ผลกระทบของการเลี้ยงหอยแมลงภู่แบบแพเชือกต่อปริมาณสารอินทรีย์ทั้งหมด และฟลักซ์ของอนินทรีย์ไนโตรเจนละลายน้ำในอ่าวศรีราชา จังหวัดชลบุรี

Effect of Green Mussel Raft Culture to Total Organic Matter (TOM) and Flux of Dissolved Inorganic Nitrogen (DIN) in Sriracha Bay, Chon Buri Province

ประนิตดา เพ็งงิ้ว[1*], สมถวิล จริตควร[2] และสุริยัน ธัญกิจจานุกิจ[3]
Pranitda Peng-ngeiw[1*], Somtawin Jaritkhuan[2] and Suriyan Tunkijjanukij[3]
[1]*ภาควิชาวิทยาศาสตร์ทางทะเล คณะประมง มหาวิทยาลัยเกษตรศาสตร์*
[2]*ภาควิชาวาริชศาสตร์ คณะวิทยาศาสตร์ มหาวิทยาลัยบูรพา*
[3]*ภาควิชาเพาะเลี้ยงสัตว์น้ำ คณะประมง มหาวิทยาลัยเกษตรศาสตร์*
[1]*Department of Marine Science, Faculty of Fisheries, Kasetsart University*
[2]*Department of Aquatic Science, Faculty of Science, Burapha University*
[3]*Department of Aquaculture, Faculty of Fisheries, Kasetsart University*

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บทคัดย่อ

ทำการศึกษาสารอินทรีย์ทั้งหมดในดินตะกอน และฟลักซ์ของอนินทรีย์ไนโตรเจนละลายน้ำระหว่างน้ำและดินตะกอนในอ่าวศรีราชา จังหวัดชลบุรี ในเดือนสิงหาคม 2557 ธันวาคม 2557 และเมษายน 2558 โดยเก็บตัวอย่างน้ำและดินตะกอนจาก 3 สถานี 1) พื้นที่ที่ไม่มีการเลี้ยงหอยแมลงภู่แบบแพเชือก 2) พื้นที่ที่มีการเลี้ยงหอยแมลงภู่แบบแพเชือก 1-2 ปี และ 3) พื้นที่ที่มีการเลี้ยงหอยแมลงภู่มากกว่า 10 ปี พบว่าสารอินทรีย์ทั้งหมดมีค่าสูงสุดในพื้นที่ที่มีการเลี้ยงหอยแมลงภู่แบบแพเชือกมากกว่า 10 ปี (5.71±2.44 %) การเลี้ยงหอยแมลงภู่แบบแพเชือกที่ยาวนานเป็นสาเหตุสำคัญที่ส่งผลกระทบต่อการเปลี่ยนแปลงของลักษณะดินตะกอน และพบว่าฟลักซ์ของอนินทรีย์ไนโตรเจนละลายน้ำในพื้นที่ที่มีการเลี้ยงหอยแมลงภู่แบบแพเชือกที่ยาวนานมากกว่า 10 ปี มีค่าสูงกว่าในพื้นที่ที่มีการเลี้ยงหอยแมลงภู่แบบแพเชือก 1-2 ปี และในพื้นที่ที่ไม่มีการเลี้ยงหอยแมลงภู่แบบแพเชือก โดยฟลักซ์ของไนไตรท์ ไนเตรท และแอมโมเนียระหว่างน้ำและดินตะกอนในพื้นที่ที่มีการเลี้ยงหอยแมลงภู่แบบแพเชือกมากกว่า 10 ปี มีค่าเท่ากับ 7.97, 32.60 และ 39.92 $\mu mol \cdot m^{-2} \cdot h^{-1}$ ตามลำดับ ซึ่งฟลักซ์ของอนินทรีย์ไนโตรเจนละลายน้ำมีการเคลื่อนย้ายจากดินตะกอนสู่มวลน้ำ ชี้ให้เห็นว่าดินตะกอนในพื้นที่ที่มีการเลี้ยงหอยแมลงภู่เป็นแหล่งปลดปล่อยอนินทรีย์ไนโตรเจนละลายน้ำ

คำสำคัญ : การเลี้ยงหอยแมลงภู่แบบแพเชือก ; สารอินทรีย์ทั้งหมด ; ฟลักซ์ของอนินทรีย์ไนโตรเจนละลายน้ำ ; อ่าวศรีราชา

