

Bacteriological Monitoring of Sea Water in Fish Cage Culture Farms on the Andaman Coast of Thailand

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ABSTRACT

The bacteriological monitoring of fish cage culture farms was carried out during the period from April 2007 to May 2008 in four provinces, Phangnga, Krabi, Trang and Satun along the coast of the Andaman Sea, southern Thailand. The water samples from the reference and cage stations were collected at bimonthly intervals. Total coliform bacteria (TC) and fecal coliform bacteria (FC) in water samples were analyzed by the standard method for the examination of water and wastewater. The TC and FC values were compared in the context of the Pollution Control Department (PCD) of Thailand guidelines for coastal water quality standards. The results showed that mean TC and FC values in most overlying water samples from the cage stations were higher than in samples from the reference stations at all study sites. A high degree of bacteriological pollution was observed at the reference and cage stations during some sampling periods at Ban Ba Gan, Krabi province, where the TC value was higher than the value recommended by the PCD standard. Maximum FC values in the examined water samples from the cage stations from some sampling periods at the study sites of Phang-nga, Krabi, Trang and Satun provinces were higher than the value recommended by the PCD standard. However, the means of TC and FC values at all study sites were lower than the value recommended by the PCD standard, except at the station at Ban Ba Gan, Krabi province. Effluent management of the sanitary sewer systems associated with rural settlements beside the river in this area should be implemented to reduce the risk from fecal bacterial contamination.

Key words: bacteriological, monitoring, total coliform bacteria, fecal coliform

INTRODUCTION

Pollution has been a major and mounting problem faced around the world in much of the 20th and into the 21st century. The most important factor for water pollution is the discharge of untreated wastewaters into seawater (Carson *et al.*, 2001). Total coliform bacteria (TC) and fecal coliform bacteria (FC) for decades have been commonly used as a bacterial indicator of sanitary

quality of water. The most common coliform bacteria are fecal coliform, which are found in the intestines of warm-blooded animals and are excreted with human and animal waste (Addy *et al.*, 2003). The presence of FC in water bodies indicates that the water has been contaminated with the feces from humans or other animals (National Research Council, 2000). According to Pipes (1981), the use of bacteria as water quality indicators can be viewed in two ways. Firstly, the

presence of such indicator bacteria can be taken as an indication of fecal contamination of the water, and thus as a signal to determine why such contamination is present, how serious it is and what steps can be taken to eliminate it. Secondly, their presence can be taken as an indication of the potential danger of health risks which fecal contamination poses. The higher the level of fecal contamination is, the greater the risk there is of contacting a disease. Thus, fish and mollusk culturing in sewage-contaminated water may also be a potential health risk (Hodgkiss, 1988). A proper approach to manage effectively the aquacultural environment requires detailed information regarding bacteriological characteristics. The aim of this study emphasized monitoring of the concentration of TC and FC of sea waters using a comparison between reference and cage stations. The use of information from the present study for future management and as criteria in an assessment are discussed, with regard to how the existing environmental conditions can

influence options for future cage farm development on the Andaman coast of Thailand.

MATERIALS AND METHODS

Study area

The site area for the study on the bacteriological monitoring of cage culture farms was located in four provinces, Phang-nga, Krabi, Trang and Satun along the coast of the Andaman Sea, southern Thailand (Figure 1). Most of the selected fish cage farms in this study were located near the mouth of a river or canal. The names of the study sites and the number of farms in each province are summarized in Table 1.

Water sampling and analytical methods

Seawater samples were collected at 30 cm below the water surface from cage and reference stations. Surface water samples were collected from fish cage culture farms. Reference surface water was also concurrently sampled at



Figure 1 Location of the study sites.

stations located outside the fish cage farms. The water sample in each station was collected with two replications. Bi-monthly collection of marine water was performed aseptically using sterile water bottles (300 ml), labeled and placed on ice inside coolers and transported to the laboratory. The TC and FC in seawater were analyzed by the standard method for the examination of water and wastewater (APHA, AWWA and WPCF 1980). The number of bacteria present was expressed as Most Probable Number (MPN) per 100 ml of water. The mean, minimum and maximum values of bacteria present in surface water of the reference and cage stations were compared with the value recommended by the Pollution Control Department (PCD) of Thailand.

