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Integration of Intensive and Semi-Intensive Aquaculture: Concept and Example

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ABSTRACT

An experiment on integrated walking catfish-tilapia culture was conducted for 5 months. The walking catfish were stocked at 400 and 800 fish/cage in two 4-m^3 nylon cages, which were suspended in each of two 250-m^2 earthen ponds. Sex-reversed male tilapia *(Oreochromis niloticus)* were reared at 1 fish/m^2 in the open pond. Whereas the catfish were reared with supplemental feed, tilapia were solely dependent on the natural diet derived from the recycled catfish waste. Weekly analysis of temperature, dissolved oxygen, ammonia, total phosphorus, total Kjeldahl organic nitrogen and chlorophyll *a* in the pond water showed that water quality was suitable for both tilapia and catfish growth. Total catfish and tilapia production was approximately 100 and 140 kg/pond, respectively. The experiment demonstrated that tilapia can efficiently use catfish waste and maintain desirable water quality.

Introduction

Cage fish culture has long been practiced in Southeast Asia (Ling 1977) and many versions of modern modification have been developed for intensive culture of commercially important species in various parts of the world (Coche 1978). Most cage culture is set up in rivers, lakes and the sea (Beveridge 1984). In many cases, the fish are fed with high protein diets in intensive cage culture, and wastes derived from the feed are either directly or indirectly released to the surrounding environment, causing accelerated eutrophication in those waters (Beveridge 1984; Ackefors 1986).

On the other hand, the integrated farming of fish and livestock is widely practiced for maximizing protein production derived from a single source of animal feed. In this system the land animals are raised on supplemental feeds and their wastes (manure and feed wastage) are used directly or indirectly for fish production in pond culture (AIT 1986). Similar to the livestock, fish reared intensively are also fed with either formulated high protein diets or trash fish, but their wastes containing organic particles and soluble nutrients are often discharged from the rearing ponds. Those wastes can be reused to stimulate growth of planktonic and benthic organisms in the ponds, providing natural diets for fish low on the food chain. A general pathway of wastes derived from intensive fish culture is illustrated in Fig. 1.

Traditionally, frequent water change is required in intensive fish culture ponds to maintain desirable water quality. The nutrient-rich wastewaters are often discharged to public waterways, becoming a source of pollutants. Walking catfish culture in Thailand, with an annual production of 10,000 tonnes, exemplifies such a problem.

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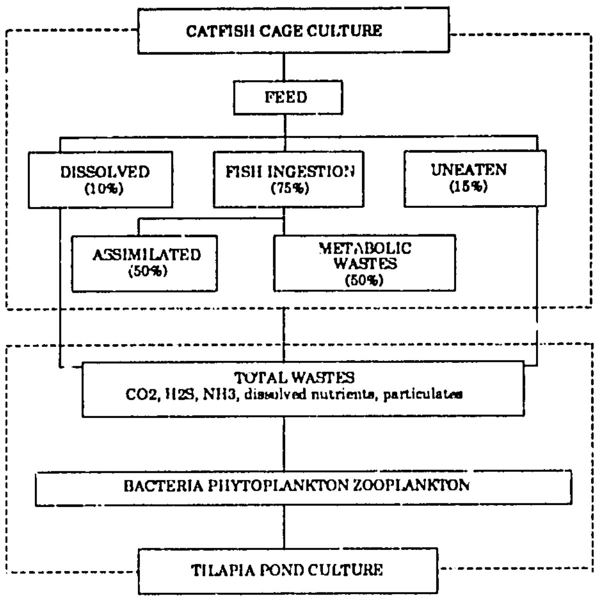

Fig. 1 A generalized pathway for fish and its waste in intensive pond culture system.

By combining cage and integrated fish culture concepts, an experiment was conducted to demonstrate the feasibility of an integrated culture system, rearing walking catfish intensively in cages in ponds, and with tilapia stocked in the ponds to use the catfish wastes.

Materials and Methods

The experiment was conducted from 28 July to 23 December 1987 at Ayuthaya Freshwater Fisheries Station, located approximately 70 km north of Bangkok, Thailand. Two 250 m^2 (10 m x 25 m) earthen ponds were used for the experiment. Two cages (2 m x 2 m x 1.2 m), made of bamboo frames and covered with 1 cm mesh nylon net, were suspended 20 cm off the bottom near the center of the pond, where the water depth was maintained at 1 m. A wooden platform was built to connect the cages to the pond bank for feeding, sampling and other services. The cages were covered with black plastic nets to prevent bird predation and to darken the growth environment.

