

Tidal Variation of Water Quality from Mouth of River to Offshore Area in Buloh River, Selangor Cockle Culture Ground, Malaysia

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Abstract

Though blood cockle is an important and cheap protein source for the Malaysian population, the production in Selangor decreased drastically from 2010 to 2013. However, production was basically constant in Perak and Penang, which are north of Selangor, during the same period. This suggests something happened specifically in the Selangor cockle culture ground. The present study investigated the influence of tidal variation over a 25-hour period on water quality from mouth of river to offshore area in Buloh River, Selangor cockle culture ground, Malaysia. Water below pH 5.7–6.5 is generally thought to be harmful to aquatic animals. The water in the tidal flat had acidic pH when ammonium was high, whereas pH was alkaline when ammonium was low; therefore, toxicity due to ammonia might be low in that area. However, pH was 4.3–5.3 at ebb tides in cockle culture ground, which suggests that pH rather than ammonia may influence cockle growth and survival rate. Accordingly, the upper stream region of this river should be surveyed to determine the origin of ammonia and pH in this water.

Keywords: blood cockle, ammonium, pH, Buloh River, Selangor, Malaysia

Introduction

Extensive aquaculture of blood cockle, *Anadara granosa*, has been present in Perak, Malaysia since 1948; it is an important and cheap protein source for the Malaysian population (Pathansali and Song 1958; Broom 1985). Natural spats of blood cockle are collected from mud shores for extensive aquaculture, scattered near intertidal flats, and cultured by the non-feeding and sowing method. As the cockles take in surrounding organisms and detritus, this culture method functions to improve water quality. Thus, the culture of bivalves including blood cockle, recycles nutrients generated as waste from humans (Nakamura *et al.* 1998; Mirsadeghi *et al.* 2013) Therefore, cockle culture is thought to function as an environmentally friendly and ecologically conservative form of aquaculture.

The coastal waters of Selangor, Malaysia are some of the major culture grounds of blood cockle. However, cockle production in Selangor has decreased drastically since 2010 (DOF Malaysia 2010–2013). Ramli *et al*. (2013) investigated ammonia concentrations from January–June, 2013 in Buloh River, Selangor, Malaysia, which flows into cockle culture ground; they found very high ammonia concentrations since April 2013. Although blood cockles are typical bivalves that have hemoglobin inside their bodies and adjust to low salinity, hypoxia, and air exposure (Davenport and Wong 1986), they conclude that high ammonia concentration is at least partially responsible for the decline in cockle production.

Water quality in coastal regions changes greatly owing to the tides. In general, there are flood tides and ebb tides twice daily, and their timing is delayed approximately 50 minutes each day. The present study investigated the influence of tidal variation of water quality in cockle culture grounds in Buloh River, Selangor, Malaysia. To this end, 9 samplings were performed at rising, flood, falling, and ebb tides over a 25-hour period.

