

Effect of Season on Water Quality of Extensive and Intensive Seabass Culture Ponds and Associated Canals

ผลของฤดูกาลต่อคุณภาพน้ำของบ่อเพาะเลี้ยงปลากะพงแบบธรรมชาติและแบบพัฒนาและคลองบริเวณใกล้เคียง

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Abstract

Human activities in the upstream areas of Bangkok could affect water quality in the coastal areas where seabass was cultured. Most farmers use water from associates canals without treatment, thus it may be polluted with organic and toxic chemicals. This research aims to study the seasonal effect on water quality of seabass culture ponds and associated canals by monitoring the water quality during culture period. Extensive farm in Bang Khun Thian district, Bangkok and intensive farm in Phra Samut Chedi district, Samut Prakarn were used as the study sites. Water samples were grabbed in ponds and associated canals during wet season (June 2017 – September 2017) and dry season (December 2017 – March 2018). Then, they were analyzed for temperature, Dissolved Oxygen (DO), pH, Biochemical Oxygen demand (BOD), Chemical Oxygen demand (COD), Nitrate (NO_3^-), Total Phosphorus (TP), Total Coliform Bacteria (TCB) and Fecal Coliform Bacteria (FCB). Results showed that TCB and FCB in wet season were higher than dry season for both canals and culture ponds because of water

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นักศึกษาปริญญาโท สาขาวิชาเทคโนโลยีสิ่งแวดล้อม คณะพลังงานสิ่งแวดล้อมและวัสดุ มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี

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นักวิจัย สถาบันพัฒนาและฝึกอบรมโรงงานต้นแบบ มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี

runoff from the land into the surface water. This also affects TCB and FCB in ponds. TCB of intensive and extensive ponds in wet season were 7.80 and 1.73 times of intensive and extensive pond in dry season, respectively. FCB of intensive and extensive pond in wet season were 8.11 and 5.20 times of intensive and extensive pond in dry season, respectively. There was a significant difference between season only in extensive pond ($p < 0.05$). In dry season, associated canals had low DO and high COD. In addition, the seawater level rise affected water quality of ponds because canal water was higher than embankment then water from canals spilled into the ponds. This affected the water quality in culture ponds. Thus, farmers should treat canal water or clarifier before importing to culture ponds. The annual seabass production of extensive pond and intensive pond were 0.33 and 20.45 tonnes/ha-crop, respectively and the yield of 74.13% and 77.50%, respectively.