RESULTS

Total coliform bacteria (TC)

Quantitative abundance and variations of

TC in samples of seawater from cage farm and reference stations are presented in Tables 2, 3 and 4. Mean TC in the reference and cage stations ranged from 0 to 8 and 21.13 to 378 MPN/100 ml, respectively. Maximum total populations of 11 and 900 MPN/100 ml were observed in the reference and cage stations, respectively, of Ban Kura (Table 2). A sample from Ban Num Khem showed the mean TC populations varied from 1 to 20 and 1 to 115.6 MPN/100 ml in the reference and cage stations, respectively. Maximum total populations of 17 and 170 MPN/100 ml were found in the reference and cage stations, respectively, of Ban Num Khem (Table 2). The values of both stations in the sampling sites at Phang-nga were not higher than the value recommended by the Pollution Control Department (PCD) of Thailand. Mean TC varied from 8.75 to 975 and 166.6 to 866.2 MPN/100 ml in the reference and cage stations, respectively, at the sampling site in Ban Ba Gan, Krabi province. A maximum total population of

Table 1 The study sites and number of farms in each province.

Province	Study sites	Number of farms
Phang-nga	Ban Kura, Kuraburi District	42
	Ban Num-Khem, Taguapa District	52
Krabi	Ban Ba Gan, Ao-Luek District	60
	Ban Tha-Ma Phow, Klong-Thom District	12
Trang	Ban Ton Harn, Palian District	42
Satun	Ban Ba Kan-Kai, Muang District	40

Table 2 Mean, minimum and maximum values of TC (MPN/100 ml) in the surface water of reference and cage stations at Phang-nga province.

Month		Ban Kura						Ban Nam Khem						PCD Standard
		Reference stations			Cage stations			Reference stations			Cage stations			
		Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	
August	2007	0	0	0	21.1	12	50	20	14	26	19.8	5	34	<1,000
November	2007	8	5	11	124.5	2	220	3.5	2	5	12	5	27	<1,000
January	2008	7	5	11	57.7	7	170	15.5	14	17	115.6	34	170	<1,000
March	2008	1.5	0	2	44.0	0	110	5	4	6	4	0	7	<1,000
May	2008	2	2	2	33.8	17	70	1	0	5	1	0	2	<1,000
July	2008	4.2	2	7	378.0	17	900	5	5	5	10.6	8	17	<1,000

PCD = Pollution Control Department of Thailand.

1600 MPN/100 ml was found in the reference stations in October, while the samples from cage stations had the highest populations of TC in August and October (Table 3). Maximum TC values were higher than the value recommended by the PCD standard. Mean TC values were lower in reference stations (0-15 MPN/100 ml) compared with cage stations (1.7-86.7 MPN/100 ml). The highest populations of 17 and 170 MPN/100 ml were observed in the reference and cage stations, respectively, of Ban Tha Ma Phow (Table 3). The highest TC values were 110 and 500 MPN/100 ml in water samples collected from the reference and cage stations, respectively, at Ban Ba Kan Kai, Satun province, while maximum values were 170 and 350 MPN/100 ml for the reference and cage

stations, respectively, at Ban Ton Harn, Trang province, (Table 4). Maximum TC values at the study sites from Satun and Trang did not exceed the value recommended by the PCD standard.

Fecal coliform bacteria (FC)

A maximum FC of 2 MPN/100 ml was found in the reference station water samples, while the highest FC value of 170 MPN/100 ml was obtained in the cage stations of Ban Kura, Phangnga province. Mean FC in water samples from cage stations in July (76.1 MPN/100 ml.) was higher than the value recommended by the PCD standard. Maximum FC values in water samples from cage stations in November, January and July exceeded the value recommended by the PCD

Table 3 Mean, minimum and maximum values of TC (MPN/100 ml) in the surface water of reference and cage stations at Krabi province.

Month		Ban Ba Gan						Ban Tha Ma Phow						PCD Standard
		Reference stations			Cage stations			Reference stations			Cage stations			
		Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	
August	2007	47	34	70	607.2	34	1,600*	7	2	13	86.7	22	170	<1,000
October	2007	975	50	1,600*	866.2	80	1,600*	6	0	17	61.2	17	170	<1,000
December	2007	6.2	4	9	268.5	17	500	15	13	17	25.6	11	34	<1,000
February	2008	12	5	23	252.3	23	900	7.5	5	11	26.6	14	50	<1,000
April	2008	12.5	11	14	264.1	9	900	0	0	0	1.7	0	6	<1,000
June	2008	8.7	8	11	166.6	22	500	7	2	11	7.7	4	14	<1,000

PCD = Pollution Control Department of Thailand.

* = Higher than the value recommended by the PCD of Thailand.

Table 4 Mean, minimum and maximum values of TC (MPN/100 ml) in the surface water of reference and cage stations at Satun and Trang provinces.

