information for stakeholders to adjust their decisions and behaviors to increase their total eco-service values. As the basic eco-service value, food supply value of aquaculture ecosystems, including human made and semi-natural ecosystems, has been studied for several decades[5-6]. Species farmed in these ecosystems, which has been studied from economics viewpoint, include oyster[7], salmon[8-6], catfish[11], shrimps[12-15], carp[16], tilapia[17], threadfin[18], trout[19], flatfishes[20], and so on. Although some economic values of these ecosystems have been analyzed in these studies, the food supply value of pond aquaculture ecosystems of China, the most significant part of aquaculture ecosystems of this biggest contributor of the world aquaculture, has not been fully explained. FAO (2007) compared the efficiency of extensive, semi-intensive and intensive CPAE[21], and Tian, Wang and Chen (2010)[22] analyzed the costs and benefits of farmed fresh water fish ecosystems of China, but the economic performance of LVPAE and MNPAE of China have not been studied yet. Yang, Tang and Yang (2013) have estimated the proportion of food supply value in the total eco-service values of pond aquaculture ecosystems of Shanghai[1], but they haven't scrutinized the impact factors of food supply value and its fluctuation over different regions, seasons and species, and were not able to answer such questions as: Which pond aquaculture ecosystem is most efficient if farmers make their decisions only according to their net food supply values? With food supply values as their basic operational goals, how could fish farmers adjust their input strategies to maximize total eco-service values of pond aquaculture ecosystems? For instance, how could they choose the farmed species and technologies according to their actual environment? To answer these questions and find the best way to maximize net eco-service values of pond aquaculture ecosystems, 18 aquaculture ponds, in which three species (named as Litopenaeus vannamei, carps, and Macrobrachium nippponensis separately) were farmed, were observed continuously from 2011 to 2012, and the input and output factors, costs and benefits of these three ecosystems were analyzed, the impact factors of net eco-service values of these ecosystems and their fluctuation laws were ex-

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* Corresponding author. E-mail: zyyang@ shou. edu. cn

plored. The following parts of this paper were arranged as this: The studied ecosystems, methodologies and sources of data were introduced in the second part, results were showed and discussions were made in the third part, and the conclusions were provided in the last part.

2 Studied ecosystems, methodologies and sources of data

2.1 Descriptions of studied ecosystems CPAE, LVPAE and MNPAE, three main pond aquaculture ecosystems in Shanghai of China, are the ecosystems studied in this research. Comparative analysis approach was adopted to estimate their input and output factors, costs and benefits, and net food supply values. On this base, the sensitivity of net food supply value to the inputted factors and prices were analyzed, and their changes over different years and species were compared. These three ecosystems have different contributions to the total aquatic production o f China. The CPAE discussed in this paper is the carp polyculture ecosystem, in which black carp (Mylopharyngodon piceus), grass carp (Ctenopharyngodon idellus), silver carp (Hypophthalmichthys molitrix), bighead carp (Aristichthys nobilis), common carp (Cyprinus carpio), crucian carp (Carassius auratus) and Chinese bream (Parabramis pekinensis) were cultured in the same pond and formed a common ecosystem. This ecosystem has been existed in fresh water aquaculture in China for a very long period, and provided the largest part of fresh water aquatic product in this country. Litopenaeus vannamei is an imported species in China, it supplied 690.7 thousand tons of production for consumers in 2012, which contributed 42.4% of fresh water shrimp and prawn production in this country[23]. Macrobrachium nippponense is named as oriental river prawn in China. It is a domestic species which has been farmed for a long time in China, and contribute 237431 tons and 14.6% of fresh water shrimp and prawn production in this country in 2012[23].