Keywords: season, water quality, seabass, culture pond

บทคัดย่อ

กิจกรรมของมนุษย์ในพื้นที่ต้นน้ำกรุงเทพมหานคร อาจส่งผลกระทบต่อคุณภาพน้ำในบริเวณชายฝั่งที่มีการเพาะเลี้ยงปลากะพง เกษตรกรส่วนใหญ่ใช้น้ำจากคลองบริเวณใกล้เคียงโดยไม่ได้ผ่านการบำบัด ดังนั้นอาจมีการปนเปื้อนมลพิษจากสารอินทรีย์และสารเคมีที่เป็นพิษ การวิจัยครั้งนี้มีวัตถุประสงค์เพื่อศึกษาผลของฤดูกาลต่อคุณภาพน้ำในบ่อเพาะเลี้ยงปลากะพง และคลองบริเวณใกล้เคียง โดยติดตามตรวจสอบคุณภาพน้ำระหว่างการเพาะเลี้ยง บ่อเพาะเลี้ยงแบบธรรมชาติในเขตบางขุนเทียน กรุงเทพมหานคร และบ่อเพาะเลี้ยงแบบพัฒนาอำเภอพระสมุทรเจดีย์ จังหวัดสมุทรปราการ เป็นพื้นที่ที่ใช้ในการศึกษา โดยทำการเก็บตัวอย่างน้ำแบบจ้วงตักในบ่อเพาะเลี้ยงและคลองบริเวณใกล้เคียง ในช่วงฤดูน้ำหลาก (มิถุนายน 2560 - กันยายน 2560) และฤดูแล้ง (ธันวาคม 2560 - มีนาคม 2561) ทำการวิเคราะห์ห่อหุ้มมีน้ำ ออกซิเจนละลายน้ำ (ดีไอ), พีเอช, ความต้องการออกซิเจนทางชีวเคมี (บีโอดี), ความต้องการออกซิเจนทางเคมี (ซีโอดี), ไนเตรต (NO_3^-) ฟอสฟอรัสทั้งหมด (TP) โคลิฟอร์มแบคทีเรียทั้งหมด (TCB) และ ฟีคัลโคลิฟอร์มแบคทีเรีย (FCB) ผลการศึกษาพบว่า TCB และ FCB ในฤดูน้ำหลากมีค่าสูงกว่าฤดูแล้ง ในคลองใกล้เคียงบ่อเพาะเลี้ยงทั้งการเพาะเลี้ยงแบบพัฒนาและแบบธรรมชาติ เนื่องจากน้ำไหลมาจากพื้นดินลงสู่แหล่งน้ำ นอกจากนี้ยังส่งผลกระทบต่อ TCB และ FCB ในบ่อเพาะเลี้ยง โดย TCB ของบ่อเพาะเลี้ยงแบบพัฒนาและบ่อเพาะเลี้ยงแบบธรรมชาติในฤดูน้ำหลากมีค่าเท่ากับ 7.80 และ 1.73 เท่า ในบ่อเพาะเลี้ยงแบบพัฒนาและแบบธรรมชาติในฤดูแล้งตามลำดับ FCB ของบ่อเพาะเลี้ยงแบบพัฒนาและบ่อเพาะเลี้ยงแบบธรรมชาติในฤดูน้ำหลากมีค่าเท่ากับ 8.11 และ 5.20 เท่า ของบ่อเพาะเลี้ยงแบบพัฒนาและบ่อเพาะเลี้ยงแบบธรรมชาติในฤดูแล้งตามลำดับ ในขณะที่คุณภาพน้ำทั้ง 2 ฤดูกาลมีความแตกต่างกันอย่างมีนัยสำคัญในบ่อเพาะเลี้ยงแบบธรรมชาติ ($p < 0.05$) ในฤดูแล้งคลองบริเวณใกล้เคียงมีค่า DO ต่ำและค่าซีโอดีสูง นอกจากนี้ระดับน้ำทะเลยังส่งผลกระทบต่อคุณภาพน้ำในบ่อเพาะเลี้ยง เนื่องจากเมื่อระดับน้ำทะเลเพิ่มสูงขึ้นกว่าคันดินกั้นน้ำทำให้น้ำจากคลองไหลเข้าสู่บ่อเพาะเลี้ยง ส่งผลกระทบต่อคุณภาพน้ำในบ่อเพาะเลี้ยง ดังนั้นเกษตรกรควร

บำบัดน้ำคลองก่อนนำเข้าบ่อเพาะเลี้ยงหรือเตรียมบ่อพักน้ำเพื่อปรับสภาพน้ำก่อนนำไปใช้ในบ่อเพาะเลี้ยง
ผลผลิตประจำปีของปลากะพงจากบ่อเพาะเลี้ยงแบบธรรมชาติและแบบพัฒนา มีค่าเท่ากับ 0.33 และ 20.45 ตัน/
เฮกตาร์/รอบการผลิต ตามลำดับ ซึ่งให้ผลผลิตเท่ากับร้อยละ 74.13 และ 77.50 ตามลำดับ