Month		Ban Ba Kan Kai						Ban Ton Harn						PCD Standard
		Reference stations			Cage stations			Reference stations			Cage stations			
		Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	
June	2007	0	0	0	8	6	12	-	-	-	-	-	-	<1,000
September	2007	5	5	110	125.5	8	500	155	140	170	213.7	110	350	<1,000
December	2007	0	0	0	4	2	7	0	0	0	15.2	8	22	<1,000
February	2008	0	0	0	1	0	2	5	4	5	7.7	7	11	<1,000
April	2008	5	4	6	6.7	2	12	4	2	6	22.2	8	30	<1,000
June	2008	0	0	0	7.5	2	17	5	5	5	8.2	5	17	<1,000
August	2008	-	-	-	-	-	-	10	9	11	18.8	8	34	<1,000

PCD = Pollution Control Department of Thailand.

standard (Table 5). A sample from Ban Num Khem showed the highest mean FC populations of 8 and 22.6 MPN/100 ml in the reference and cage stations, respectively. The maximum total populations found in the reference and cage stations did not exceed the value recommended by the PCD standard (Table 5). Mean FC was found to be higher than the value recommended by the PCD standard in the cage station during the sampling period in August (376.6 MPN/100 ml) and November (637.8 MPN/100 ml) at Ban Ba Gan, Krabi province. FC values in the reference stations in August exceeded the standard criteria given by PCD (<70 MPN/100 ml). The maximum FC values in water samples from the cage stations were found to be higher than the PCD standard

during all sampling periods, except in March (Table 6). A sample from Ban Tha Ma Phow, Krabi province showed the highest mean FC population values of 1.7 and 27.5 MPN/100 ml in the reference and cage stations, respectively. The maximum FC found in the reference and cage stations did not exceed the value recommended by the PCD standard (Table 6). The maximum FC values in the reference and cage stations at Ban Ba Gan Kai, Satun province did not exceed the standard criteria given by PCD, except during the sampling period in September (170 MPN/100 ml) (Table 7). The highest mean FC values were 45 and 106.2 MPN/100 ml in the reference and cage stations, respectively, at the sampling site from Ban Ton Harn, Trang province. A maximum total

Table 5 Mean, minimum and maximum value of FC (MPN/100 ml) in surface water of reference and cage stations at Phang-nga province.

Month		Ban Kura						Ban Nam Khem						PCD Standard
		Reference stations			Cage stations			Reference stations			Cage stations			
		Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	
August	2007	0	0	0	8.2	2	23	0	0	0	5	0	11	<70
November	2007	0.5	0	2	66.6	0	170*	0	0	0	1.1	0	5	<70
January	2008	0	0	0	28.6	0	110*	8	7	9	22.6	5	44	<70
March	2008	0	0	0	5.6	0	21	0	0	0	0	0	0	<70
May	2008	0	0	0	13.1	5	26	0	0	0	0	0	0	<70
July	2008	0	0	0	76.1*	2	170*	0	0	0	2.5	0	4	<70

PCD = Pollution Control Department of Thailand.

* = Higher than the value recommended by the PCD of Thailand.

Table 6 Mean, minimum and maximum value of FC (MPN/100 m) in surface water of reference and cage stations at Krabi province.

Month		Ban Ba Gan						Ban Tha Ma Phow						PCD Standard
		Reference stations			Cage stations			Reference stations			Cage stations			
		Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	
August	2007	26.2	23	30	376.6*	26	900*	0.5	0	2	27.5	2	60	<70
November	2007	147.5*	110*	170*	637.8*	17	1,600*	0	0	0	20.3	5	50	<70
January	2008	1	0	2	60	6	170*	0	0	0	6.2	5	9	<70
March	2008	0	0	0	19.1	0	60	0	0	0	8.5	4	19	<70
May	2008	1.5	0	2	58.7	0	190*	0	0	0	0	0	0	<70
July	2008	1.5	0	4	28.6	7	80*	1.7	0	5	1.7	0	4	<70

PCD = Pollution Control Department of Thailand.

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population of 170 MPN/100 ml was found in the cage stations in September, which was higher than the value recommended by the PCD standard (Table 7).

DISCUSSION

Elevated TC values reflect contributions from both fecal and non-fecal matter, while elevated FC values generally reflect contributions from fecal matter. The results from this study showed that mean TC and FC in most overlying water samples from the cage stations were higher than in waters from the reference stations at all study sites. A high degree of bacteriological pollution was observed at Ban Ba Gan, Krabi province. The contribution from TC and FC was high at the reference and cage stations during some sampling periods. TC and FC values were higher than the value recommended by the PCD standard. The PCD standard states that no water sample should contain more than 1000 TC/100 ml (Pollution Control Department, 1994), which is the same as the WHO standard (WHO, 1967). The EEC guideline (Council of the EEC, 1975) states that not more than 20% of water samples should contain more than 500 TC or 100 FC/100 ml. The highest measured abundance of TC and FC at Ban Ba Gan was due to the anthropogenic influence,

