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Cage Culture of Nile Tilapia and its Loadings in a Freshwater Reservoir in Northeast Thailand

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Abstract: An impact on nutrient loadings from cage culture of Nile tilapia, a freshwater fish, was carried out using sediment samples collected from the bottom of Prayeun District Reservoir, Khon Kaen Province, Northeast Thailand during October 1998 to September 1999. The water surface area of the reservoir was approximately 38.4 ha with water depth of approximately 6-8 m. Twenty cages (5x5x2.5 m) were used for Nile tilapia culture in the reservoir. The results showed that the amount of feeding stuff being used and the final fish production during the study period were 29,520 and 19,229 kg, respectively. The average feed conversion ratio over the studied period was 1.54. Organic matter, total nitrogen contents and available phosphorus of the bottom sediments of the reservoir under cage area, in most cases, tended to increase with time during the cage culture period. The percentages of organic matter contents in the sediments under cage sites and surrounding cage sites were at the range of 0.53-4.68 and 2.07-4.32, respectively. Total nitrogen contents in the sediments under cage sites and surrounding cage sites ranged from 0.03-0.25 % and 0.08-0.34 %, respectively. Available phosphorus in the sediments under cage sites and surroundine cage sites were 16.6-425 ppm and 43.6-82.8 ppm, respectively.

Key words: Nile tilapia, bottom sediment, reservoir, cage culture

Introduction

Cage fish culture has presumably been originated in the Yangtze River delta in China, approximately 750 years ago (Hu, 1994). Up to 1978 more than 70 freshwater species have been cultured (Beveridge, 1984) since then cage culture of fish in freshwater has been increased in number more rapidly with time. However, fish production being cultured in freshwater was relatively low with high fluctuations in yield compared with other fish culture methods (Kwei Lin and Kaewpaitoon, 2000). Poor water quality for freshwater fish culture often caused sudden death of caged fish as a result of low dissolved oxygen concentration particularly with those intensive cage cultures, i.e. with high stocking density (Yambot, 2000). Furthermore, Gooley *et al.* (2000) reported that cage culture in freshwater normally causes the increasing amount of nutrients in the sediments and water pollutants. In the Philippines, Marte *et al.* (2000) showed that an increasing amount of units of cage culture with over feeding leads to the deterioration of water quality. In addition, ADCP (1983) reported that cage culture of Nile tilapia fed with more than 30 % protein contents of feeding stuff tended to increase nutrient loading sediments and they further suggested that the optimum protein level of feed stuff for caged fish was 27 %. Nevertheless, Wanniggama *et al.* (1985) found no significant effect on growth or feed conversion ratio among Nile tilapia with the average sizes from 22 to 30 g live weights.

It has been stated by Beveridge (1984) that the impact of cage culture in terms of nutrient loadings could presumably be divided into two points: (1) it increases nutrient concentration in environment, if intensive cage culture is carried out with the use of complete diets. (2) It could reduce nutrient concentration in environment, if the extensive cage culture is fed by natural foods. Nevertheless, Hu (1994) stated three culture methods, with cage fish culture using silver carp and bighead fingerlings. The methods are. (1) nursing the fish in cages without supplementary feeding, (2) culture the fish in fertile water, based on natural feed with aquatic macrophyte supplementation, and (3) culture the fish with complete feeding at high stocking density. He further stated the impact of cage fish culture research as (1) the examination of environment between cage area and control area, (2) the quality of environment before, on going, and after caged culture. Most of the publications are concerned on the increasing amounts of PO_4^{-2}, NH_4^+, organic matter, organic nitrogen and the reduction of dissolved oxygen. Whilst other research investigations involved mostly the impact of cage culture with respect to oxygen consumption, nitrogen, phosphorus and organic matter in the bottom sediments (Tucholski *et al.* 1980; Enell, 1982). In spite of the available information, data on cage culture of Nile tilapia in freshwater reservoir in Thailand are relatively limited. Therefore, the main purpose of this investigation lies on the determinations of the impact of practical cage culture of Nile tilapia with respect to other main factors having significant effects on water qualities of the respective reservoir, i.e. organic matter, total nitrogen contents and available phosphorus, accumulated in the bottom sediments of the freshwater reservoir being used.