Materials and Methods

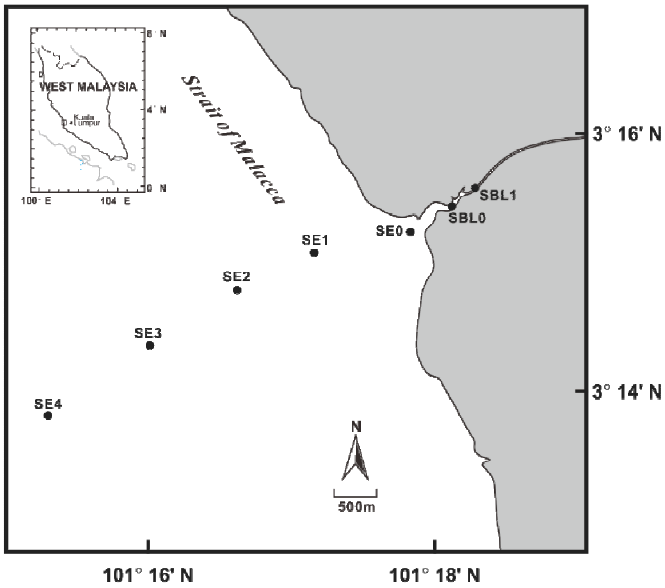

Fig. 1. Sampling stations in Buloh River and the offshore area

Water quality observations were performed around Buloh River, Selangor, Malaysia at neap tide over approximately 25 hours from 4:00 on October 31 until 5:30 on November 1, 2014. Five stations designated SE0–SE4 were set from the river mouth to the offshore area, whereas one station, SBL0, was set within the river (Fig. 1). Nine samplings were conducted at the ebb, rising, flood and falling tides over the 25-hour period. The investigation was performed at SBL1, upstream in the river, at 16:30 at the lower low tide on October 31. There are blood cockle culture ground between SE0–SE2, mainly vicinity of SE1. The following water quality parameters were evaluated: water temperature, salinity, pH, nutrients (ammonium, nitrate, nitrite, phosphate, and silicate), total nitrogen, total phosphorus, chlorophyll *a*, and suspended solids. Water temperature and salinity were measured by a water quality meter (AAQ-RINKO, JEF Advantech Co. Ltd., Japan), and pH was measured by a portable pH meter (HM-21P, DKK-TOA Cor., Japan). Surface water was collected directly in 500mL plastic bottles. Sampled water was filtered through a 0.6-μM Whatman Nuclepore membrane filter and a Whatman GF/F filter to measure suspended solids and chlorophyll *a*, respectively. The filtrate was used to measure nutrients.

Ammonium was analyzed as described previously by Sasaki and Sawada (1980) according to the modified indophenol method (Solórzano 1969). Nitrate, nitrite, phosphate, and silicate were analyzed by the standard methods as described previously by Persons *et al*. (1984) using a spectrophotometer (V-630, JASCO, Japan). Chlorophyll *a* was extracted with *N,N*-dimethylformamide (Suzuki and Ishimaru 1990) and determined using a fluorometer (Trilogy, Turner Designs, USA) as described previously by Strickland and Parsons (1972). Meanwhile, for total nitrogen and phosphorus analysis, potassium persulfate was added to sampled water; nitrate and phosphate were formed, respectively, using an autoclave under alkaline and acid conditions (D'Elia et al. 1977; Menzel and Corwin 1965; Solórzano and Sharp 1980). Finally nitrate and phosphate were analyzed to determine total nitrogen and phosphorus, respectively.

Results

Temperature, salinity, and pH

Water temperature, salinity, and pH at four tidal situations are shown in Figure 2. Water temperature was high at 13:00, 16:00, and 20:00, and was influenced by solar radiation besides the tidal variation in the river (SBL0) and tidal flat (SE1 and SE2). At offshore station SE4, the variations in temperature, salinity, and pH were small. In the river (SBL0), salinity was 0.2–0.5 psu at ebb tides and 1.6–2.7 psu at flood tides, respectively. However, at SE1 and SE2 (i.e., the culture ground), the variations in the above mentioned parameters were large regardless of ebb or flood tide. The variations of salinity and temperature were small at SE4. pH in water was 3.97–4.26 at ebb tide, and 4.64 and 4.36 at flood tide in the river (SBL0). Hence, water in the river was always acidic. pH at SE1 almost exceeded 7 at flood and rising tides, and it exceeded 7 at SE3 even at ebb tides. In general, pH converged at approximately 8 at offshore station SE4.