2.2 Methodologies and criteria As a part of the total eco-service value of pond aquaculture ecosystems, food supply value is most important part that created by the ecological productivity and can be realized by market mechanism. It consists of two parts: one is the value of inputs from outside economic ecosystems, which should be compensated; the other is the newly created value, which is the fruit of these ecosystems, for all the inputs were rearranged in these ecosystems, and then combined in them to provide new functions for human beings and realized their values. The former is costs of inputted factors, and the later is the farmers' net economic benefits, or named as the net food supply value of pond aquaculture ecosystems. Apparently, what farmers want to maximize is this net food supply value. What is concerned in this paper is this net food supply value of pond aquaculture ecosystems and its distribution characteristics among differently species and in different years. For the reason that this kind value are decided both by values of output and costs of inputted costs, both of the total and net values of these ecosystems were estimated in this study. That means the total value is the results of quantity of productions of these ecosystems multiplied by their market price, and the net food supply value is the surplus of total value of these ecosystems deducted by their costs. In order to estimate the total value and net food supply value, such criterion as total costs (TC), fixed costs (FC), variable costs (VC), total benefit (TB, the total food supply value of these ecosystems), net benefit (NB, the net food supply value of these ecosystems), benefit - cost ratio (BCR), [(net food supply value/costs of inputted factors) × 100%], net profit ratio [(net food supply value/total benefit) × 100%], breakeven production, breakeven price, the sensitivity of net food supply value to fixed costs, variable costs, and prices were adopted in this paper. Total costs include fixed and variable costs. According to the actual situation, those costs, which do not change with the volume of aquatic production, including land rent, expenditures for pumps and aerator, repairing costs for ponds and facilities and depreciation of facilities (such as small boats and houses built beside the ponds and used for watching). It must be pointed out that in some studies, land rent was taken as variable cost[21], but in this research, it was included as fixed costs, because it doesn't change with production. In fact, it was also treated as fixed costs in some other studies[24-25]. On the contrary, because they vary with production, costs for feed, lime, disinfectant, fishery drugs, electricity, water, labor and diesel and gasoline are all included in variable costs. Breakeven production and breakeven price are two of important indicators reflecting fish farmers' ability to resist market risks. It is believed that the lower the breakeven production than practical capacity, the better the fish farmers' ability to resist market risks. Similarly, the lower the breakeven price than real price, the larger the producers' margin for surplus. In the sensitivity analysis part, the elasticity of fixed costs, variable costs and price of output to fish farmers' net profit were calculated. In order to calculate the elasticity of these factors, all them but one was kept in constant, and the variable one was changed in the range of 10% and then the new net profit was calculated and compared with the original profit when the value of this variable hasn't changed, and then the ratio of the difference of net profit to original profit was divided by the ratio of the difference of the value of the variable to its original value.

2.3 Source of data The data used in this study were collected by continued records from 2011 to 2012 of 18 ponds of the three pond aquaculture ecosystems, which were explained in the above lines. That is to say, on the basis of authors' former studies, pre-investigation was done in Jiading, Qingpu and Fengxian, three suburban districts of Shang, and then 18 aquaculture ponds were selected, and water of the ponds and rivers, from which pond water were supplied, were collected and their quality and related biological and chemical indicators (such as COD, total nitrogen, total phosphorus, chlorophyll a) were tested monthly, and the input and output of these observed pond ecosystems were recorded by fish farmers, and then collected and checked by research team members monthly from 2011 to 2012. The number out of the 18 observed ponds farming carps, Litopenaeus vannamei and Macrobrachium nipponensis were 7, 6, and 5 respectively.

2.4 Studied area and aquaculture mode Jiading (121°24′ E, 31°4′ N), Qingpu (121°1′ E, 31°15′ N) and Fengxian (121° 46′ E, 30°92′ N) locate in north, west and south part of Shanghai separately. They are the main production regions of aquatic produce of Shanghai and they extend 1 851.1 km^2, and are 31.93% of the total area of Shanghai. According to the data from Shanghai government, their fresh water aquaculture area and production were 7809 hm^2 and 48419 tons in 2011, and contributed 32.7% and 30.2% of the total aquaculture area and production of Shanghai in the same year. Their production of CPAE, LVPAE and MNPAE were 14677.0, 23909, and 320.0 tons and occupied 16.2%, 56.9% and 52.6% of the total production of correspondent ecosystem of Shanghai in 2011.

The main fishes farmed in these districts include black carp (Mylopharyngodon piceus), grass carp (Ctenopharyngodon idellus), silver carp (Hypophthalmichthys molitrix), bighead carp (Aristichthys nobilis), common carp (Cyprinus carpio), crucian carp (Carassius auratus) and Chinese bream (Parabramis pekinensis). All of these species were farmed together in the 7 observed ponds. For this reason, the polyculture ecosystem was defined here as CPAE. Different to species in CPAE, Litopenaeus vannamei was farmed independently in LVPAE. So was the Macrobrachium nipponense, but in MNPAE, aquatic grasses are also planted to provide protection for farmed Macrobrachium nipponense, especially when they are in the earlier stage. In all the three ecosystems, the feeds were inputted by fish farmers. The inputted feed was mainly formulated feed, supplemented with green grasses and soybean cakes sometimes.

2.5 Description of aquaculture pond and fish farmers' basic information The information of sampled ponds was summarized in Table 1. The average area of all the 18 ponds is 0.6 hm^2. The average areas of the three ecosystems are different, with that of CPAE highest at 0.9 hm^2, LVPAE in the middle at 0.5 hm^2, and MNPAE lowest at 0.4 hm^2.