Abstract

Total organic matter (TOM) in sediment and flux of dissolved inorganic nitrogen (DIN) at the water-sediment interface in Sriracha Bay, Chon Buri Province, were investigated in August 2014, December 2014 and April 2015. Samples of water and sediment were taken from three stations: The first station was identified as an area where there was no green mussel raft culture activity, the second station was in an area where green mussel raft culture activities were just performed for 1-2 years. The third station was identified as an area where green mussel raft culture has been performed for over 10 years. Total organic matter (TOM) showed high values in the area which has been used for mussel culture for more than 10 years (5.71±2.44 %). The prolonged green mussel raft culture has a major effect on the sediment texture as well as on the components of the sediment. The values of DIN fluxes were higher in the area of the prolonged culture for over 10 years than the one of 1-2 years. The lowest DIN fluxes were found in the area with no mussel raft culture activity. Flux of nitrite, nitrate and ammonia in the area where green mussel raft culture has been performed for over 10 years were 7.97, 32.60 and 39.92 $\mu mol \cdot m^{-2} \cdot h^{-1}$, respectively. Flux of DIN at the water-sediment interface moving from the sediment to the water, indicated that the sediment in the green mussel culture area acted as a source of DIN.

Keywords : green mussel raft culture ; TOM ; DIN ; Sriracha Bay

***Corresponding author. E-mail** : jeab_croc@hotmail.com

Introduction

Sriracha Bay in Chon Buri Province, is a semi-open bay located in the eastern upper region of the Gulf of Thailand. Its coast is composed of mud flat, sandy beaches and rocky shoreline. Most areas of Sriracha Bay have been used for the green mussel (*Perna viridis* Linnaeus 1758) raft culture. The increased amount of intensive green mussel farming affected the sediment and water quality. Thus, the amounts of nitrite, nitrate and ammonia in pore water and sediment water content (WC), total organic matter (TOM) and acid volatile sulfide (AVS) were higher in the green mussel raft culture area than in the area where no green mussel raft culture activity is present. (Intarachart, 2008). The prolonged green mussel raft culture causes changes and has a major effect on the sediment texture. From sand to silt & clay and to clay, respectively (Intarachart & Khaodon, 2008). Under the mussel farm conditions, the high deposition of organic matter might cause an anoxic environment in surface sediments (Rampazzo *et al*., 2013). Sediment is a large reservoir of nutrients. Organic matter (OM) produced by phytoplankton from inorganic nutrients in the euphotic zone through photosynthesis sinks to the sediment. OM degradation is the main driver to release inorganic nutrients into the pore water. Then the inorganic nutrients can release into the overlying water and return to the euphotic zone (Zhang *et al*., 2013). Benthic nutrient fluxes depend on temperature, primary productivity, rate of organic sedimentation and decomposition, bottom-water O_2 concentrations, concentrations of nutrients in water and sediment, riverine freshwater and nutrient loads (Callender & Hammond, 1982; Herbert, 1999; Mazouni, 2004; Zhang *et al*., 2013; Mu *et al*., 2017). The primary producers in a coastal area are important in sediment-water column fluxes of organic and inorganic nitrogen compounds (Tyler & McGlathery, 2003). They can accumulate on the seafloor when phytoplankton die after blooming. Shallow bays are habitats for high productivity due to an increased level of nutrients from sediments (Engelsen *et al*., 2008).

Nitrite, nitrate and ammonia are the three main dissolved inorganic forms of nitrogen in a coastal system. The objective of this study is to compare the TOM in the sediment and flux of DIN at the water-sediment interface between a green mussel raft culture area and an area where there is no green mussel raft culture activity and to determine the effects of green mussel raft culture activity on TOM and DIN sediment flux. The results of this survey elucidate the sinks and sources of DIN in the sediment in the green mussel raft culture in Sriracha Bay.

Methods

Sampling sites

Samples of water and sediment were collected from three stations in Sriracha Bay, Chon Buri Province, Thailand (Table 1 and Fig 1) in August 2014 (wet season), December 2014 (winter season) and April 2015 (summer season). The first station was identified as the area without green mussel raft culture (R), the second one was the area where green mussel raft culture was just performed for 1-2 years (N) and the third station was identified as the area where green mussel raft cultured more than 10 years (O).