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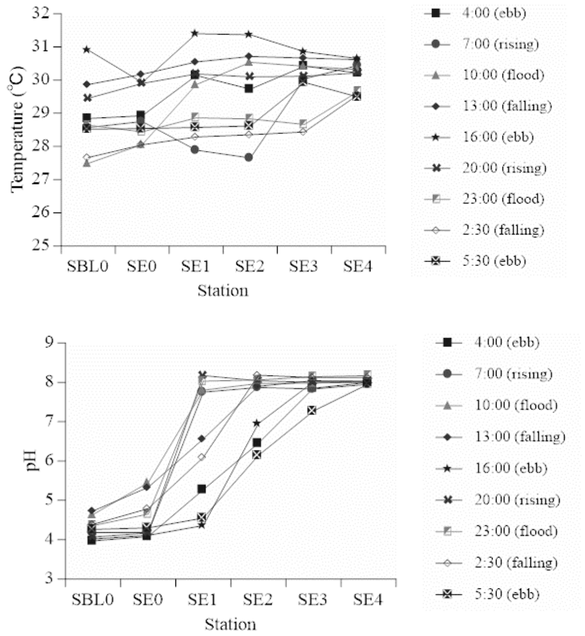


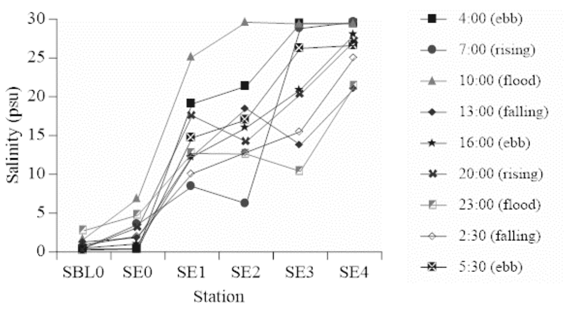
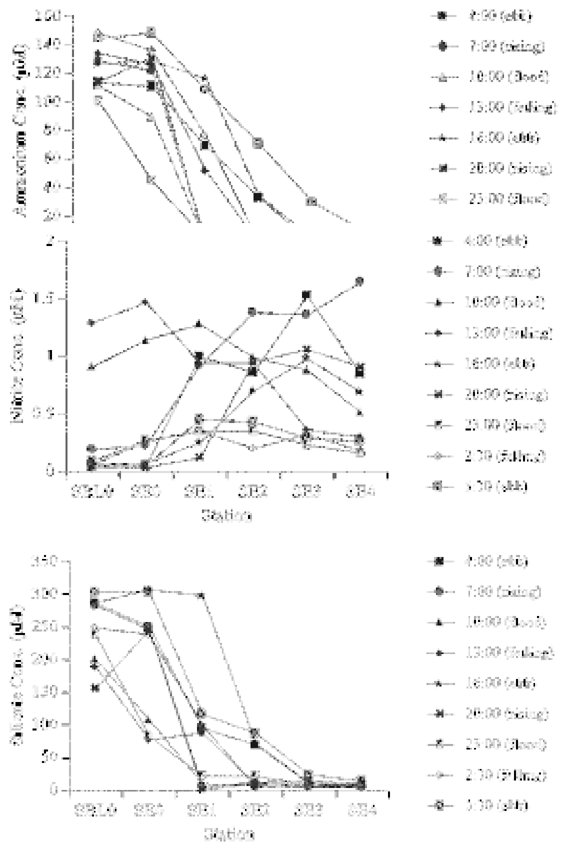