Table 1 Overview of the aquaculture ponds

Species	Number of sample ponds				Pond area//hm^2			
	Jiading	Qingpu	Fengxian	Total	Mean	Maximum	Minimum	Standard deviation
Carp	3	2	2	7	0.9	1.3	0.5	4.5
Litopenaeus vannamei	2	1	3	6	0.5	1.0	0.4	3.5
Macrobrachium nipponensis	3	2	0	5	0.4	0.8	0.2	3.4
Total	8	5	5	18	0.6	1.3	0.2	4.3

By the end of 2012, all the sampled farmers (owners of the ponds) are male, with the age between 44 and 56. Their fish farming years varied from 7 to 12years, and numbers of family member were 4 to 5. 57.1%, 14.3%, and 28.0% of them graduated respectively from middle school, higher school and university.

3 Results and analysis

3.1 Costs of pond aquaculture ecosystems

3.1.1 Total costs. From 2011 to 2012, the total costs of carps farmed in CPAE are 206280.0 yuan/hm^2 and 219087.9 yuan/hm^2, higher than that of Litopenaeus vanamei farmed in LVPAE (139 288.3 yuan/hm^2 and 162 499.3 yuan/hm^2) and Macrobrachium nipponensis farmed in MNPAE (106904.4 yuan/hm^2 and 132 610.7 yuan/hm^2) in the same period (Table 2). It can be found that the total costs of carps are highest and Macrobrachium nipponensis lowest, that of Litopenaeus vanamei are in the middle. The results of analysis of variance showed there were significant differences among the total costs of three ecosystems in 2011, and this kind differences did appeared in 2012, but at the same time, this kind of analysis denied there significant difference between the total costs of the same ecosystem across years, whether the ecosystem is CPAE, LVPAE, or MNPAE. It can be concluded from the results that the difference in total costs of pond aquaculture ecosystems are mainly caused by the difference of farmed species.

Table 2 The total costs of different pond aquaculture systems

Species	Year	Sample size	Mean yuan/hm^2	Standard deviation yuan/hm^2	Minimum yuan/hm^2	Maximum yuan/hm^2
Carp	2011	7	206 280.0	78 991.4	147 248.6	344 590.5
	2012	7	219 087.9	61 184.1	121 911.0	285 874.7
Litopenaeus vannamei	2011	6	139 288.3	15 726.6	117 525.0	15 590.7
	2012	6	162 499.3	58 209.3	97 486.1	247 348.5
Macrobrachium nipponensis	2011	5	106 904.4	317 53.9	75 602.1	138 066.4
	2012	5	132 610.7	26 392.7	100 603.2	170 833.6

3.1.2 Fixed costs. The fixed costs of carps, Litopenaeus vanamei and Macrobrachium nipponensis were 30153.9Yuan/ hm^2, 28171.8 Yuan/ hm^2 and 29165.3 Yuan/ hm^2 in 2011, 28198.4 yuan/hm^2, 29442.6 yuan/hm^2, 25905.8 yuan/hm^2 in 2012 (Table 3). The proportion of fixed costs in total costs for all the three ecosystems was all less than27%. The results of analysis of variance showed that there were no significant differences among the fixed costs of three ecosystems, neither in 2011 nor in 2012. At the same time, the fixed costs of CPAE in 2011 were not significantly different from those in 2012, and this trend also appeared in LVPAE and MNPAE. With these results, one can see that the significant differences, which do exist in total costs of three ecosystems, were not mainly caused by the differences of their fixed costs. It should be also noticed from the values of standard deviation in Table 3 that whether in 2011 or 2012, CPAE was the ecosystem with most violent change in fixed costs.