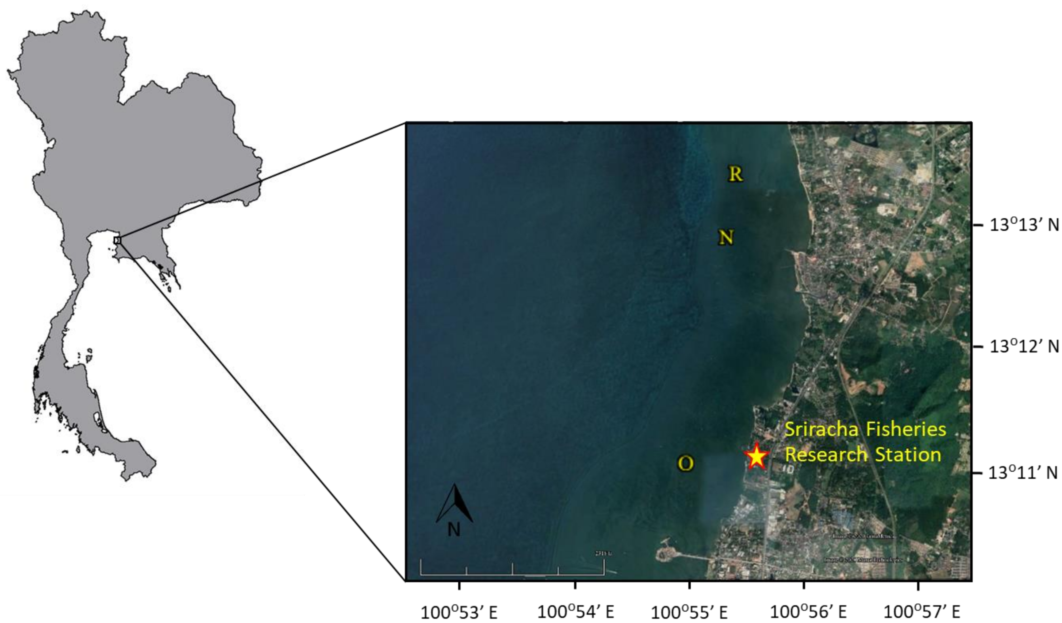

Figure 1 Lacation of sampling stations in the Sriracha Bay (R = no green mussel raft culture, N = cultured 1-2 years, O = cultured >10 years).

Table 1 Lacation of sampling stations in the Sriracha Bay among the three sampling station.

longitude	latitude	station
100°55'28.00" E	13°13'16.60" N	R
100°55'28.00" E	13°12'54.00" N	N
100°55'17.02" E	13°11'4.59" N	O

<u>*Sampling and analysis*</u>

Sediment samples were collected 5 point from each station. The sediment samples were collected by scuba divers using a hand push-corer (7 cm inside diameter of plastic cylinder). Three sediment cores were collected at each point for total organic matter, water content and grain size analyses. The top 5 cm of the sediment cores were sliced at 1 cm interval. Mix and homogenize sediment samples from each same interval of the three cores.

Total organic matter (TOM) was determined by Ignition loss method, the sediment samples were combusted at 600°C for 3 hours in a muffle furnace. TOM was calculated from the weight loss of the sediment after combustion (Verardo *et al*., 1990).

Water content was determined by weight difference after drying the samples in an oven at 60°C for at least 3 days (Meksumpun *et al*., 1999).

The grain size was determined by dry sieving method, the sediment samples were dried in an oven at 105°C for 24 hours. Then sift the dry sediment through a sieve to separate the sediment particle size by the sieve shaker. Use a sieve with the size of 0.063, 0.125, 0.25, 0.50, 1.00 and 2.00 millimeter, respectively. And weighed after shaking for 15 min (Briggs,1977; Pitty,1971).

Fluxes of dissolved inorganic nitrogen (DIN)

Fluxes of DIN through water-sediment interface are measured in the dark using sediment chamber incubation methods modified from Corredor & Morell (1989). The water using in the experiment was collected at 1 m above the sediment surface with a 5 L Van Dorn water sampler. The bottom water was filtered immediately through Whatman GF/F filters. Three sediment samples were collected by scuba divers using a PVC core tubes (3.5 inch inside diameter (surface of 62 cm^2) and 40 cm in height), the length of sampled sediment core was 15 cm. Upon arrival at the laboratory, overlying water was removed from the tubes and replaced with 1 L filtered bottom water. The sediment tubes kept in the dark for the duration of the experiment. Five samples of overlying water were taken with plastic syringes at 0, 6,12, 18 and 24 h. After the water was removed from each core tube, the same volume of external bottom water was injected to the tube. Concentrations of nitrite, nitrate and ammonia in water samples were determined by diazotization, cadmium reduction and modified indo-phenol blue method (Strickland & Parsons, 1977). DIN fluxes were calculated after the incubation time as the difference between initial and final concentration of DIN (Horak *et al.,* 2013; Mazouni *et al.,* 2012; Mu *et al.,* 2017). Fluxes of DIN were calculated according to,

$$J_{DM} = M(t) / (\Delta At)$$

where J_{DM} is the exchange flux of nutrient, A is the cross-section area of the core tubes and $M(t) = V[C(t) - C'(t-1)]$ is the mass of nutrient released from the sediment from time t-1 to t, with V being the volume of the overlying water.

A negative flux value represents nutrient exchange from water to the sediment (influx) whereas a positive flux value refers to nutrient exchange from sediment to the water (efflux).

Statistical analysis

The data were analyzed with analysis of variance (ANOVA), tested after the analysis of variance (Post Hoc Test) of the mean by the Duncan Multiple Rank Test or DMRT method and analyzed Pearson Product Moment Correlation.

