The Impact of Fish Cage Culture on Water Quality of Taasarn-Bangpla Canal, Nakhon Pathom Province, Thailand

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ABSTRACT

Concerns over the impact of cage culture on water quality alteration arose when the number of fish cages in the Taasarn-Bangpla Canal in Nakhon Pathom province, Thailand increased. This study aimed to assess the impact of cage culture on the water quality of the canal. Water quality in three stations around the dense cage culture areas were monitored monthly from October 2013 to August 2014. Dissolved oxygen, pH, temperature and transparency were monitored *in situ*. Water samples for analysis of phosphorus, ammonia and BOD_5 were analyzed at the Water Chemistry Laboratory by standard methods. The study found that water quality is influenced by wastes released from different activities and apparently influenced by seasonal water flow regime. Water quality, particularly dissolved oxygen, from January to July are considerably good when the accumulated water flow was more than $40x10^6$ m^3/month. Poor water quality occurs when the flow was less than $40x10^6$ m^3/month. High flow period had significantly higher dissolved oxygen than during the low flow period, whereas alkalinity, hardness, ortho-phosphate phosphorus, and total ammonia were significantly low. Statistical indifference in water quality among the three stations was due to predominating temporal variation. However, water quality tended to be altered from upstream to downstream due to wastes generated from different activities in and along the river basin. The approximately 1,057 tonnes annual production of red tilapia currently has, no doubt, worsened the situation. Self-inflict of cage culture and other water users living downstream could suffer from poor water quality if the current situation is allowed to continue without environmental impact mitigation/prevention measures.

Keywords: Cage culture, red tilapia, Taasarn-Bangpla canal, environmental impact, water quality

INTRODUCTION

The Taasarn-Bangpla canal is a tributary of the Tha Chin river in Nakhon Pathom province, Thailand. The canal originates at Taa Rua village, Ta-Khram-end subdistrict, Tha Maka district in Kanchanaburi province, and flows eastward through Kamphaeng Saen, Don Tum and Bang Len districts where it confluences with the Tha Chin river (Figure 1). With a total length of 66 km, the canal with its 88 tributaries was used for water transportation in the past only, since in recent years, better road systems have been developed. Currently, the canal is used mainly for water diversion and irrigation purposes. A large volume of water is diverted from the Mae Klong river in Kanchanaburi province to the Tha Chin river in Nakhon Pathom through the Taasarn-Bangpla canal during dry season to protect the intrusion of saline water into the lower reach of the Tha Chin river. Three sluice gates were constructed along the canal to control water for agricultural purposes. Concerns for environmental deterioration have arisen when the number of fish cages in the canal increased. Therefore, a study on cage culture in the Taasarn-Bangpla canal

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was conducted to assess its impact on water quality alteration. The study consists of 2 inter- related aspects, namely: 1) background and socio-economic information of cage culture operators, and, 2) environment impact assessment. This paper reports on results of the environmental impact study, with two objectives, namely, 1) monitor temporal and spatial water quality variation, and, 2) assess the impact of cage culture on water quality.

MATERIALS AND METHODS

Water quality was monitored monthly at specific stations i.e. upstream, intermediate and downstream, surrounding the tilapia cage culture area (Figures 1 and 2). The monitoring was performed during October 2013 and August 2014. Dissolved oxygen (DO), pH, temperature, water depth and transparency were measured *in situ* from two levels at each station, i.e. 30 cm below the water surface and approximately 30 cm above the canal base. Water samples were also taken to the water quality laboratory at Kamphaeng Saen Fisheries Research Station to determine concentrations of total ammonia nitrogen, NO_3-N, total phosphorus, ortho PO_4-P and BOD_5 by standard methods (APHA, 1998). Spatial, temporal and vertical variation of water quality was analyzed.

RESULTS

Temporal variation

Annual variation of water quality could be divided into two periods, with the variations apparently influenced by the accumulated monthly flow in million cubic meters. These could be divided into two consecutive periods: high flow with >40 x10^6 m^3/month from December 3013 to July 2014, and low flow with <40 x10^6 m^3/month from October to November 2013 and August 2014. Water quality parameters including average dissolved oxygen, alkalinity, hardness, ortho-phosphate phosphorus, and total ammonia during the high flow period were significantly lower than during the low flow period (Table 1).