Table 3 The fixed costs of different pond aquaculture systems from 2011 to 2012

Species	Costs	Year	Sample size	Share in the fixed costs//%	Mean yuan/hm^2	Standard deviation yuan/hm^2	Minimum yuan/hm^2	Maximum yuan/hm^2
Carp	Rent	2011	7	49.1	13 761.4	162.0	10 200.0	18 000.0
		2012	7	49.8	14 035.7	209.6	7 500.0	16 500.0
	Depreciation	2011	7	36.1	11 997.4	758.0	1 200.0	6 499.5
		2012	7	38.0	10 720.7	660.2	3 590.7	32 273.9
	Low-value consumption goods	2011	7	10.2	3 056.3	147.1	750.0	7 500.0
		2012	7	9.5	2 681.5	179.0	1 200.0	8 695.7
	Repair costs	2011	7	4.7	1 248.8	72.8	225.0	3 000.0
		2012	7	2.7	760.5	19.8	300.0	1 125.0
	Fixed costs	2011	7	100.0	30 153.9	914.8	18 293.6	57 027.2
		2012	7	100.0	28 198.4	743.2	16 321.1	51 586.4
Litopenaeus vannamei	Rent	2011	6	60.7	14 223.7	332.0	11 065.6	22 500.0
		2012	6	62.8	18 500.0	206.6	15 000.0	24 000.0
	Depreciation	2011	6	27.7	6 762.0	168.0	4 890.0	10 480.9
		2012	6	24.9	7 321.0	182.8	4 165.6	10 816.3
	Low-value consumption goods	2011	6	8.2	2 219.2	96.2	1 000.0	5 163.9
		2012	6	8.3	2 455.8	103.6	1 071.4	5454.6
	Repair costs	2011	6	3.4	942.4	52.6	313.5	2 459.0
		2012	6	4.0	1 165.8	69.5	0 .0	2 727.3
	Fixed costs	2011	6	100.0	28 171.8	441.6	18 390.0	36 621.2
		2012	6	100.0	29 442.6	348.8	23 591.8	37 317.3
Macrobrachium nipponensis	Rent	2011	5	58.7	16 080.0	292.8	10 200.0	20 700.0
		2012	5	48.3	12 510.0	235.1	7 500.0	15 000.0
	Depreciation	2011	5	33.4	10 667.5	290.1	6 881.0	17 880.9
		2012	5	37.8	9 788.4	272.1	6 548.1	16 550.0
	Low-value consumption goods	2011	5	5.9	1 836.9	49.5	625.0	2500.0
		2012	5	9.7	2 007.1	95.8	1 000.0	4285.7
	Repair costs	2011	5	2.0	581.0	22.3	250.0	1071.4
		2012	5	4.3	1 100.2	52.8	333.3	2142.9
	Fixed costs	2011	5	100.0	29 165.3	396.2	22 614.3	34 395.0
		2012	5	100.0	25 905.8	257.5	21 019.7	31 065.0

One can also tell from Table 3 that rent of land and depreciation, are the main parts of the fixed costs for all the three ecosystems. The sum of them occupied over 85% of the fixed costs for each system. Among these two main contributors, rent of land was apparently higher than depreciation. For LVPAE, the proportion of rent of land in its fixed costs was up to 60.7% in 2011and 62.8% in 2012. For CPAE and MNPAE, the proportion of rent were lower than that for LVPAE, but were still the biggest part among all the fixed costs, to be specifically, 49.1% and 49.8% for CPAE in 2011 and 2012, and 58.7% and48.3% for MNPAE in 2011 and 2012 respectively. Other fixed cost did change to some extent across different ecosystems and different years, but comparatively stable.

3.1.3 Variable costs. CPAE are the ecosystem with the highest total variable cost both in 2011 and 2012. On the contrary, MNPAE are the one with lowest of this cost. One can see from table 4 that the total variable costs of these three ecosystems in year 2011 and 2012 were 176126.1 yuan/hm^2 and 190889.4 yuan/hm^2 for CPAE, 111116.5 yuan/hm^{2}and 133056.7 yuan/hm^{2}for LVPAE and 77739.1 yuan/hm^2 and 106705.0 yuan/hm^2 for MNPAE. The results of analysis of variance showed that both in 2011 and 2012, significant differences did exist among the total variable costs of these three ecosystems, but no such differences were observed for total variable costs of the same ecosystem across year 2011 and 2012. Combining the results mentioned in above lines, one can conclude that the significant differences among the total costs of the three ecosystems were mainly caused by the differences of their total variable costs.

Total variable costs of pond aquaculture ecosystems consist of several parts. Which one of them caused the significant differences among the three ecosystems? To answer this question, the structure of total variable was explored in detail and showed in Table 4. One can see from the table that costs for feeds, fry and labor were the top three variable costs, and the sum of them contributed over 77.3% of total variable costs for all the three ecosystems. Among the three parts, feed cost was the biggest one and occupied 40.1% –69.8% of the total variable costs for all the three ecosystems. It contributed 69.8% in the LVPAE in 2011 and 40.1% in CPAE in 2012(table 4). The top two contributor, fry cost, occupied 7.9% –28.5% in the total variable costs, with highest portion of 28.5% in CPAE in 2011and lowest portion of 7.0% in MNPAE in 2012. As for the third part, wages for labor, ranged from 9.2% to 16.6% in total variable costs for the three ecosystems, and was up to 16.6% in LVPAE in 2011 and 9.2% in MNPAE in 2012.