คำสำคัญ : ฤดูกาล คุณภาพน้ำ ปลากะพง บ่อเพาะเลี้ยง

Introduction

Seabass (*Lates calcarifer*) are known as Plakapong in Thailand. It is an aquatic animal that grows in both of fresh water, brackish and coastal water (Pethiyagoda and Gill, 2012). Seabass are the most popular fish in Thai cuisine and are economically important in Thailand. Normally seabass live near coastal areas where there are suitable conditions for living such as Chachoengsao, Trat and Samut Prakarn provinces. The optimum water quality in aquaculture ponds is; water temperature; 26-32 °C, pH: 7.5-8.5, dissolved oxygen: 4-8 mg/L (Jerry, 2014). Water quality in fish ponds were significantly impacted by pond management practices, water from associates canals and seasonal variations such as the overfeeding causes DO falls to less than 4 mg/L then the mass mortality of fishes (Das et al., 2005, Thapa and Pal, 2012). The increasing deterioration of coastal water quality resulting from the discharge of domestic, agricultural and industrial wastes into coastal waters has affected aquaculture production (Chua et al, 1989). The objectives of this study are to compare the water quality between the two types of sea bass ponds (extensive and intensive ponds) and to compare the water quality of canals that be changed according to season effect and pond activities.

Materials and Methods

Study area and seabass culture

The extensive and intensive seabass culture ponds in the coastal area were selected for this study. The extensive pond is located in Bang Khun Thian district, Bangkok and Huakrabue canal is used for water exchange. The intensive pond takes the water from Suan canal where it is in Phra Samut Chedi district, Samut Prakarn Province. The extensive pond uses low stocking density in the area of 5.10 ha and no supplemental feeding to stimulate the growth. The intensive pond uses higher stock density than the extensive pond in the area of 0.45 ha and uses a water pump for water exchange, aerates for increased oxygen and feeds the fish regularly in the morning and evening during culture as summarized in Table 1.

Table 1. Aquaculture ponds systems

	Extensive Pond	Intensive Pond
Layout	- Very big pond - No aerators - seldom sediment dredging and pond drying	- Small pond - Used water pumps and aerators to control water quality and quantity
Fertilizer	- Used to enhance natural productivity	- Not used
Chemicals	- Used to control weed around the earth dyke	- Used for pond preparation and during aquaculture
Fish feed	- None	- During culture every day (2 times/day)
Cropping Frequency (crops/year)	- 1	- 2
Quality of product	- Variable sizes (30-60 cm.)	- Uniform sizes (25-30 cm.)
Annual production (tonnes/ha-crop)	- 0.33	- 20.45
% yield	- 74.13	- 77.50

Water sampling and analysis

Water samples were grabbed once a month at 9:30 - 10:00 a.m. in seabass ponds and associated canals during the wet season (June 2017 – September 2017) and dry season (December 2017 – March 2018). Water samples were analyzed for biological, physical and chemical parameters as shown in Table 2. In this study, pH, DO, EC and temperature were measured at the study sites using by multi-parameter probe (EXO2 Multiparameter Sonde, YSI). The aseptic technique was used for TCB and FCB analysis and water samples were kept in an ice box for analysis within 24 hours. To analyze BOD, SS and NO_3^- , the 1,000 ml of sample water was kept in polyethylene bottles. The 100 ml of water sample was acidified with H_2SO_4 to a pH below 2.0 for analysis of COD and TP. All sample bottles were kept in an ice box at approximately 4 °C. Then, water samples were analyzed following the Standard Methods for Examination of Water and Wastewater (APHA, AWWA, WPCF, 2012). Canal water quality was compared to the surface water quality criteria class 2 for aquaculture production as recommended by the Pollution Control Department. In addition, pond water quality was compare to water quality for seabass culture as recommended by Jerry (2014).

Table 2. The water quality parameter and analysis methods.