Spatial variation

The average dissolved oxygen, transparency, alkalinity, hardness and BOD5 during the 11- month study period showed a decreasing trend from upstream to downstream station (Station 1 to Station 3) (Table 2). Differently, the average temperature and total phosphate phosphorus tended to increase from upstream to downstream. However, statistical analysis revealed no significant difference of these water quality parameters among the three stations. The other parameters, pH, ortho-phosphorus and total ammonia did not show any trend.

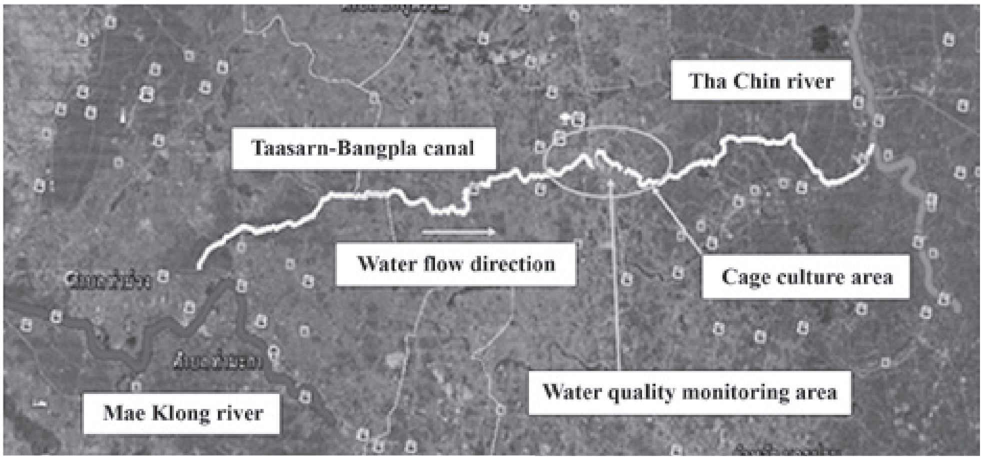

Figure 1. Distribution of fish cage culture along the Taasarn Bangpla canal (green circle) at location between 13° 59' 47.26" N, 99° 57' 45.01" E and 13° 59' 22.10" N, 100° 3' 38.15" E

Figure 2. Water quality monitoring stations: st1 (14° 00' 09.05" N, 99° 59' 35.34" E), st2 (14° 00' 07.53" N, 99° 59' 52.79" E), and, st3 (13° 59' 54.34" N, 100° 00' 01.33" E)

Table 1. Water quality parameters during low flow and high flow periods (mean±SD).

Water quality parameters	Water flow (x10^6 m^3/month)	
	<40	>40
DO (mg/l)	2.9±1.1^a	5.1±0.7^b
pH	7.4±0.4	7.9±0.4
Temperature (^{o}C)	27.9±2.3	28.2±2.6
Transparency (cm)	41±15	35±7
Alkalinity (mg/l as $CaCO_3$)	149±22^a	101±17^b
Hardness (mg/l as $CaCO_3$)	145±18^a	98±19^b
Ortho Phosphorus (mg/l)	0.115±0.034^a	0.042±0.013^b
Total Phosphorus (mg/l)	0.287±0.083	0.323±0.432
Total Ammonia Nitrogen (mg/l)	0.205±0.059^a	0.071±0.036^b
BOD_5 (mg/l)	3.6±1.0	3.4±0.8

Note: different' letter after figure on the same row means statistically different (p<0.05)

Stratification

Water quality parameters such as DO, pH and temperature at the two depth layers were relatively consistent and their annual variation was apparent. DO was relatively low during low flow period and increased to favorable levels during high flow period (Table 3).