The results of analysis of variance showed that the feed costs (per hectare) differed significantly among the three ecosystems in 2011, but this trend didn't appear in 2012. On the contrary, fry costs (per hectare) didn't change significantly among the three ecosystems in 2011, but significant differences were observed in 2012. It must be noticed that the sum of feed and fry costs did vary significantly among the ecosystems both in 2011 and 2012. The results also said that there are no significant differences for labor costs (wages) among the ecosystems both in 2011 and 2012. As for the same ecosystem, the feed costs, fry costs, and labor costs (per hectare) didn't vary significantly from year 2011 to 2012. In a word, the total costs of the three ecosystems differed significantly; this difference was mainly dominated by the variable costs, which also vary significantly among the ecosystems. The fixed costs of these ecosystems also change from one ecosystem to another, but no significant difference was observed. The variable costs of these ecosystems were decided mainly by costs of feeds, fry and labor. While fry costs didn't changed noticeably among the ecosystems, feed and fry costs did differ significantly among them, and these significant differences were the main sources of difference of the total costs of the three ecosystems.

Table 4 The variable costs of different pond aquaculture systems from 2011 to 2012

Species variables	Year	Carp		Litopenaeus vannamei		Macrobrachium nipponensis	
		Share in the variable costs//%	Mean yuan/hm^2	Share in the variable costs//%	Mean yuan/hm^2	Share in the variable costs//%	Mean yuan/hm^2
Fry	2011	28.5	50 165.8	9.2	10 252.1	7.9	6 172.9
	2012	27.0	51 497.1	22.2	29 483.8	16.8	17 973.4
Lime	2011	0.3	575.7	0.5	503.2	0.8	620.7
	2012	1.5	2 771.0	1.7	2 253.5	0.9	910.7
Fertilizer	2011	0.5	904.4	0.8	868.8	1.4	1 058.6
	2012	0.7	1 321.9	1.0	1 320.1	0.8	836.9
Disinfectant	2011	0.6	1 051.9	1.6	1 755.6	0.7	517.4
	2012	0.8	1 500.8	1.1	1 460.0	1.0	1 076.0
Fish medicine	2011	1.0	1 672.0	1.7	1 890.0	1.2	899.3
	2012	0.8	1459.9	0.9	1212.0	0.9	998.6
Feed	2011	51.9	91 467.8	69.8	76 427.8	67.5	52 444.2
	2012	40.1	76 427.8	59.9	79 744.8	62.2	66 323.8
Water fees	2011	0.6	1 010.7	0.8	864.8	0.0	0.0
	2012	0.8	864.8	0.0	0.0	0.0	0.0
Electricity fees	2011	3.8	6 650.2	3.9	4 286.2	3.5	2 716.2
	2012	3.9	4 286.2	3.4	4 566.8	4.8	5107.1
Oil and gas fees	2011	0.7	1 258.0	0.0	0.0	0.6	437.4
	2012	0.0	0.0	0.6	829.6	0.4	375.0
Taxes	2011	0.6	1071.4	0.0	0.0	0.0	0.0
	2012	0.0	0.0	0.0	0.0	0.0	0.0
Other costs	2011	0.1	214.3	1.1	1199.5	0.0	0.0
	2012	0.0	53.6	0.0	0.0	0.0	0.0
Wages	2011	11.4	20 083.9	11.8	13 068.7	16.6	12872.5
	2012	10.3	19 725.5	9.2	12186.2	12.3	13 103.4
Variable costs	2011	100.0	176126.1	100.0	111 116.5	100.0	77 739.1
	2012	100.0	190 889.4	100.0	133 056.7	100.0	106 705.0

3.2 Benefits of pond aquaculture ecosystems

3.2.1 Total and net food supply values of pond aquaculture ecosystems. As what was stated above, the total food supply value of pond aquaculture ecosystems are the value of the produce which are produced by these ecosystems and are realized by market mechanism. They become fish farmers' total benefit from these ecosystems. According to the observed data, the total production, total benefits and total net total benefits per hectare are listed on the Table 5.

3.2.1.1 Total food supply value. The figure on Table 5 shows that with the value of 282540.7 yuan/hm^2, the total food supply value per hectare of LVPAE was highest among the three ecosystems, followed by 258903.1 yuan/hm^2 of CPAE and 242788.1 yuan/hm^2 of MNPAE in 2011. In 2012, the order changed a little: The total food supply value of CPAE moved to the highest in the list, while that of LVPAE moved down to the second, and the total food supply value of MNPAE still stayed in the bottom. The figure on Table 5 also says that compared with the total food supply values in 2011, those values of CPAE, LVPAE and MNPAE increased 2.2%, −6.9% and −10.7% in 2012.