Fig. 2. Tidal variations of temperature, salinity, and pH at sampling stations



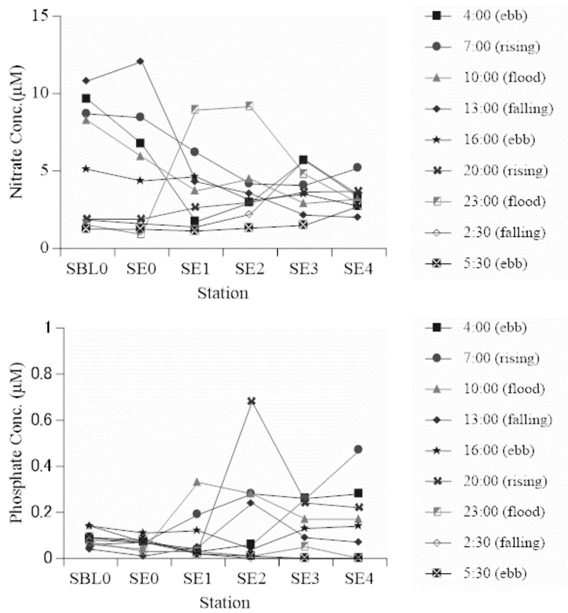


Fig. 3. Tidal variations of ammonium, nitrate, nitrite, phosphate, and silicate concentrations at sampling stations

Nutrients

Ammonium concentration was high in the river, SBL0 at all tidal stations, decreasing gradually from the river to the offshore area (Fig. 3). At SE1, the cockle culture ground, it was high at ebb tides (70–110 μM) but low at flood tides (2.4 and 4 μM); thus, the change of ammonium concentration owing to tidal variation was large. Meanwhile, the nitrate concentration at SBL0 in the river differed according to time rather than tidal variation: it was comparatively high from 4:00 to 13:00 and low from 20:00 to 5:30 the next day. Although nitrate concentration was higher than ammonium concentration at SE1 and SE2 at flood tides, it was <10 μM.

Meanwhile, although the nitrite concentration was high in estuaries and offshore areas, it was <2 μM in all samplings. The phosphate load from land regions was low, and its concentration in the river ranged from 0.04–0.14 μM; it was occasionally high at SE1–SE4. Silicate was 150–300 μM in the estuary, decreasing gradually from the river to the offshore area.

Total nitrogen and phosphorus

Total nitrogen changed with respect to ammonium concentration, which accounts for 60–80% of nitrogen in the river; the concentration decreased gradually from the river to the offshore area (Fig. 4). Although total phosphorus was very high at 5 points, it ranged from 0.3–1.2 μM except for these stations; high total phosphorus was observed in the river, SBL0, and cockle culture ground, SE1 and SE2, and resuspended substances might be included from bottom sediment.

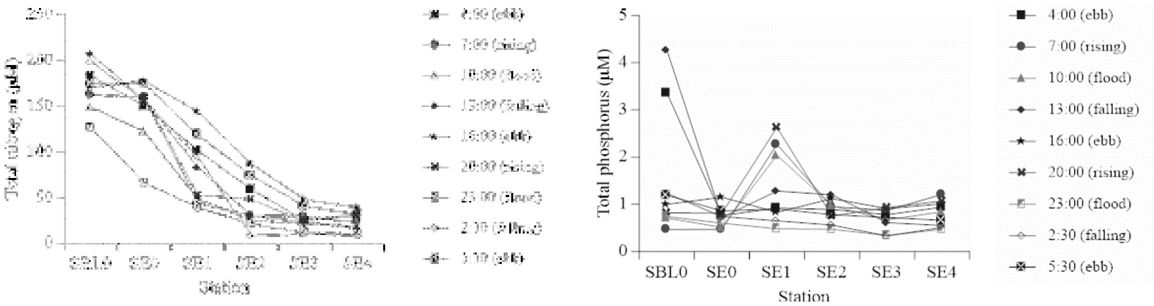


Fig. 4. Tidal variations of total nitrogen and total phosphorus at sampling stations

Chlorophyll a and suspended solids

Chlorophyll *a* concentration, an index of phytoplankton, spiked in cockle culture ground (i.e. SE1 and SE2) (Fig. 5). Chlorophyll *a* concentration varied widely at SE1, ranging from 1.6–30 μg/L. As there was a spike in daytime, this might indicate the influence of photosynthesis rather than tidal variation. Suspended solids were also high at the 5 stations with high total phosphorus; therefore, resuspension might influence its concentration. At other stations, suspended solids ranged from 4–37 mg/L.