Table 2. Variations in water quality parameters at the three study stations (mean±SD)

Water quality parameters	Study stations		
	St 1	St 2	St 3
DO (mg/l)	4.5±1.4	4.3±1.5	4.1±1.5
pH	7.7±0.4	7.8±0.6	7.7±0.5
Temperature (^{o}C)	28.0±2.7	28.1±2.4	28.2±2.5
Transparency (cm)	38±10	37±11	37±12
Alkalinity (mg/l as $CaCO_3$)	124±34	116±33	115±33
Hardness (mg/l as $CaCO_3$)	119±23	114±33	113±33
Ortho-Phosphorus (mg/l)	0.073±0.042	0.064±0.083	0.068±0.045
Total Phosphorus (mg/l)	0.295±0.271	0.333±0.386	0.342±0.394
Total Ammonia Nitrogen (mg/l)	0.123±0.085	0.112±0.080	0.123±0.080
BOD_5 (mg/l)	3.5±0.9	3.4±0.9	3.4±0.9

Table 3. Water quality of the upper and the lower layers of water column (mean±SD).

Year	Month	DO (mg/l)		pH		Temperature (^{o}C)	
		upper	lower	upper	lower	upper	lower
2013	Oct	2.0±0.3	2.0±0.3	7.2±0.0	7.1±0.0	29.1±0.5	28.8±0.1
	Nov	2.6±0.4	2.6±0.3	7.2±0.0	7.2±0.0	28.1±0.2	28.0±0.2
	Dec	4.6±0.3	4.5±0.2	8.0±0.1	7.9±0.1	24.4±0.5	24.2±0.7
2014	Jan	6.5±0.2	6.4±0.2	7.9±0.1	8.0±0.1	22.5±0.4	22.5±0.2
	Feb	5.6±0.2	5.7±0.4	8.0±0.1	7.9±0.3	27.6±0.3	27.2±0.3
	Mar	4.9±0.1	5.0±0.2	7.4±0.1	7.4±0.1	29.1±0.4	28.7±0.3
	Apr	4.6±0.1	4.8±0.2	7.6±0.1	7.6±0.2	30.4±0.2	30.1±0.1
	May	4.6±0.3	4.6±0.2	7.8±0.1	7.7±0.1	30.6±0.1	30.4±0.1
	Jun	4.6±0.3	4.5±0.2	7.4±0.2	7.7±0.1	29.0±0.3	28.9±0.2
	Jul	4.7±0.2	4.8±0.1	8.7±0.5	7.6±0.8	28.5±0.5	28.7±0.2
	Aug	2.2±0.2	2.3±0.2	7.2±0.0	7.2±0.0	30.1±0.1	30.1±0.1

DISCUSSION

The Taasarn-Bangpla canal has been used to divert water from Mae Klong river to Tha Chin river. People living in the canal's watershed, however, have exploited water for daily activities such as household utilization and agricultural activities. The canal and its 88 tributaries function as irrigation canals as well as drainage canals by receiving discharge from land-based activities.

Cage culture has become more popular through the years, as evidenced by the total number of 35 operators in 2013. Cage culture is being operated approximately 17 km from 13° 59' 47.26" N, 99° 57' 45.01" E and 13° 59' 22.10" N, 100° 3' 38.15" E along the canal. Dense fish cages located between 14° 00' 09.05" N, 99° 59' 35.34" E and 13° 59' 54.34" N, 100° 00' 01.33" E upstream of the Kampaeng Saen sluice gate could be possibly related to community settlement (Figure 1). People living along the canal just take advantage by placing cages at their residence water front.

Flow characteristics of the canal change annually due to water management scheme for irrigation purposes (Figure 3). Water flow apparently influenced water quality. Large volumes of water diverted into Tha Chin river via the canal during dry season (January-May) aimed to protect intrusion of saline water into the lower reach of the river (Mr Pongsawad P, 2016, pers.comm., 27 August). A small volume of water was diverted during rainy season (June-September) to avoid worsening situation of flood in the central plain. The central plain is a lowland and always get flooded when heavy precipitation occurs and is worsened by additional surface runoff from the north by late rainy season. Therefore a small volume of water was generally diverted to the canal during the rainy season.

No water was diverted in Taasarn-Bangpla canal from October to November when the irrigation canal needed to be renovated.

Water quality parameters, dissolved oxygen in particular, were considerably good from January and July when accumulated water flow was higher than $40x10^6$ m^3/month, but poor water quality was found when the flow decreased to lower than $40x10^6$ m^3/month. Average DO of the three stations, however could be divided into two distinctive groups according to flow volume, namely, lower than 3 mg/l in November 2013 and August 2014 or at low flow period, and, higher than 4 mg/l in the other high flow period (Figure 4).