while the decrease in abundance in the seaward direction was due to the auto-purification process. In addition, a high river input was found in August and October. River discharges have been ascribed as stimulants for higher rates of microbial population and heterotrophic activity in coastal waters (Mohandass *et al.*, 2000). Sewage from the community is generally attributed as the source of the rich organic content, which stimulates the growth of bacteria in marine water (Markosova and Jezek 1994; Wang, 1999). A significantly high number of FC in the examined water samples during several sampling periods at all study sites in the present study shows that there is human and animal pollution of this part of the river. The sources of FC in the cage culture farms can be grouped into point source and non-point source categories. The point sources include the effluent from the sanitary sewer systems of rural settlements beside the river and sewage from the hut for the caretaker at each cage farm. The non-point sources include urban runoff and waste from livestock and wildlife. Fish and shellfish can survive without any significant effects in coastal waters contaminated by sewage microorganisms. However, molluscan shellfish are known filter feeders and tend to accumulate bacteria along with the suspended food particles present in the water. As such, shellfish harvested from suitable coastal

Table 7 Mean, minimum and maximum value of FC (MPN/100 mL) in surface water of reference and cage stations at Satun and Trang provinces.

Month		Ban Ba Kan Kai						Ban Ton Harn						PCD Standard
		Reference stations			Cage stations			Reference stations			Cage stations			
		Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	
June	2007	0	0	0	5.1	5	7	-	-	-	-	-	-	<70
September	2007	10.7	0	26	49.5	4	170*	45	40	50	106.2*	50	170*	<70
December	2007	0	0	0	0	0	0	0	0	0	9.8	4	14	<70
February	2008	0	0	0	0	0	0	0	0	0	1.1	0	4	<70
April	2008	0	0	0	0.5	0	2	0	0	0	8.3	2	13	<70
June	2008	0	0	0	1.1	0	4	0	0	0	1.8	0	4	<70
August	2008	-	-	-	-	-	-	2.5	0	5	6.3	1	13	<70

PCD = Pollution Control Department of Thailand.

* = Higher than the value recommended by the PCD of Thailand.

and estuarine waters are of great public concern. The acceptable international microbiological criterion for waters where shellfish are grown and harvested is 70 TC/100 ml, while an ASEAN marine water quality criterion of 70 fecal coliforms/100 ml of water (geometric mean; sampling of overlying water 30 cm below water surface) is recommended for fish and shellfish cultivation (Wang, 1999).

CONCLUSION

The seawater in cage culture farms from this study poses a risk in terms of the levels of coliform indicators for coastal aquacultural activities. Effluent management of the sanitary sewer systems of rural settlements beside the river, and sewage from the huts of farm caretakers is suggested.

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LITERATURE CITED

- Addy, K., E. Herron and L. Green. 2003. Bacterial Monitoring <<http://www.uri.edu/ce/wq/ww/html/ww.html>> (March, 2003).
- APHA, AWWA and WPCF. 1980. **Standard Method for the Examination of Water and Wastewater**. 15th ed. American Public Health Publishers, New York. 1368 p.
- Carson C. A., B. L. Shear, M. R. Ellersieck and A. Asfaw. 2001. Identification of fecal *E.coli* from humans and animals by ribotyping. **Appl. Env. Micro.** 67: 1503-1507.
- Council of the European Economic Community (EEC). 1975. Council directive concerning the quality of bathing water. **Off. J. Euro. Com.** 76: 1-7.
- Hodgkiss, I. J. 1988. Bacteriological monitoring of Hong Kong marine water quality. **Envi. Inter.** 14: 495-499.
- Markosova, R. and J. Jezek. 1994. Indicator bacteria and limnological parameters in fish ponds. **Wat. Res.** 28: 2477-2485.
- Mohandass, C., N. C. Shanta, T. Achuthankutty and P. A. Loka Bharathi. 2000. Pollution monitoring of coastal and estuarine areas: I. Bacterial indicators along the south Gujarat coast. **Ind. J. Mar. Sci.** 29: 43-47.
- National Research Council. 2000. **Infectious Diseases. From Monsoons to Microbes: Understanding the Ocean's Role in Human Health**. National Academy of Sciences. 58 p.
- Pipes, W. O. 1981. **Bacterial Indicators of Pollution**. CRC Press Inc., Boca Raton, FL. 215 p.
- Pollution Control Department. 1994. **Laws and Standards on Pollution Control in Thailand**. 3rd edition. Pollution Control Department, Ministry of Science Technology and Environment, Bangkok, Thailand. 285 p.
- Wang, C.W. 1999. ASEAN Marine Water Quality Criteria for Bacteria. <<http://www.marinepcd.org/document/marine/bacteria.pdf>> (March, 1999).
- WHO. 1967. **Control of Water Pollution**. W.H.O. Geneva, Switzerland. 67 p.