Parameter	Analysis
pH	pH meter
Dissolved oxygen (DO)	DO meter
Electrical conductivity (EC)	Conductivity meter
Temperature	DO meter
Suspended Solids (SS)	Gravimetric method
Biochemical oxygen demand (BOD)	Azide modification
Chemical oxygen demand (COD)	Closed reflux
Phosphorus (TP)	Ascorbic acid Method
Nitrate (NO ₃ ⁻)	Sodium Salicylate Procedure
Total Coliform Bacteria (TCB)	Membrane Filtration
Fecal Coliform Bacteria (FCB)	Membrane Filtration

Statistical analysis

T-test was applied to compare means of the water parameters of two sites. Significant differences were indicated at p-value < 0.05. The similar impact of seasonal on water quality was shown as the same letter.

Results

Seasonal and farming activities

Seabass fry were raised in the extensive pond (size 5-6 cm) at the numbers of 1,500 fry. The intensive pond used seabass fry (size 4 cm) at the numbers of 15,000 fry. Details in seabass culture and environmental data of each month are shown in Table 3.

Table 3. Summarization of the culture activities in extensive and intensive sea bass ponds.

Month,year	Extensive	Intensive	Total rainfall (mm)*	Average Temp. (°C) *	Sea level (m) **		
					High	Low	
June, 2017	Pond preparation by water intake from canal to pond and use herbicide on earth dyke	Pond preparation by water intake from canal to pond	150.8±14.5	29.9±0.6	3.7±0.4	2.2±0.6	
July, 2017	No water exchange and chemical use	Pond conditioning by chemical (Lime, sodium chloride and chlorine)	293.9±17.2	28.9±0.6	3.7±0.4	2.2±0.6	
August, 2017	Release sea bass fry and herbicide on earth dyke	- Release sea bass fry - the fish were fed twice daily (7:00-8:00a.m. and 4:00-5:00 p.m.)	252.4±13.6	29.4±0.9	3.8±0.3	2.0±0.5	
September, 2017	Sea bass culture, no water exchange, no feed and chemical until the fishes were harvested in August 2018.	- water exchange every 2 weeks and add chemical to control water quality.	114.8±8.9	29.6±0.8	3.8±0.3	2.0±0.5	
October, 2017			358.6±28.5	28.7±0.9	4.0±0.2	2.2±0.4	
November, 2017			54.8±6.6	27.9±1.1	4.0±0.3	2.4±0.6	
December, 2017			15.7±2.5	26.3±2.5	4.0±0.2	2.5±0.7	
January, 2018			95.5±20.4	27.1±1.6	3.9±0.3	2.2±0.6	
February, 2018			Fish were harvested	84.3±12.2	27.2±1.2	4.0±0.2	2.3±0.5
March, 2018			Pond preparation	16.0±3.2	29.0±1.0	4.0±0.2	2.2±0.4

Note: water sampling in wet (June 2017 – September 2017) and dry season (December 2017– March 2018).

* Thai Meteorological Department (2018).

** Marine Department (2018).

During water sampling in the wet season, it was found that total rainfall and average temperatures were in the range of 114 – 293 mm and 28 – 29 °C., respectively. Temperature and rainfall amount in wet season were higher than in the dry season, however sea level in the wet season was lower than in the dry season. Activities in the extensive pond during wet season were pond preparation by taking water from canal to pond and releasing seabass fry. In June and August 2017, farmer used herbicide for weed controlling around the earth dyke but no chemicals used in the pond. After release seabass fry, no feed until the fishes were harvested in August 2018.

The activities of the intensive ponds were different from the extensive ponds such as water quality control using chemicals, aeration by aerator and water changing using a water pump, fish were fed twice daily during culture and were harvested in February 2018.

Effect of season on general parameters

Water analysis of pH, temperature, EC, DO and suspended solid in extensive, intensive ponds and associated canals are shown in Table 4. Water characteristics were compare to Thailand surface water quality criteria class 2 (for aquaculture) by Pollution Control Department.

Results revealed that water temperature were correlated to air temperature. Other factors such as, wind speed, water depth, light intensity and water turbidity also have influences on water temperature (Boyd and Tucker, 1998; Saudee et al., 2016). Average water temperatures in dry season were lower than in wet season. In addition, there were high variation of temperature in dry season. Water temperature plays an important role in the health of aquatic animals because it strongly influences the occurrence and outcome of infectious diseases (Boyd and Tucker, 1998).