The results of analysis of variance showed that (1) there were no significant differences among the total food supply value of these three ecosystems both in 2011 and 2012; (2) there were also no significant difference between the total food supply values of the same ecosystem in different years (year 2011 and 2012) for all the three ecosystems; (3) For all the three ecosystems, both the prices of their produces and per hectare productions differed significantly over 2011 and 2012. These results mean that although the differences existed of their produce prices and per hectare productions, when the prices timed by per hectare production, the differences disappeared in their results (total food supply values).

3.2.1.2 Net food supply value. As for the per hectare net food supply value, LVPAE is highest in 2011 among the three ecosystems, with the value of 143252.4 yuan/hm^2, followed by MNPAE (135883.7 yuan/hm^2) and CPAE (52623.1 yuan/hm^2). This trend appeared again in 2012, but compared with those in 2011, the net values of CPAE, LVPAE and MNPAE decreased 13.7%, 30.0%, 38.0% respectively (Table 5).

The results of the analysis of variance showed that there were significant differences among the net food supply values of the three ecosystems in 2011, but no such differences were found among them in 2012. The analysis in above lines showed that there were significant differences among the costs of the three ecosystems both in 2011 and 2012. So what could be the reasons for this fact: the significant differences among the costs of these ecosystems in both of the two years only resulted significant differences among the net food values of them in 2011? According to the results in the former analysis, this might be caused by the interaction of the total food supply value and total costs of these ecosystems in 2012, because only the later showed the significance in 2012.

The results of the analysis of variance also showed that as for the same ecosystem, no significant differences appeared among the net food supply values of CPAE both in 2011 and 2012, so didn't among those of LVPAE, but significant differences were observed among the net food supply values of MNPAE in 2011 and 2012. This results showed that the net food supply value of MNPAE fluctuated with time more violently than that of CPAE and PVPAE.

Table 5 Indicators of production and output value per unit area from 2011 to 2012

	Year	Carp	Litopenaeus vannamei	Macrobrachium nipponensis
Aquaculture production//kg/hm^2	2011	17641.2	7 876.5	6 313.1
	2012	15 698.9	5 871.9	5 825.6
Output value	2011	25 8903.1	282 540.7	242 788.1
yuan/hm^2	2012	264 487.5	263 028.0	216 798.2
Net value	2011	52 623.1	143 252.4	135 883.7
yuan/hm^2	2012	45 399.6	100 528.7	84 187.5

3.2.2 Benefit – Cost Ratio and Net Profit Ratio of pond aquaculture ecosystems. The benefit – cost ratio (BCR) and Net Profit Ratio (NPR) of pond aquaculture ecosystems are showed on Table 6. In 2011, the net benefits of per unit production of carps, Litopenaeus vannamei, and Machrobrachium nipponense were 3.4 Yuan/Kg, 17.0 Yuan/Kg and 21.6 Yuan/Kg respectively. The correspondent net benefits changed into 3.2 Yuan/Kg, 19.5 Yuan/Kg and15.9 Yuan/Kg. Their BCR of per unit production are 27.5%, 91.7% and 129% respectively for carps, Litopenaeus vannamei and Macrobrachium nippponense in 2011. In 2012, their BCR changed into 23.0%, 73.8% and 63.8% correspondently. One can see from these data that on one hand the BCR of Litopenaeuse vannamei and Mcachrobrachium changed more violently from year 2011 to 2012 than carps, on the other hand, the BCR of carps are much lower than those of Litopenaeuse vannamei and Macrobrachium nipponense both in 2011 and 2012. This means that given other factors unchanged, LVPAE and MNPAE have comparative advantage over CPAE but with higher risks.

As for NPR, one can see from Table 6 that of carps are also much lower than those of Litopenaeuse vannamei and Macrobrachium nipponense in these two years, and those of carps and Litopenaeuse vannamei are more stable than that of Machrobrachium nipponense from 2011 to 2012.

3.3 Analysis of uncertainty

3.3.1 Breakeven production and breakeven price. The results of breakeven analysis are listed on Table 7. One can see from the table that from 2011 to 2012, the breakeven production of CPAE decreased slightly from 5 244.9 kg to 4 567.1 kg. Contrarily, those of LVPAE increased violently from 2 868.7 kg to 4 417.8 kg and those of MNPAE increased slightly from 2 120.3 kg to 2 665.3 kg. The reasons for these different trends are the different changes of prices and costs of the produces. One can also see from the table that all the three ecosystems only used small part of their practical capacity.