Materials and Methods

This practical cage culture was carried out at Pra Yeun District, Khon Kaen Province, Thailand in a constructed freshwater reservoir during October 1998-October 1999. The reservoir has a water surface area of approximately 38.4 hectares with water depth ranging from 6-8 m. Twenty fish cages, each has the dimension of 5 m x 5 m x 2 m, were used for the culture of Nile tilapia. Each initial fish sample weighed approximately 50 g and they were used for two crops. For the first crop, 20 cages were used with the stock density of 120 fish/m^2 and it was carried out in October 1998 - February 1999. Whilst the second crop was done with 18 cages and the stock density was rated at 60 fish/m^2 for each of the 4 cages and 48 fish/m^2 for each of the 14 cages. This was carried out in May 1999 to August 1999. Pellet feeding stuffs with the protein contents of approximately 32 % were used to feed *ad libitum* twice a day. Feed and production in each cage of both crops were recorded individually for feed conversion ratio calculations. Two sources, bottom sediments under cage sites and surrounding cage sites were used for sediment samples. Six spots of each source were used as representative samples. The collected samples of the bottom

sediments surrounded cages were defined as the sediments being accumulated around cage sites at 2 m radius. While the samples of the bottom sediments under cage sites were defined as the sediments being accumulated directly under cage sites. The sediment samples of each source were collected at monthly interval and they were air-dried in room temperature and then ground into meshes for the determinations of organic matter (Broadbent, 1965), total nitrogen contents (Bremner, 1965) and available phosphorus (Olsen and Dean, 1965).
The collected data were statistically analyzed with the use of simple correlations (Steele and Torrie, 1980) using SPSS Software Programme version 7.5 and the significant differences were measured at the probability of 0.05.