The pH of most surface waters varies diurnally dues to photosynthesis and respiration which changes in dissolved carbon dioxide concentrations (Boyd and Tucker, 1998). While, pH of water in aquaculture ponds is regulated by the same processes as in natural waters but biological activity usually has a greater effect on pH in aquaculture ponds than in most natural waters (Boyd and Tucker, 1998). The pH values in pond were higher than in canals. It can be explained that aquatic plants and phytoplankton remove free and combined carbon dioxide from water for photosynthesis during the daytime. The pH values in intensive pond were higher than extensive pond because high algae and also pond water was aerated, thus CO₂ was emitted to air and then raise the pH of the water. However, the pH values of ponds and canals in the study area were in the range of optimum levels for seabass culture

(pH 7.50–8.50) as recommended by Jerry (2014) and surface water quality criteria (pH 5.00 – 9.00) as recommended by Pollution Control Department (2019).

DO variation had affected by climate variables such as wind flow, temperature and hydrology by precipitation, water flow and river depth (Saudee et al., 2016), salinity and organic waste pollution (Boyd and Tucker, 1998). The major difference between aquaculture ponds and surface water is the much higher biomass of bacteria, plants and animals than aquaculture ponds in surface water. DO concentrations in the water bodies affected survival of fishes and thus altering water quality and ecological balance (Paerl et al., 1998). DO concentration in wet season were higher than dry season for ponds and Suan canal. However, Huakrabue canal had low DO in wet season because it was affected by domestic wastewater from upper stream. In dry season, canals had low DO concentration because the effect of sea level rise. The canal water cannot flow to the gulf of Thailand, then organic wastes were accumulated. In addition, canal water level was higher than embankment and it was overflow into the ponds. DO in canals and ponds were less than surface water quality criteria (not less than 6.00 mg/L) and seabass culturing (4.00-8.00 mg/L). Too low DO concentration can affect the survival of fish and may cause mortality of seabass.

The average value of suspended solids (SS) in ponds tends to increase during dry season. Suspended solids (SS) in water could reduce the sunlight passing through water in canal and pond. Nyanti et al. (2018) reported SS and warm water influenced the fish survival rate. Moreover, SS can damage the fish gills, consequently to respiratory failure and mortality. SS concentration in wet season was higher than dry season because of water runoff from land carried soil into canals resulted in high SS. In wet season SS concentration in ponds higher than canal possibly because of algae bloom.

EC of the water depends on the water temperature and concentration of dissolved minerals in water (Weiner, 2008). It can be an indicator of the total dissolved solids, but it does not provide any information about the ion composition in the water. However, these study areas are in the coastal area which high concentration of chloride. EC in canals during wet season was lower than in the dry season because the dilution from rainwater. Extensive pond had EC higher than associated canal because it had no water exchange. Hence, minerals were concentrated by water evaporation. However, EC of intensive pond was closed to associated canal because of water exchange.