Table 6 The profits of the pond aquaculture systems from 2011 to 2012

	Year	Carp	Litopenaeus vannamei	Macrobrachium nipponensis
Total costs	2011	9.3	18.5	16.8
yuan/kg	2012	11.9	26.4	24.9
Total output	2011	15.6	35.5	38.4
value//yuan/kg	2012	14.8	46.0	40.8
Net income	2011	3.4	17.0	21.6
yuan/kg	2012	3.2	19.6	15.9
Ratio of profits	2011	27.5	91.7	129.0
to costs//%	2012	23.0	73.8	63.8
Rate of return	2011	24.3	47.8	56.0
on sales//%	2012	22.0	42.7	39.0

The breakeven prices of carps, Litopenaeuse vannamei and Macrobrachium nipponense are 12.2 Yuan/Kg, 18.5 Yuan/Kg and 16.8 Yuan/Kg in 2011, and all of them increased separately to 14.1 Yuan/Kg, 31.4 Yuan/Kg and 24.8 Yuan/Kg in 2012. As a result, all the differences of their real prices and breakeven prices decreased noticeably from 2011 to 2012. One can see also from these figures that LVPAE and MNPAE have more capacity to resist market risks than CPAE: for the differences of the real prices and breakeven prices of their produces are larger than that of carps.

3.3.2 Sensitivity analysis. The sensitivity of net benefit to different factors of the three ecosystems is showed on Rable 8. One can see from the table that the sensitivity of net benefit to factors varied with time and ecosystems. The sensitivity coefficient of net benefit to sale price is largest among all the coefficients (except carps in 2012) for the produce of the three ecosystems. That means that given other factors unchanged, the fluctuation of produce price caused most violent change of fish farmers' net benefits, and so it is the most important factor which should be controlled if fish farmer want to increase their net benefit.

Sensitivity coefficient of net benefit to production is also larger than 1.0, that means to one percent increase of the production can bring more percentage of net benefit growth for fish farmer in each ecosystem. So, if fish farmers want to increase their net benefits, the second important factor need to be cared about is the production of these ecosystems, especially for those using CPAE. The absolute of Sensitivity coefficient of net benefit to feed costs is larger than 1.0 for carps, but smaller than 1.0 for Litopenaeuse vannamei and Macrobrachium nipponense. So the change of feed costs is more sensitive for CPAE than LVPAE and MNPAE. Decreasing feed costs should be the third method for fish farmers to increase their net benefits for those using CPAE.

Table 7 Break-even situation of the pond aquaculture systems from 2011 to 2012

	Year	Carp	Litopenaeus vannamei	Macrobrachium nipponensis
Break-even yield//kg	2011	5 244.9	2 868.7	2 120.3
	2012	4 567.1	4 417.8	2 665.3
Actual production capacity//kg	2011	14 635.7	16 364.3	12 365.9
	2012	12 617.4	11 306.0	10 912.3
The existing production capacity utilization rate of breakeven point//	2011	35.8	17.5	17.2
	2012	36.2	39.8	24.4
Break-even prices//yuan/kg	2011	12.2	18.5	16.8
	2012	14.1	31.4	24.9
Sales prices//yuan/kg	2011	15.6	35.5	38.4
	2012	15.1	46.0	40.8
The difference between sales prices and break-even prices//yuan/kg	2011	3.4	17.0	21.6
	2012	1.0	14.6	15.9

Table 8 The coefficient of sensitivity of net profits of pond aquaculture systems from 2011 to 2012

	Year	Carp	Litopenaeus vannamei	Macrobrachium nipponensis
Fixed costs	2011	−0.5	−0.2	−0.2
	2012	−3.1	−0.4	−0.3
Variable costs	2011	−2.7	−0.7	−0.6
	2012	−6.6	−1.8	−1.2
Feed costs	2011	−1.4	−0.5	−0.4
	2012	−1.5	−1.0	−0.7
Fry costs	2011	−0.4	−0.1	−0.1
	2012	−0.8	−0.4	−0.2
Sales prices	2011	4.1	1.9	1.8
	2012	3.1	2.6	2.5
Production	2011	1.4	1.2	1.2
	2012	1.8	1.2	1.3

4 Further discussion

Estimating environmental costs of pond aquaculture ecosystems by CVM and calculating their net eco-service values by using their total eco-service value to minus their environmental costs, former studies showed that the net eco-service values of CPAE, LVPAE and MNPAE were about 479830.3 yuan/hm^2, 468684.2 yuan/hm^2 and 509464.2 yuan/hm^2 in Shanghai respectively. If the environmental costs were estimated by COD price method and the net eco-service value were still calculated by the same way, the correspondent net eco-service values of these ecosystems were estimated as 486541.3 yuan/hm^2, 475470.8 yuan/hm^2 and 518234.2 yuan/hm^2 respectively. Both of the results of these estimations showed the same trend: The net eco-service values of MNPAE > the net eco-service values of CPAE > The net eco-service values of LVPAE[12]. The results of this study showed that whether in 2011 or 2012, the food supply values of LVPAE > the food supply values of MNPAE > the food supply values of CPAE. Apparently, this trend is different with that of net eco-service values showed in former study. Combining these results, one can see that if fish farmers or the societies only want to maximize their net benefit (net food supply value), LVPAE should be their first choice, followed by MNPAE, and then CPAE. But if fish farmers or societies want to maximize the net eco-service value of these ecosystems, MNPAE should be the first choice, and followed by CPAE, and the LVPAE should be the last one. In both of these trends, MNPAE is in the middle or top of the list, so it might be a better choice for society which can maximize the net eco-service values of pond aquaculture ecosystems on the one hand, and keep fish farmers' income on a upper level on the other hand.

