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ENERGY CONVERSION EFFICIENCY IN THREE ECOLOGICAL TYPES OF POND IN THE PEARL RIVER DELTA IN CHINA

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ABSTRACT The energy conversion efficiencies of three pond types in the Pearl River Delta were measured: 1) a still－water pond, 0.247 ha. in size, without water renewing nor other oxygen increasing equipment; 2)a renewing－water pond, 0.193 ha. in size, with a daily water－renewing of 2,700－3,000 m^3/ha; and 3) a slight－flow pond, 0.193 ha, in size, with a daily flow of 30,255－42, 480 m^3/ha, of tide－water. In addition, 3 kilo－watt lobe aerators were installed in the renewing－water and slight－flow ponds. These aerators were used when fishes were surfacing. The increased water exchange in two ponds permitted increased loading rates of fish and feeds, and resulted in a marked increase in net fish production, from 10.8 tonnes/ha in the still－water pond to over 40tonnes/ha in the slight－flow pond. The results showed that the energy conversion efficiencies and the percentage of biologidal energy were higher in those ponds with higher water exchange, while the percentage of photosynthetic energy dropped. So it is necessary to stock more direct－feeding species and apply much supplementary feed in order to achieve higher energy conversion efficiency and fish production.
KEYWORDS Pond, Energy conversion efficiency, The Pearl River Delta

As an object of study, research on energy conversion efficiency in pond ecological system is the most important thing. Many a scientist has done some research work in this field[1-5]. Fish pond is a semi－man－made ecological system. By improving its ecological environment, higher ecological efficiency and higher fish production can be achieved. Higher water exchange rates in aquaculture systems generally lead to higher areal production rates because water exchange transports oxygen into the system and removes wastes from it. However, it is not understood how water exchange rates alter the basic efficiency of energy transfer in the ponds. In integrated fish ponds in the Pearl River Delta area, a range of water exchange rates can be found, determined by the degree of tidal influence on the rivers near which the ponds are located. In this study, three ponds were chosen for comparison. The objective was to stock each

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pond with its maximum fish carrying capacity, determined by past experience with the ponds, and to determine the maximum production rate as well as the energy conversion efficiency for each type of pond.

1 MATERIALS AND METHODS

1.1 Pond conditions

The ponds were: (1)a still-water pond, 0.247 ha. in size, without water-renewal nor other oxygen increasing equipment; (2)a renewing-water pond, 0.193 ha. in size, with daily water-renewing of 2,700 to 3,000m^3/ha; and (3) a slight-flow pond, 0.193 ha. in size, with a daily tide-driven water exchange of 30 255 to 42 489 m^3/ha. The ponds were 1.8m in depth. In addition, 3 kilowatt lobe aeroters were installed in the renewing-water and slight-flow ponds. These aerators were used only when fishes were surfacing. Each pond was stocked with the maximum weight of fish it would support based on past experience and, was suppled with an amount of fish feed in accordance with the fish biomass. The standing stocking rates of fingerlings (Table 1) were 1.9 tonnes/ha for the still-water pond, 8.8 tonnes/ha for the renewing-water pond and 17.6 tonnes/ha for the slight-flow pond.

Table 1 Stocking and harvesting in three types of ponds

	Stocking (kg/pond)			Harvesting (kg/pond)		
	Still-water pond	Renewing-water pond	Slight-water pond	Still-water pond	Renewing-water pond	Slight-water pond
Grass carp	145.4	872.6	2153.5	1226.2	2558.1	6384.4
Mud carp	64.0	54.8	60.6	452.5	246.8	904.5
Tilapia	3.3	2.0	43.5	359.6	737.2	820.1
Big-head carp	146.5	147.3	106.7	482.1	442.8	227.4
Silver carp	21.5	13.6	555.9	251.2	191.1	894.4
Common carp	67.3	33.1	453.6	215.3	548.1	1791.0
Rabeo rohita	12.2	29.6	9.6	147.6	153.1	202.4
Black carp	15.2	1.7	14.5	15.2	2.9	53.1
Total	475.4	1154.7	3397.9			
Gross output				3149.7	4880.1	11277.3
Net output				2674.3	3725.4	7879.4

1.2 Input and output statistics

All input and output were converted into energy(J), and the energy contents of feed and fish are listed in Table 2. Input energy was classified as biological energy (feeds, fertilizer and grasses), industrial energy (fish fingerlings, human labor and electricity) and photosynthetic energy. Photosynthetic energy was estimated by measuring primary production in the ponds. Primary production was measured once every 15 or 30 days using the light and dark bottle method[6]. Energy conversion efficiencies were calculated according to Li Sifa[5].