Table 4. General water parameters

Season	Type	pH	Temperature (°C)	EC (mS/cm)	DO (mg/L)	SS (mg/L)
Extensive						
Wet season	Huakrabue canal	7.23±0.26 ^a	31.78±1.15 ^{a,b}	2.2±1.45 ^{a,b,c}	2.51±0.66 ^{a,c,d}	43.25±20.77 ^a
	Pond	7.74± 0.38 ^{a,b,c}	32.13±1.90 ^{a,b}	12.50±3.64 ^a	3.80± 2.03 ^{a,b,c,d}	39.00±11.81 ^{a,b}
Dry season	Huakrabue canal	7.65±0.32 ^{a,b,c}	28.30±3.43 ^b	10.8±10.83 ^{a,b,c}	2.82±2.16 ^{a,b,c,d}	41.88±10.15 ^a
	Pond	8.03±0.35 ^{b,c}	28.64±4.42 ^{a,b}	11.10±5.671 ^{a,b,c}	2.24±0.75 ^{a,c}	50.75±20.24 ^{a,b}
Intensive						
Wet season	Suan canal	7.46±0.08 ^{a,b,c}	32.45±1.70 ^{a,b}	5.68±5.3 ^b	4.57±0.82 ^{b,d}	35.03±18.34 ^{a,b}
	Pond	7.71±0.68 ^{a,b,c}	33.73±2.13 ^a	6.21±0.76 ^c	3.80± 2.03 ^{a,b,d}	22.25±6.09 ^b
Dry season	Suan canal	7.67±0.33 ^{a,b,c}	28.68±4.00 ^{a,b}	10.8±10.83 ^{a,b,c}	3.9±1.42 ^{a,b,c,d}	34.5±9.33 ^{a,b}
	Pond	8.11±0.54 ^c	29.25±3.65 ^{a,b}	9.09±6.37 ^{a,b,c}	3.07±1.57 ^{a,b,c,d}	63.50±37.73 ^{a,b}
Surface water quality criteria*		5.00–9.00	-	-	6.00	-
Optimum levels for seabass culture**		7.50–8.50	26.00-32.00°C	-	4.00–8.00	-

Remark: The ^{a,b,c} was significant difference at the 95% confidence level (P-value < 0.05)

* Pollution Control Department (2019).

** Jerry (2014).

Effect of season on chemical parameters

BOD refers to the amount of oxygen used by microorganisms to decompose organic waste (Weiner, 2008). When BOD levels are high, DO levels decrease because the available oxygen that is available in the water is being consumed by the bacteria. Less available DO in the water cause fish and other aquatic organisms may not survive. COD refers to the amount of oxygen consumed when all the organic matter in a given volume of water is chemically oxidized to CO_2 , and H_2O (Weiner, 2008). Phosphorus is a common constituent of agricultural fertilizers, manure, herbicides and organic wastes in sewage and industrial effluent. It was an essential element for plant growth. High phosphorus can stimulate algal growth and speed up eutrophication process (a reduction in dissolved oxygen in water bodies caused by an increase of mineral and organic nutrients).

In wet season, high BOD, COD and TP concentrations were found in canals because water runoff brought soil and organic substances from land to canals (Fig. 1a, 1b, 1d) The BOD in canals was over surface water quality criteria (1.5 mg/L). It was found that BOD in the intensive pond was higher than in the extensive pond because of excess feed and fish waste. Figure 1a shows BOD:COD values in the extensive and intensive canals (0.23 and 0.13, respectively) which indicates low biodegradable organic substances in the water. The BOD:COD ratio of extensive pond in dry season was higher than in wet season because the herbicide was used in wet season.

Nitrate concentration in canals was relatively low and meet the surface water quality criteria (5 mg/L). Major source of river water pollution comes from domestic sewage, animal waste, agricultural waste, soil erosion and runoff from the settlement (Christensen et al., 2012). Nitrate in ponds was higher than in canals because the decomposition of ammonia from fish waste to nitrate. However, nitrate was found in low concentration which meet the surface water quality criteria (Fig. 1c).