To provide catfish fingerlings for stocking in the cages, 10-day old fry were nursed for three weeks in 1 m^3 nylon hapas (1 mm mesh openings). During nursing, fry were fed five times daily with commercial starter diet (White Crane 100). When fish grew to fingerlings of 3-7 g/fish they were stocked in cages at densities of 100 and 200/m^2 in each cage. Two cages, each containing 400 and 800 fish/cage, were suspended in the center of each of two duplicate ponds. A styrofoam feeding ring (30 cm x 30 cm) was placed inside each cage to confine the floating feed pellets (manufactured by Charoen Pokphand Co., a local feed company). Fish were fed at 10, 8, 5 and 3% body weight/day during growing periods of 1, 2, 3-4, and 5 months respectively.

Sex-reversed male tilapia with an average weight of 11-12 g/fish were stocked at 1 fish/m^2, a total of 220 fish in each pond. Average weights of both catfish and tilapia were determined monthly by weighing individuals of 10% initial populations. Tilapia were sampled by seining and catfish were sampled with a dip net. The feeding rate of catfish was adjusted monthly according to the estimated total fish weight. At the end of the five month grow-out period the fish were harvested, weighed and marketed.

The water quality parameters were monitored weekly near the center of the pond. Temperature and dissolved oxygen were determined at 0700-0800 hr with an oxygen-temperature meter (YSI model 54), and transparency with a Secchi disc. Vertically integrated column water samples taken with a PVC tube sampler were analyzed for pH, ammonia, total phosphorous, total Kjeldahl nitrogen and chlorophyll *a*.

Results and Discussion

Fish Production

One of the major problems often encountered in cage culture of catfish is the requirement of fingerlings with size greater than the mesh opening of the net (1 cm). To obtain such size, fry had to be nursed for several weeks, during which the fish often suffered from bacterial and parasitic infections, resulting in high mortality. The water quality standards required for fry nursing is higher than that for grow-out.

Final total production of catfish ranged from 33.7 to 83.0 kg/cage. Individual weights ranged from 111-137 g with a daily weight gain of 0.6-0.9 g in the 146-day grow-out period (Table 1). The fish weight increased steadily during the first four months and slowed down drastically in the last month in December (Table 2). The reduction in growth might be attributed to low water temperature (below 25°C) and lower feeding rate, which dropped to 50% of that consumed in the previous month. Fish weight in the final sample period (Table 2) were considerably greater than those averaged from total harvest (Table 1), possibly due to the inaccuracy in sampling only

Table 1. Summary of growth performance of tilapia and walking catfish during a 5-month experiment (A and B designate ponds; a and b for duplicate cages).

Fish Assignment	Walking catfish (cage)				Tilipia (pond)	
	Aa	Ab	Ba	Bb*	A	B
Water volume (m^3)	3.2	3.2	3.2	3.2	220	220
Initial stocking						
Density (fish/m^2)	125	250	125	250	1	1
Number of fish	400	800	400	800	220	220
Total wt (kg)	1.2	4.8	1.2	5.6	2.6	2.4
Mean wt (g/fish)	3	6	3	7	12	11
Harvest						
Number of fish	370	640	266	429	197	171
Total weight (kg)	37.0	83.0	33.7	41.3	80.3	62.8
Mean wt (g/fish)	100	130	127	96	408	367
Weight gain						
Total harvest (kg)	35.8	78.2	32.5	38.5	77.7	60.4
Mean (g/fish)	97	123	122	90	394	356
Fish/day (g)	0.66	0.84	0.84	0.61	2.7	2.4
Survival(%)	92	80	67	54	90	78
Total feed input (kg)	52	210	111	140	-	-

Table 2. Monthly mean weight (g/fish and 1 s.d.) of walking catfish sampled from cages a and b in ponds A and B.

Pond	Cage	Growth Period (days)					
		0	30	62	90	118	146
A	a	3±1.2	14±6.7	40±20.8	58±28.5	108±36.1	116±21.4
	b	6±2.3 2	6±8.8	71±22.5	84±23.2	115±32.2	129±30.0
B	a	3±0.9	17±8.4	40±19.6	58±22.0	94±28.4	111±33.0
	b	7±2.0	30±14.4	63±23.8	79±20.3	116±26.2	137±27.5

10% of the population. The large difference in final survival rate between ponds A (80-92%) and B (54-67%) was caused by poaching in pond B (which was estimated at 50% loss). The feed conversion ratio (FCR) also exhibited a large variation, ranging from 1.5 to 3.4. The upper values were relatively high compared to the land-based pond culture and were probably due to inaccurate estimates of the fish standing crop in the crowded cages, which made representative sampling difficult. As handling stresses catfish easily, frequent counting and weighing for adjusting feed rate can upset feeding behavior and cause infections. Comparing the catfish varieties cultured in Thailand, the hybrid (*Clarias macrocephalus x C. gariepinus*) exhibits an average FCR of 1-1.5, which is considerably lower than the pure native species.