Table 2 Energy content of various inputs to the ponds

Feeds	MJ/kg	Fishes	MJ/kg
Rice bran	18.183	Grass carp	5.3646
Pellet feed	16.496	Big - head	3.358
Peanut cake	19.1026	Silver carp	3.96
Silkworm pupa	21.318	Tilapia	3.838
Elephant grass	1.404	Common carp	3.971
		Rabeo rohita	3.66
		Black carp	5.31
		Mud carp	3.70

2 RESULTS

Table 3 Input and output in three types of ponds. (whole - pond basis)

	Still - water pond		Renewing - water pond		Slight - flow pond	
	Energy (GJ)	Total (GJ)	Energy (GJ)	Total (GJ)	Energy (GJ)	Total (GJ)
INPUTS						
Photosynthetic energy		58.271		50.0662		70.095
Biological energy		111.369		126.432		257.394
Rice bran	20.459		26.545		69.151	
Pellet feed	27.856		36.127		94.098	
Peanut cake	12.001		14.420		23.544	
Silkworm pupa	12.786		15.190		7.196	
Elephant grass	38.267		34.150		63.405	
Industrial energy		4.554		18.727		30.25
Fingerlings	1.999		5.688		16.382	
Labour	2.555		2.555		2.555	
Electricity	- -		10.484		11.313	
OUTPUTS						
GROSS PRODUCTION		13.722		22.4614		53.184
Grass carp	6.578		13.723		34.249	
Mud carp	1.674		0.913		3.347	
Tilapia	1.380		2.829		3.148	
Big - head carp	1.619		1.487		0.763	
Silver carp	0.995		0.757		3.542	
Common carp	0.885		2.177		7.112	
Rabeo rohita	0.540		0.560		0.741	
Black carp	0.081		0.0154		0.282	
NET PRODUCTION		11.724		16.7732		36.767
Grass carp	5.798		9.042		22.697	
Mud carp	1.437		0.710		3.122	
Tilapia	1.368		2.822		2.981	
Big - head carp	1.127		0.993		0.405	
Silver carp	0.910		0.703		1.34	
Common carp	0.588		2.045		5.311	
Rabeo rohita	0.496		0.452		0.706	
Black carp			0.0062		0.205	

Daily average gross oxygen productions in the still - water pond, the renewing - water pond and the slight - flow pond were 4.718g/m^2, 5.172g/m^2 and 7.241g/m^2 respectively. In Guangzhou area, the annual solar energy input was 4589.6 MJ/m^2. It was assumed that 1g O_2 equals 6.1g wet phytoplankton, and 444.7g wet phytoplankton equals 1.0 MJ. The gross energy input from photosynthesis in the three ponds was 23.622 MJ/m^2/yr, 25.895 MJ/m^2/yr and 36.254 MJ/m^2/yr respectively. Inputs of feeds, fingerlings, labour, electricity and photosynthetic energy and outputs of fish, for the three types of ponds were shown in Table 3. These inputs and outputs were then summarized as energy conversion efficiencies and as the amount of energy required to produce one tonne of fish (Table 4).