Results and Discussion

Total amount of food being used to feed the fish in cages during the study period and fish production were 29,520 kg and 19,229 kg, respectively. This reflects the average feed conversion ratio of 1.54. Some amounts of feeding stuff could presumably be used for fish metabolic requirements rather than totally for growth of the fish. Foy and Rossel (1991) reported that feed conversion ratio could increase not only from food waste but also from under feeding. Even though the feed was consumed, a high proportion may have been used for metabolic requirements rather than for the growth while some amount of phosphorus in the diet being consumed by fish could have been largely metabolized. Organic matter, total nitrogen contents and available phosphorus accumulated in the bottom sediments under cage sites and surrounding cage sites are summarized in Table 1. There were slight fluctuations in the amounts of organic matter, total nitrogen contents and available phosphorus found in the bottom sediments during the studied period. However, values of regressions on correlation coefficient revealed an increase in the amounts of organic matter contents with time. The organic matter contents in the bottom sediment under cage sites ranged from 0.528-4.681 %, while organic matter contents in the bottom sediment surrounding the cage sites were from 2.07-4.32 %. The accumulation of organic matter contents underneath the cage sites was, increased in general, with time, r = 0.70, (Fig. 1). A similar time trend was also found in accumulation of organic matter contents surrounding cage sites, r = 0.60, (Fig. 2). The results indicated that feeding stuff had influence on the accumulation of organic matter and nitrogen contents underneath and surrounding cage site, apart from the disturbance being created by the natural fish, those being thrived on out of the cages in the reservoir. The disturbance of fish out of the cages right at the feeding periods could have some effects on the amounts of nitrogen in the sediments at the bottom of the cage sites and the surrounding cage sites, i.e. some amounts of feeding stuff could possibly have blown out to the surrounding area rather than fallen down to the bottom of the cages. Therefore, the amounts of nitrogen contents in the sediments at the bottom of the cages (0.03-0.25 %) were lesser than that of the surrounding cage sites (0.075-0.336 %). The accumulation of nitrogen at the bottom sediments under cage sites increased with time throughout the examination period, r = 0.70, (Fig. 3). Similarly, the amounts of available phosphorus in the sediments at the bottom of the cage sites ranged from 16.6-425.00 ppm, while the surrounding cage sites was ranging from 43.6-82.80 ppm. The accumulation of available phosphorus in the sediment under cage sites also increased with time, r = 0.84, (Fig. 4). Phosphorus tends to accumulate in a greater amount than that of nitrogen in the sediments. Another possibility for the supply of phosphorus and nitrogen to the sediments could possibly depend upon the sink of phytoplankton from water reservoir and some parts of them may have been adsorbed through the clay surface as stated by Nakanishi *et al.*, (1986). Hepher (1958) showed that most of the phosphorus in farm pond could have been adsorbed by mud, whilst Beveridge (1984) reported that phosphorus tended to accumulate more than nitrogen, particularly in the bottom sediments. Phillips (1985) found that phosphorus in the bottom sediments was found to accumulate up to 58.7 % of the phosphorus inputs added to the lake. Feth (1966) stated that most of the nitrogen presented in bodies of the animals and plants ultimately have formed ammonia and some of nitrogen compounds were adsorbed on clay soils. In most reservoirs being used for fish culture, main sources of nutrients especially nitrogen and phosphorus derive mostly from fish wastes and the unconsumed feeding stuff. This result confirms the findings of the present investigation. The accumulation of organic matter and the decomposition of feeding stuff in the bottom sediments may have played its important role in relation to oxygen consumption of the fish in cages and surrounding area and the accumulation of nitrogen compounds within the settled sediments could take place from time to time and some amounts could have been used for growth by some biotic creatures such as water plants and others. The water plants could be used for fish as feeding stuff for some fish in the reservoir. DeLaune *et al.* (1990) stated that nitrification and denitrification processes have significant effects in removing inorganic nitrogen from freshwater lake. Therefore, the development of anaerobic condition under cage sites may lead to the accumulation of toxic nitrogen compounds and eventually resulted in the depletion of the water dissolved oxygen. The increasing amount of ammonia in cage vicinity may have some adverse effects on the increasing live weights of fish in cages. Yambot (2000) reported that the decomposition of wastes from cage culture normally caused anaerobic and toxic conditions of the bottom sediments. It is of imperative value to improve water condition all of the time to ensure adequate amount of oxygen available for fish both in cages and surrounding areas, i.e. the use of electrical power water pumps to rotate the water into the air as that being innovated by His Majesty the King Bhumipol of Thailand. The involvement of oxygen from the air could be of tangible value in providing adequate amount of oxygen for the fish. Avoidance of the feeding stuff to fall off from the cages as much as possible by increasing the frequency period in feeding the fish could possibly be very helpful. Although some amounts of organic matter and nitrogen may be lost through biological and chemical processes. Organic matter at the bottom of the cages may have been utilized by available benthic organisms such as microorganisms and also some invertebrates. The results of the present study indicated that the accumulation of phosphorus in the bottom sediments under cage sites and surrounding cage sites tended to increase with time. Beveridge (1987) analyzed Nile tilapia feeding stuff and carcasses and found that the feeding stuff usually contains phosphorus up to approximately 1.3 %, while carcass of Nile tilapia contains phosphorus only up to 0.34 %. Therefore, with feed conversion ratio of 1.54 found in this study it should indicate the amount of phosphorus content by this calculation, i.e. (29,520 kg of feeding stuff) x 13 %P) B (19,229 kg fish) x 0.34 %P) = 318.4 kgP.

Table 1: Accumulations of organic matter, total nitrogen and available phosphorus of the reservoir sediment samples at the bottom of the cage sites during the cage culture of Nile tilapia carried out in a Khon Kaen constructed freshwater reservoir.

Month	Under cage sites			Surrounding cage sites		
	OM (%)	TN (%)	AP (ppm)	OM (%)	TN (%)	AP (ppm)
October	0.528	0.032	16.6	2.34	0.092	54.4
November	1.80	0.087	26.2	2.48	0.102	51.6
December	3.26	0.165	40.3	3.19	0.336	82.8
January	3.48	0.168	49.0	3.13	0.142	43.6
February	3.86	0.213	344	3.23	0.238	61.4
March	2.85	0.184	278	3.32	0.185	58.2
April	3.96	0.235	366	3.78	0.212	48.7
May	3.14	0.193	197	2.06	0.075	45.6
June	4.48	0.224	250	2.30	0.089	62.2
July	3.34	0.196	250	3.58	0.159	52.6
August	4.68	0.245	348	3.64	0.162	61.5
Sept.	3.38	0.194	402	4.32	0.198	59.4
October	4.12	0.187	425	4.12	0.187	50.9
Ranges	0.528-4.68	0.032-0.254	16.6-425	2.06-4.32	0.075-0.336	43.6-82.8

Remarks: OM = organic matter, TN = Total nitrogen, AP = Available phosphorus.