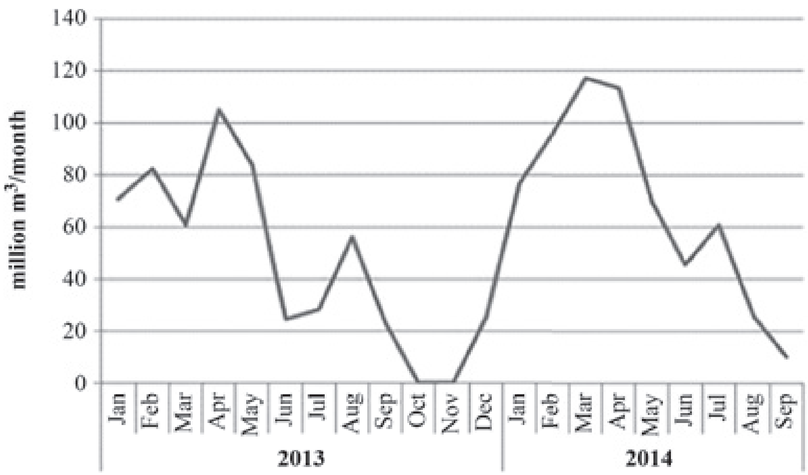

Figure 3. Annual variation of water flow in the Taasarn-Bangpla canal ($x10^6$ m^3/month) (Royal Irrigation Department, 2014, pers. comm.)

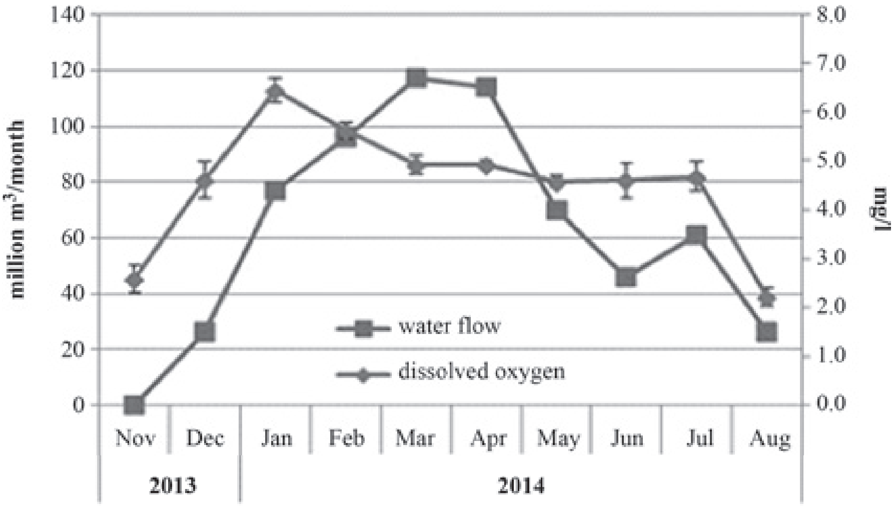

Figure 4. Variations in water flow and dissolved oxygen

Water quality parameters including DO, alkalinity, hardness, ortho-phosphorus and total ammonia were significantly different between the high and the low flow periods (Table 1). Fish cage operators are aware of this typical water flow and quality, therefore many of them avoided stocking fish, or they would stock at low densities during low flow period. Many farmers are equipped with a water pump or paddle wheels to improve the anoxic conditions and maintain DO at a favorable level.

Three water quality monitoring stations were designated to cover the concentrated fish cage area. Hypothesis was that cage culture practice could negatively impact water quality. Consequently, upstream of the dense cage culture area should have better water quality than downstream. However, there was no significant difference in water quality among the three stations possibly due to the flow of water minimized the difference, coupled with the large annual variation.

Three water quality parameters (DO, pH and temperature) monitored at two water depth layers aimed to verify the settlement of solid wastes. Assumption was that cage culture could release large amounts of solid wastes to settle at the canal base which could cause poor water quality especially at the lower depth layer. However, consistent variation of water quality of the two depth layers confirmed that water column was homogeneous.