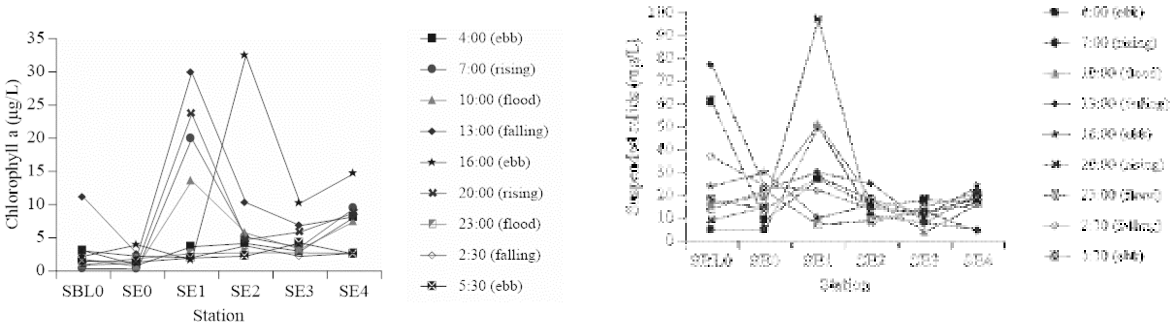


Fig. 5. Tidal variations of chlorophyll *a* and suspended solids at sampling stations

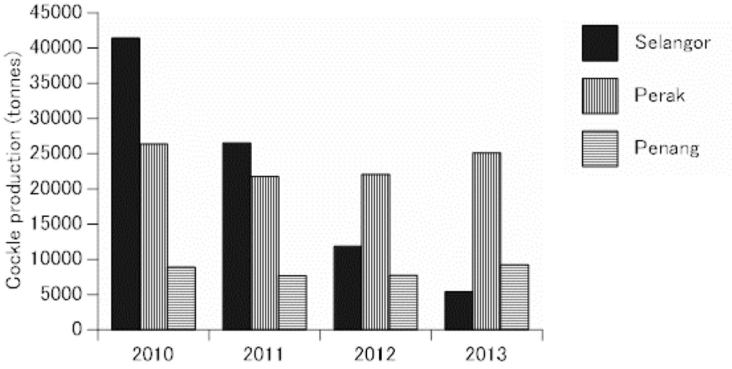
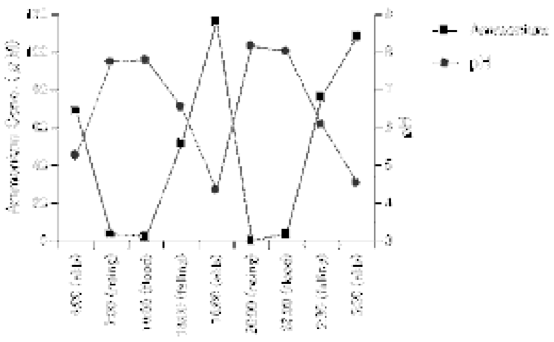


Fig. 6. Blood cockle production in Selangor, Perak, and Penang States from 2010–2013



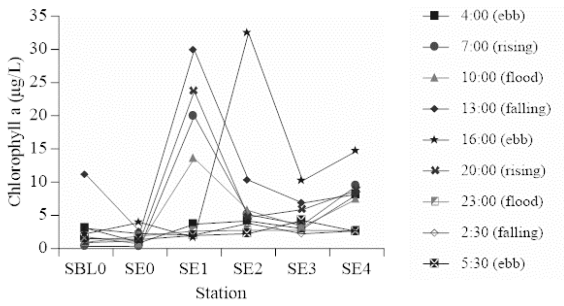


Fig. 7. Tidal variations of ammonium concentration and pH at SE1, a cockle culture ground