The tilapia production was outstanding, with total harvests of 80.3 and 62.8 kg and with average daily weight gains of 2.7 and 2.4 g/fish in ponds A and B, respectively. The consistently higher chlorophyll biomass and lower Secchi disc depth in pond A indicate that a more abundant food source was available for tilapia, which grew to 444 g/fish compared to 367 g/fish in pond B (Table 3). The extrapolated tilapia production from the present experiment was approximately 8,000 kg/ha/year, a level of production which surpasses that of both conventional integrated fish-livestock system (AIT 1986) and a system optimally fertilized with chicken manure (Diana et al. 1988).

Table 3. Monthly mean weight (g/fish and 1 s.d.) of tilapia sampled from experimental ponds A and B.

Pond	Growth Period (days)					
	0	30	62	90	118	146
A	42±2.8	78±18.5	147±30.4	220±5	1.1331±73.0	444±57.4
B	11±3.37	7±17.7	156±20.7	242±32.2	327±46.4	380±59.5

Water Quality

The water temperature was relatively stable in both ponds, ranging from 26 to 32°C during most of the grow-out period, except during the last month in December when it decreased to 20-25°C (Fig. 2). Catfish are sensitive to cool temperatures (<25°C) which reduce their feeding activity (Supranee Chinabut, pers. comm.). It is commonly observed that catfish stocked during the cool part of the year often suffer from disease. The relatively great Secchi disc depth (35-50 cm) in the initial period decreased rapidly to 20-30 cm during most of the experimental period, but a considerable difference existed between the two ponds (Fig. 2). Chlorophyll *a* concentration, representing phytoplankton biomass, ranged from 20 to 180 mg/m^3, and showed an inverse pattern to that of Secchi disc depth. The suspended solids were dominated by phytoplankton. Dissolved oxygen concentration fluctuated mostly between 2 and 6 mg/L.

While total nitrogen concentrations showed a trend of slight increase towards the later part of the grow-out, total phosphorus and ammonia levels remained relatively stable with most values around 0.2-0.3 mg/L and 0.05-0.3 mg/L, respectively (Fig. 3). In comparison, the water quality in conventional monospecies culture of walking catfish in Thailand exhibits extremely low DO (often anaerobic) and high ammonia (>2-3 mg/L) and sulfide concentrations (Srisuwantach et al. 1981).

The nutrient inputs in each pond derived from the catfish feed can be estimated as shown in Table 4. For pond A, with a feed input of 262 kg and net catfish yield of 114 kg, the total N and P in the waste are calculated to be 9.1 and 1.8 kg, respectively. In comparison with chicken manure, which contains 2% N and 1% P on average, the P and N input derived from the fish feed is equivalent to 400 kg of chicken manure for N and 180 kg for P. While the N:P ratio in chicken manure was 2:1, in fish waste it was 5:1, making a more theoretically balanced nutrient source for pond fertilization.

Although catfish is an air breather that can tolerate extremely poor water quality, disease has been a serious problem (Anon. 1981). To