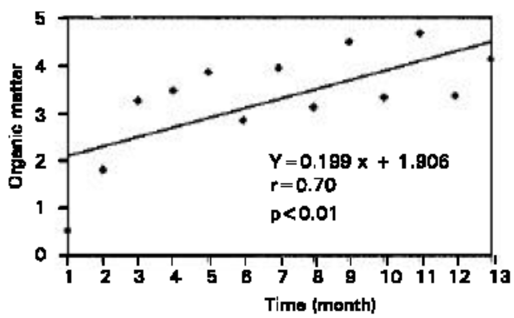

Fig. 1: Orgranic matter accumulated in the bottom sediments under the cage sites

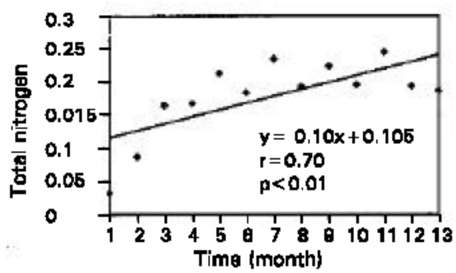

Fig. 3: Total amount of nitrogen accumulated in the bottom sediments under the cage sites in a Khon Kaen constructed freshwater reservoir within year of the cage culture period.

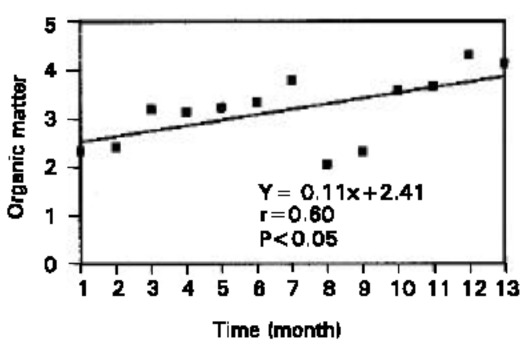

Fig. 2: Organic matter accumulated in the bottom sediments of the surrounding cage sites in a Khon Kaen constructed freshwater reservoir within a year of the cage culture period.

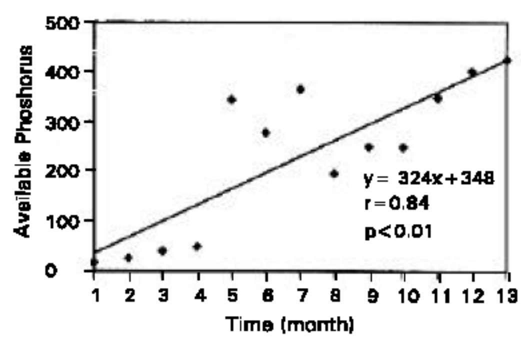

Fig. 4: Available phosphorus accumulated in the bottom sediments under the cage sites in a Khon Kaen constructed freshwater reservoir within a year of the cage culture period.

This figure of P may have been released to the reservoir within the investigation period. However, phosphorus compounds do not normally have a direct affect on live fish. Phosphorus contents in the feeding stuff may be reduced with the use of the low P materials in the feeding formula. It is a common practice that phosphorus contents in the feeding stuff could be greater than that of the fish requirements and some parts of it may turn to waste, i.e. without fish utilization (Tacon and De Silva, 1983). The improved formula of feeding stuff may lead to feeding stability and it could possibly improve the feed conversion ratio of fish live weights (Stickney, 1979).

Conclusions: Cage fish culture experiments lead to an increase in amounts of organic matter, nitrogen, and phosphorus at the bottom sediments of the freshwater reservoir being used. Among them, phosphorus tends to accumulate in the sediments at a higher level than that of the organic matter and nitrogen. The accumulation of organic matter, nitrogen and phosphorous in the sediments was higher at the surrounding cage sites than that of the bottom of the cage sites. Cage fish culture experiment may create the reduction of dissolved oxygen concentration of water reservoir as a result of the decomposition of organic feeding stuff resulted in an occurrence of the anaerobic condition and eventually leads to the accumulation of toxic nitrogen compounds, and ammonia.

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