Discussion

Blood cockle production in Selangor decreased greatly from 2010 to 2013 (Fig. 6; DOF Malaysia 2010–2013). However, production was basically constant in Perak and Penang, which are north of Selangor, during the same period. This suggests something happened specifically in the Selangor cockle culture grounds. Ramli et al. (2013) measured ammonia concentrations in Buloh River, and suggest high ammonia concentration is one of the factors responsible for the decline of blood cockle production. Concordantly, the ammonium concentration was very high in the present study. However, we used the modified indophenol blue method, which was based on the method of Sasaki and Sawada (1980), to measure the total concentrations of ammonium and ammonia. When pH and temperature increase, the ratio of ammonia to ammonium also increases, creating toxicity for aquatic life (Kikuchi and Wakabayashi, 1997; U.S. Environmental Protection Agency, 2013).

Ramli et al. (2014) investigated the tolerance of blood cockle to ammonia in detail. In the present study, as the river water was acidic (pH 3.97–4.26), it was thought that ammonium was present in the river. The tidal variation of ammonium concentration and pH at SE1 (the center of cockle culture grounds) is shown in Figure 7. The pH in the culture grounds was acidic when ammonium was high, whereas the pH was alkaline when ammonium was low. Therefore, ammonia-induced toxicity might be low under such conditions. However, pH at ebb tides at SE1 was acidic at 4.3–5.3. Although it is difficult to specify how water acidity affects aquatic lives, water below pH 5.7–6.5 is thought to be harmful (Fukuhara and Furuki 2010). Therefore pH rather than ammonia is suggested to influence cockle growth and survival rate. Although water treatment plants might be a source of ammonia (Ramli *et al*. 2014), the origin of the acidic water remains unknown and should therefore be evaluated.

Few mangrove region has developed around Selangor. Because there is no feed supply from a mangrove region, phytoplankton and benthic algae are thought to play important roles as feed for blood cockle. The phosphate concentration was very low in the present study, considering the Redfield ratio (Redfield et al. 1963), i.e., the atomic ratio of phytoplankton, N:P = 16:1. Therefore, phosphate might be a limiting factor in phytoplankton growth. Phosphate characteristically adsorbs particles, making it comparatively easily to be removed by water treatment plants. If water treatment plants influence on nutrient load from upstream of the Buloh River estuary, this would explain the low phosphate concentration. However, there was some spike in phosphate concentration owing to resuspension from bottom sediment. Phosphorus was supplied to tidal flats with a large amount of sediment due to rainfall and might suspended to the water column. Thus, it is necessary to consider nutrient supply from bottom sediment to tidal flats.

There are some shrimp culture ponds and a fishing village between SBL0 and SBL1 (uppermost part of the river). In order to investigate effects of wastewater from culture ponds and the fishing village, salinity, pH, and ammonium and phosphate concentrations collected at ebb tide (16:30) were compared between SBL0 and SBL1 (Table 1). However, there were no differences between stations, although salinity increased slightly owing to the influence of seawater. Therefore, the results suggest the load origin of nutrients and low pH is upstream of the shrimp culture ponds and fishing village. In order to determine their origins, it is necessary to survey the upper stream region including water treatment plants.

Table 1. Comparison of salinity, pH, and ammonium and phosphate between SBL0 and SBL1.

Station	S (psu)	pH	Ammonium (µM)	Phosphate (µM)
SBL1 (upstream)	0.283	4.03	138.42	0.10
SBL0 (downstream)	0.502	4.02	126.32	0.14

Conclusion

Blood cockle production in Selangor decreased greatly from 2010 to 2013. The water in the tidal flat of Buloh River had acidic pH when ammonium was high, whereas pH was alkaline when ammonium was low; therefore, toxicity due to ammonia might be low in that area. However, pH was 4.3–5.3 at ebb tides in cockle culture ground, which suggests that pH rather than ammonia may influence cockle growth and survival rate. So it is necessary to survey the upper stream region of the river near cockle culture ground.

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