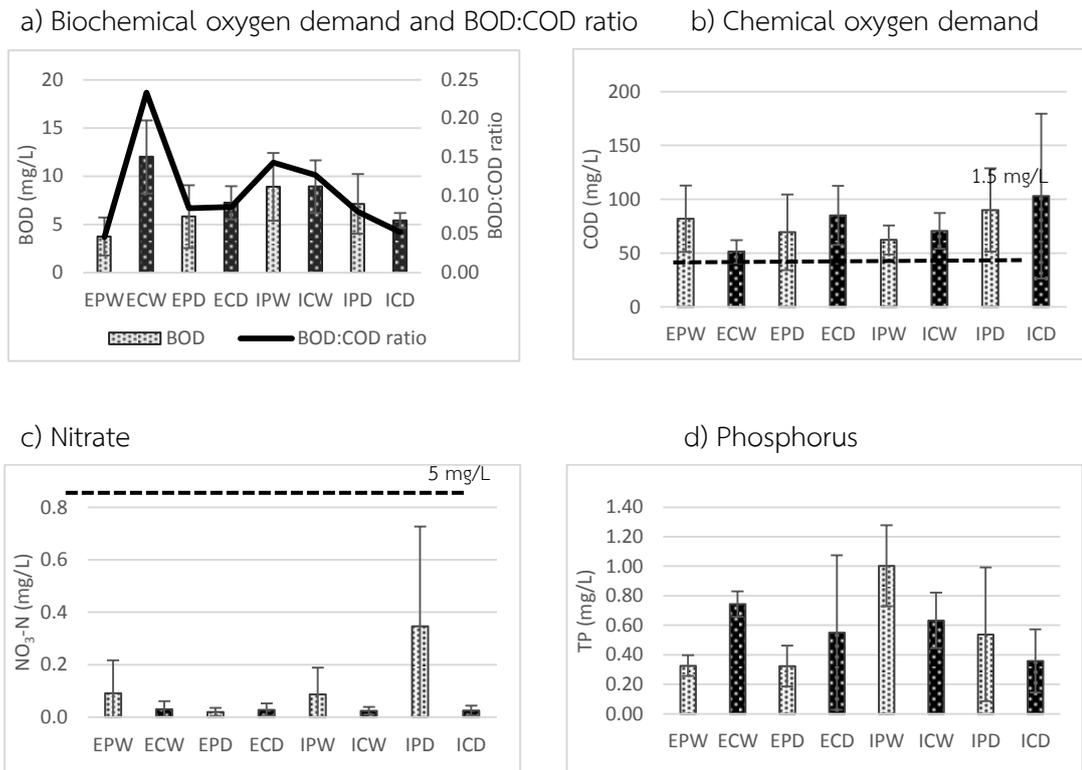


Figure 1: Effect of season on chemical parameters

Surface water quality

Note: EPW: Extensive pond in wet season, IPW: Intensive pond in wet season, ECW: Extensive canal in wet season, ICW: Intensive canal in wet season, EPD: Extensive pond in dry season, IPD: Intensive pond in dry season, ECD: Extensive canal in dry season, ICD: Intensive canal in dry season

Effect of season on biological parameters

Coliform bacteria come from the same sources as pathogenic organisms for humans. Thus, coliforms were used as a biological indicator. Total coliforms are widespread found in plant, soil and animal intestine habitat. As for FCB, it is specifically in the gut and feces of warm-blooded animals. Fecal coliforms bacteria are considered a more accurate indication of animal or human waste than the total coliforms (Weiner, 2008).

TCB and FCB values were high in both seasons and they were higher in canals than in ponds (Fig. 2). The TCB and FCB concentrations should no more than 5,000 MPN/100 mL and 1,000 MPN/100 mL, respectively. (Pollution Control Department, 2019). The results show that TCB and FCB in wet season were higher than dry season for both intensive and extensive canals. This finding indicates the canal water was polluted from household. The results were correspondence to BOD and COD concentrations which were high in wet season. TCB of

intensive and extensive ponds in wet season were 7.80 and 1.73 times of intensive and extensive pond in dry season, respectively. FCB of intensive and extensive pond in wet season were 8.11 and 5.20 times of intensive and extensive pond in dry season, respectively. This indicates a higher risk of pathogenic being present to human such as dysentery, bacterial gastroenteritis and may other waterborne diseases. Fishes live in these polluted habitats can easily intake these bacteria. However, coliform bacteria does not affect fish but affect to human from fish consumption. (Mandal, et al. 2009, Doyle and Erickson, 2006).