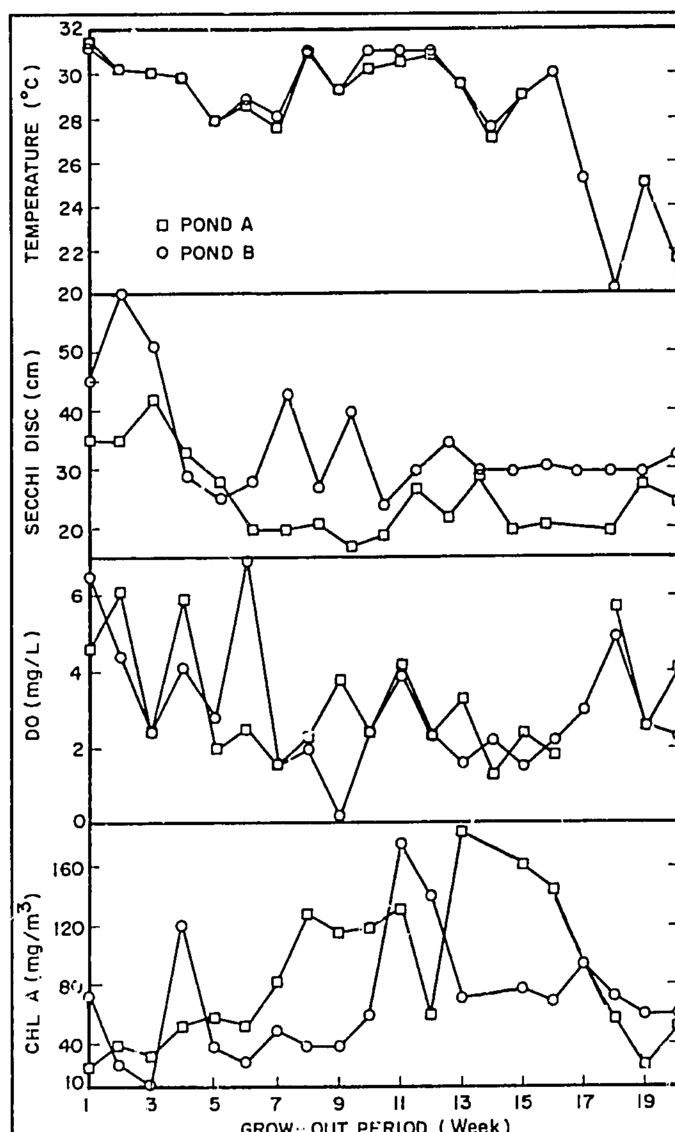

Fig. 2 Fluctuation of water temperature, Secchi disc depth, dissolves oxygen and chlorophyll *a* concentrations in ponds A and B.

improve water quality in commercial farms, the pond water is partially flushed out and refilled with new source water. In an area like Suphan Buri, where a large number of fish farms are located, the wastewater discharged from fish ponds enters the public water supply canals, from which the water is taken to fill the ponds. As a result, the canal water quality is generally poor and also becomes a communal source for disease transmission.

The concept of using herbivorous fish to take advantage of the abundant food source derived from intensive aquaculture is practical as shown by the present results. This system can be applied to other species such as snakehead, seabass and even shrimp in both large- and small-scale intensive fish farms.

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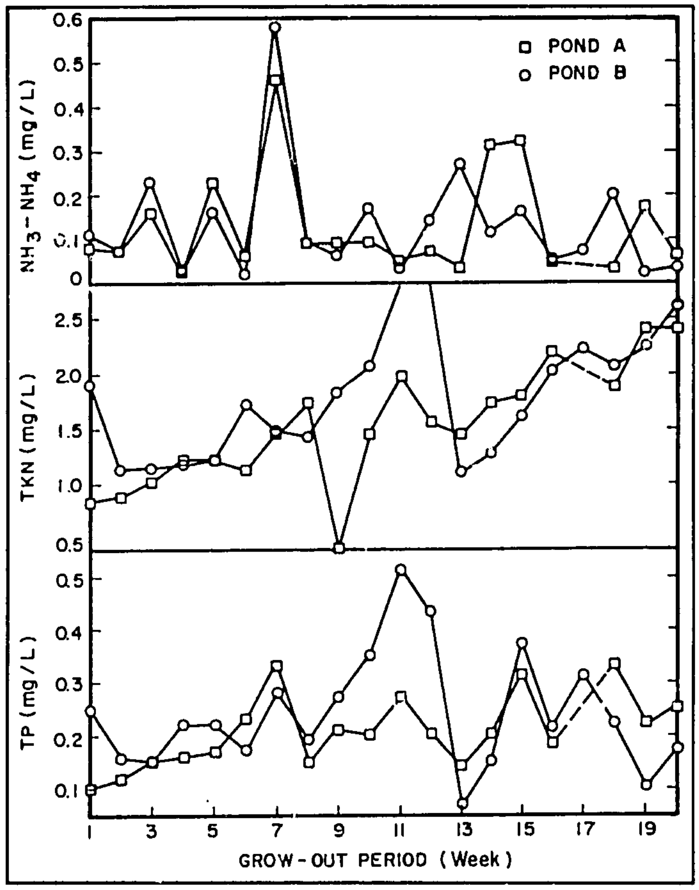

Fig. 3 Fluctuation of total ammonia, total Kjedahl (TKN) and total phosphorus concentrations in ponds A and B.

Table 4. Inputs of phosphorus and nitrogen from fish feed and waste outputs (all weights are in kg/pond)

Pond/cage	Aa	Ab	Ba	Bb
Wet fish weight gain (kg/pond)	35.8	78.2	32.5	38.5
Dry fish weight gain (kg/pond)	9.9	21.7	9.0	10.7
Feed input (kg/pond)*	52	210	111	140
Feed conversion ratio (FCR)				
dry feed/wet fish	1.5	2.7	3.4	3.0
dry feed/dry fish	4.7	8.7	11.1	11.8
Total P in feed input (kg)**	0.7	2.8	1.5	1.9
Total N in feed input (kg)***	2.5	9.8	5.3	6.7
Assimilated P in fish (kg)#	0.2	0.4	0.2	0.2
Assimilated N in fish (kg)##	1.0	2.2	0.9	1.0
Waste P (P in feed-P in fish)	0.5	1.3	1.3	1.7
Waste N (N in feed O N in fish)	1.5	7.6	4.4	5.7

*10% moisture, ** 1.3% P, ***4.7% N, #1.9% P, ##10% N. (Udomkarn 1990).

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