Table 4 Energy conversion efficiency and energy consumption

	Gross output			Net output		
	Still pond	Renewing pond	Silght pond	Still pond	Renewing pond	Slight pond
Energy conversion efficiency (%)						
Total energy	7.88	11.51	14.87	6.73	8.59	10.28
Biological energy	12.32	17.77	20.66	10.53	13.27	14.28
Bio - industrial energy	11.84	15.47	18.49	10.11	11.56	12.78
Energy consumption (GJ/tonne fish)						
Total energy	55.30	40.00	31.72	65.13	52.40	45.40
Biological energy	35.36	25.91	22.82	41.64	33.94	32.67
Bio - industrial energy	36.80	29.74	25.51	43.35	38.96	36.51

3 DISCUSSIONS

The water exchange rates in these three ponds varied remarkably. Increased water exchange allowed the ponds to be stocked with a higher biomass of fish, and allowed a higher loading of feeds and fertilizers. The main effect of the increased water exchange was a higher fish production per unit area, from 10.8 tonnes/ha in the pond without water exchange, to over 40 tonnes/ha in the pond with the highest water exchange.

The effect of water exchange rates on the efficiency of energy conversion in the ponds however, appeared to be minimal. For example, the conversion of energy put into the ponds by humans, (biological plus industrial energy) to net fish production ranged from 10.11% in the pond without water exchange (the still - water pond) to 12.78% in the pond with the highest water exchange (the slight - flow pond). This slight increase was likely more related to the types of feeds added to the ponds than to the rate of water exchange per se. For example, Table 5 shows the percentage of the three types of energy input to the three ponds. Among the ponds, the percentage of biological energy was higher in those ponds with higher water exchange, while the percentage of photosynthetic energy dropped. The quality, i.e. the protein content, of the biological inputs such as pelleted feed, rice bran and peanut cake was much higher than that of photosynthetic input, even though the energy content might be the same.

The effect of water exchange rate also did not have a marked effect on the amount of biological and industrial energy required to produce one tonne of fish, which ranged from 43.35 MJ in the pond without water exchange (the still - water pond) to 36.51 MJ in the pond with the highest water exchange (the slight - flow pond). These differences were more likely related to the fact that photosynthetic energy made up a higher percentage of the total energy input to the ponds as the rate of water exchange decreased (Table 5), and also to the fact that in the still - water pond, the stocking model (the relative amounts of different types of fish stocked) was relatively biased towards filter - feeding fishes (Table 6). For example, in the stagnant pond, filter - feeding fishes made mp about 35% of the stocked fingerlings, whereas they made up 15 - 20% in the other two ponds. The results showed that it was necessary to stock more direct - feeding species and fewer filter - feeding species in order to achive higher energy conversion efficiency and fish production.

Table 5 Percentage of input energy

Energy type	Still - water pond	Renewing - water pond	Slight - flow pond
Photosynthetic energy	33.5	25.6	19.6
Biological energy	63.9	64.8	72.0
Industrial energy	2.6	9.6	8.4

Table 6 Percentage of direct - feeding species, periphyton - feeding species and filter - feeding species which were stocked

	Still - water pond	Renewing - water pond	Slight - flow pond
Direct - feeding species[a]	47.9	78.6	77.1
Penphyton - feeding species[b]	16.7	7.5	3.3
Filtrate - feeding species[c]	35.3	13.9	19.5

[a] Grass carp, Black carp, Common carp; [b] Mud carp, Tilapia, Labeo; [c] Silver carp, Bighead carp.

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珠江三角洲不同生态类型池塘的能量转换效率

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摘　要　本文研究了珠江三角洲三种不同生态类型池塘的能量转换效率。三种不同类型的池塘分别是：1）静水塘，面积 0.247ha，试验期间不换水，也没有其它增氧设施；2）加水塘，面积 0.193ha，每天加水 2,700－3,000M^3/ha；3）微流水塘，面积 0.193ha，每天由潮汐自然进水 30,255－42,480M^3/ha。另外，加水塘和微流水塘各配一台 3 千瓦的叶轮式增氧机，在鱼浮头时使用。结果表明增加池塘的换水量可以增加鱼产量，提高池塘的能量转换效率。还表明换水量大的池塘其生物能占的比例较大，而光合能占的比例则较小。为提高池塘的能量转换效率和鱼产量，必须增加"直食性"鱼类的放养量、减少"滤食性"鱼类的放养量。

关键词　池塘，能量转换效率，珠江三角州

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