5 Conclusion

Taking Qingpu, Jiading and Fengxian, three suburban districts of Shanghai, as example, 18 ponds of three pond aquaculture ecosystems, namely CPAE, LVPAE and MNPAE were continually observed and related input and output data were recorded from 2011 to 2012, and food supply values of these ecosystems were studied and their impact factors were analyzed on this basis. The results showed that: (1) From 2011 to 2012, the net food supply values of CPAE, LVPAE and MNPAE were 52623.1 yuan/hm^2, 143252.4 yuan/hm^2 and 35883.7 yuan/hm^2 respectively in 2011, and 45399.6 yuan/hm^2, 100528.7 yuan/hm^2 and 84187.5 yuan/hm^2 correspondently in 2012, with order of the net food supply value of LVPAE > that of MNPAE > that of CPAE in both years. (2) The main influencing factors of the net food supply values are the prices of their produces and variable costs, these variable costs contributed over 70% to the total costs in these two year for all the three ecosystems. Feed, fry and labor costs were the dominant factors of variable costs which should be paid more attention to and cut down if fish farmers want to increase their net benefits. (3) The differences among the variable costs of the three ecosystems were dominated by feed and fry costs. (4) No significant differences appeared among the net food supply values of CPAE both in 2011 and 2012, so didn't among those of LVPAE, but significant differences were observed among the net food supply values of MNPAE in 2011 and 2012, which showed that the net food supply value of MNPAE fluctuated with time more violently than that of CPAE and PVPAE. (5) Whichever the ecosystem is, its net food supply values and net eco-service values do not always change in the same trend, so if stakeholders want to keep balance between these two kinds of values, MNPAE should be encouraged in these areas. (6) For all the three ecosystems, if fish farmers and societies want to increase net food supply values and by thus to increase net eco-service values of these ecosystems, they should firstly tried to increase the produce prices, which may include develop fish farmers' organizations, forge brand of the produces and so on. At the same time, such methods as fish farming technology training and extension to increase productions of these ecosystems, to cut down the feed and fry costs also should be adopted to this end.

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content of paddy soil, and the Cu content of dry land soil is the lowest, indicating that in the three land use types, Cu is easier to accumulate in the vegetable field soil, and the exogenous impact on the vegetable field is the greatest.

Studies have shown that the comparison results of 11 control groups are the same as the comparison results of the average Cu content of soil between three land use types.

4 Conclusions

There are great changes in the Cu content of farmland soil in the suburbs of Changchun City, and the Cu content of soil is high. In all 60 samples, the minimum value of Cu content is 41.71 mg/kg, the maximum value of Cu content is 116.77 mg/kg, and the average content is 53.35 mg/kg. The Cu content of soil in all sampling points is higher than the background value of soil in Jilin Province. There are significant differences between the Cu content of soil in dry land, paddy and vegetable field and the background value (Table 1), showing normal distribution (an unusually high value excluded from vegetable field and paddy, respectively). Cu is accumulated at different levels in the dry land, paddy and vegetable field. In Fig. 5, the comparison of Cu content between the 3 control groups of dry land and paddy shows that the Cu content of paddy soil is higher than the Cu content of dry land soil, indicating that Cu is easier to accumulate in the paddy soil, and the exogenous impact on paddy is greater than the exogenous impact on dry land. In terms of the Cu content of soil, different land use types are sequenced in descending order (vegetable field > paddy > dry land). The average Cu content of vegetable field soil is the highest, reaching 54.61 mg/kg, followed by the paddy soil, and the Cu content of the dry land soil is the lowest, with an average of 50.09 mg/kg. The vegetable field is significantly affected by the exogenous heavy metal pollution. There are great differences in the Cu content of paddy soils, and Cu is accumulated more in individual paddy soils. The average Cu content of the dry land soil is the lowest, and its standard deviation is also the lowest, but the content differences are not significant. There are significant differences in the Cu content of soil in different land use types in different regions.

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