Environmental impact assessment

Intensive cage culture can cause environmental and economic difficulties because fish can only retain 20 to 30 % of the ingested nitrogen from commercial pellet feeds and the rest (about 75%) are excreted as ammonium into the water (Valbuena-Villarreal and Vásquez-Torres, 2011; Avnimelech *et al*., 2015). Use of more artificial feeds to produce high production from cage culture can cause serious problems such as water pollution (Guo and Li, 2003).

The approximate annual production of red tilapia from cage culture during the study period was 1,057 tonnes. Based on the estimation of Neto and Ostrensky (2013) it could generate 1,100 tonnes, 47.5 tonnes and 15.1 tonnes of organic matter, nitrogen and phosphorus, respectively. Sihapitukgiat *et al*. (2000) reported a similar amount of phosphorus from cage culture that the amount of 14.65-17.05 kg phosphorus could be generated from one ton of tilapia production.

Cage culture in the canal either during high or low flow periods nevertheless caused environmental impacts. Good water quality during high flow period favored cage culture practice. However, untreated wastes directly released into the water, potentially impact not only fish cage operators but also other resource users. Based on DO (2.9±1.1 mg/l) and BOD_5 (3.6±1.0 mg/l) of the low flow period, water quality of Taasarn-Bangpla canal could be classified as Class 4 (fairly clean fresh surface water resources) according to Surface Water Quality Standards of the Pollution Control Department (PCD, http://www.pcd.go.th/info_serv/en_reg_std_water05.html).

More than 40% of Thailand's surface waters have "poor" or "very poor" quality. Simachaya (2002) reported the poor water qualities are related to fecal coliform bacteria, high solids, organic matter and nutrients (phosphates, ammonia and nitrates). There was a high potential for pollution of water sources through irrigation runoff, return flows and infiltration (Tirado *et al*., 2008). Lots of activities in the Taasarn-Bangpla river basin including agriculture, livestock, paddy field, pond aquaculture, communities and others potentially generated wastes to the canal via the connected 88 sub-tributaries. Different stretches of the canal received wastes from different activities. For example, stations 1 and 2 have more impact from household sewage discharge while station 3 apparently obtained wastes from agricultural activities (Figure 2).

Cage culture continuously releases wastes into the canal during culture period, potentially interacting with the entire water body. Failure to control the number of cages, and allowing production to increase beyond the carrying capacity of the water source could result in severe environmental problems, and lead to unsustainable development (Beveridge and Stewart, 1998; Belton *et al*, 2009). Proliferation of water hyacinth in the lower reach of the canal was proof of nutrient enrichment of the canal. People living downstream could suffered from poor water quality caused by wastes released from upstream cage culture.

Consistent DO, pH and temperature at both water depth layers in the canal indicated that the water column was well mixed in the canal. Thus there was less/no settlement of solid wastes at the canal bottom. The homogeneity of water could be a combined effect of the canal's shallowness of 2.5-4.0 meters and water flow that flushed solid wastes to downstream via the sluice gate. Therefore no stratification and less/no settlement at the study area were found.

CONCLUSION

The remarkable temporal variation of water quality in the canal was apparently influenced by water manipulation with the purpose of water diversion from the Mae Klong river to maintain aquatic ecosystem of the lower reach of the Tha Chin river from saline water intrusion during dry season. Spatial variation of water quality was less apparent due to mediation of the flow. Based on the low DO concentrations and relatively high BOD_5 at certain periods, Taasarn-Bangpla could be classified as a deteriorated canal.

Fish cage culture, together with other activities including agriculture, pond aquaculture, livestock, paddy field and household sewage discharge contributed to water quality alteration in the canal. Enriched nutrients partly were retained in the canal by the proliferation of water hyacinth and the large unknown amount was certainly flushed into the Tha Chin river.

RECOMMENDATION

It is clearly seen from the study results that Taasarn-Bangpla is in a deteriorated condition. Cage culture and a number of other activities contributed to the alteration. Therefore appropriate measures should be launched to sustain social and environment development of the canal in particular, and the Tha Chin river in general.

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