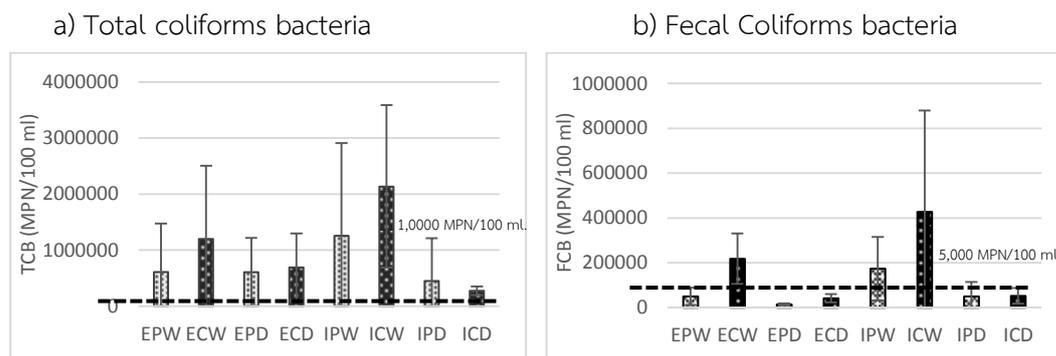


Figure 2: Effect of season on biological parameters

--- Surface water quality

Note: EPW: Extensive pond in wet season, IPW: Intensive pond in wet season, ECW: Extensive canal in wet season, ICW: Intensive canal in wet season, EPD: Extensive pond in dry season, IPD: Intensive pond in dry season, ECD: Extensive canal in dry season, ICD: Intensive canal in dry season

Table 5 illustrates the mean values of water quality for each parameter in wet and dry seasons of culture pond and associated canal. This study found associated canal of extensive pond was higher BOD values than culture pond. FCB and TCB values in wet season were higher than dry season. Although the statistical analysis shows only 2 sites significant difference. FCB value of extensive ponds and TCB value of associated canal of intensive pond only were a significant difference between season (P-value < 0.05). Attributable water runoff from the land into the surface water. This also affects TCB and FCB in ponds.

Table 5 The mean values of water quality for each parameter

Parameter	EPW	EPD	IPW	IPD	ECW	ECD	ICW	ICD
DO (mg/L)	3.80	2.24	5.19	3.07	2.51	2.82	4.57	3.91
TP (mg/L)	0.33*	0.33	1.00*	0.54	0.74	0.55	0.63	0.36
FCB (MPN/100 ml)	50,666*	14,875*	173,750	17,825	218,125	41,937	427,500	52,687
TCB (MPN/100 ml)	609,791	607,500	1,257,291	450,000	1,199,583	691,875	2,137,916	274,166
BOD (mg/L)	3.75*	5.82	8.91*	7.13	12.02	7.25	8.94*	5.41*
COD (mg/L)	82.00	69.40	62.28	90.00	51.43	95.00	70.56	103.00
EC (mS/cm)	12.50	11.10	6.21	9.09	2.20	10.80	5.68	10.92
SS (mg/L)	39.00	50.75	22.25	63.50	43.25	41.88	35.03	34.50

Remark: * a significant difference at the 95% confidence level (p-value < 0.05)

Note: EPW: Extensive pond in wet season, EPD: Extensive pond in dry season, IPW: Intensive pond in wet season, IPD: Intensive pond in dry season, ECW: Extensive canal in wet season, ECD: Extensive canal in dry season, ICW: Intensive canal in wet season, ICD: Intensive canal in dry season

Conclusion

The season affects to average temperature, total rainfall and sea level which influenced the water quality in pond and canal. In addition, aquaculture activities also affect water quality such as water exchange and chemical uses. Although season had high variation of temperature, but it was in the optimum range for seabass culture. To cope with the climate change in the future, it should install solar energy aerator to increase dissolved oxygen in the pond and build embankment for protecting canal water into the pond from high sea level rise in dry season. In addition, farmers should install water filtration or water treatment before import canal water into the aquaculture pond.

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