Results

Total organic matter (TOM)

The results showed that the total organic matter (TOM) in the area where no green mussel raft culture activity was present, the area where green mussel raft culture activities was just performed for 1-2 years and the area where green mussel raft culture has been performed for over 10 years were from 1.17 to 2.31 % (1.65±0.40 %), 1.57 to 5.74 % (2.47±1.07 %) and 4.12 to 12.95 % (5.71±2.44 %), respectively. The highest values of TOM were found at the area where green mussel raft culture has been performed for over 10 years. TOM in sediment have shown no clear seasonal change, and depth profile has no clear vertical change (Fig. 2). Statistical analysis indicated that TOM were significantly different among the stations ($p<0.05$) but insignificantly different among the sediment depth and seasons ($p>0.05$).

The prolonged green mussel raft culture caused a major effect and changes to the sediment texture including the components of the sediment. This was an important factor of accumulated water content and TOM. The results of statistical data analysis showed that the TOM was significantly correlated with silt & clay fraction and the water content ($p<0.01$). Our investigation showed that the accumulation pattern of TOM depended on the grain size of the sediments (Table 2).

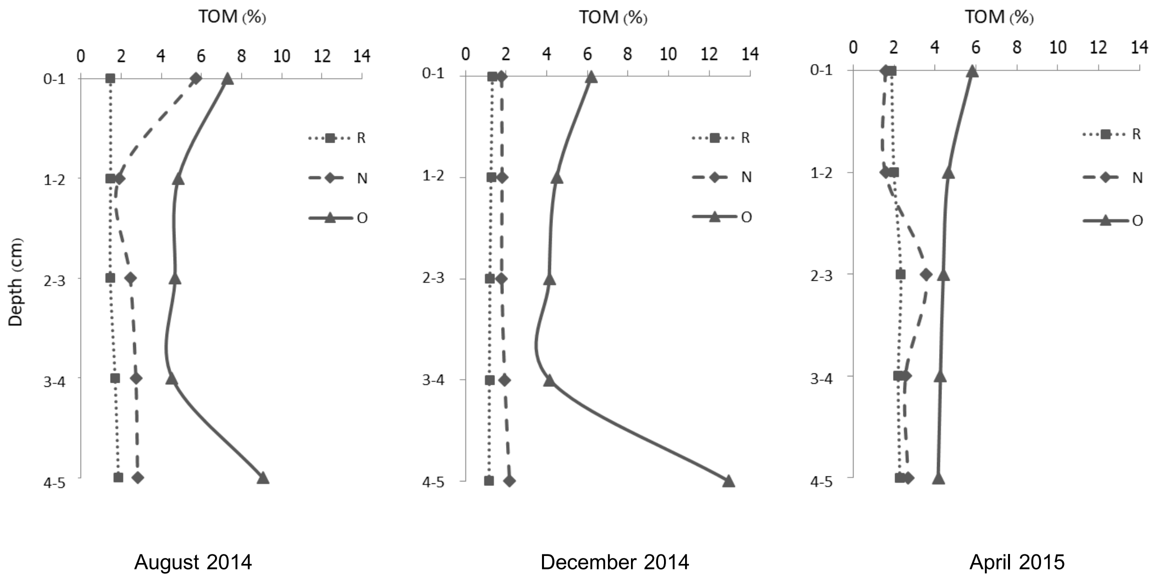

Figure 2 Total organic matter (TOM) among the three sampling station.

Table 2 Pearson correlations between TOM (%), WC (%) in the sediments and their grain size (%).

parameters	Silt & clay <0.063 mm	Fine sand 0.063-0.25 mm	Medium sand 0.25-0.5 mm	Coarse sand 0.5-2 mm	Gravel >2 mm	TOM	WC
Silt & clay <0.063 mm	1						
Fine sand 0.063-0.25 mm	0.042	1					
Medium sand 0.25-0.5 mm	-.420**	0.248	1				
Coarse sand 0.5-2 mm	0.164	-.914**	-.511**	1			
Gravel >2 mm	-.623**	-.625**	-0.083	.378*	1		
TOM	.785**	-0.116	-.395**	0.256	-.365*	1	
WC	.914**	-0.059	-.516**	0.28	-.505**	.719**	1

** Correlation is significant at the 0.01 level (1-tailed) and * at the 0.05 level (1-tailed).

Water content (WC)

The results showed that the water content (WC) was higher in the area where green mussel raft culture has been performed for over 10 years than in the area with 1-2 years or with no green mussel raft culture activity. WC were ranged from 29.87 to 41.45 % (33.97±4.55 %), 17.36 to 26.48 % (20.99±2.23 %) and 16.27 to 19.83 % (17.96±0.93 %), respectively. WC in sediment depth were not clear vertical change and seasonal (Fig. 3). Statistical analysis indicated that WC were significantly different among the stations ($p<0.05$) but insignificantly different among the sediment depth and seasons ($p>0.05$).

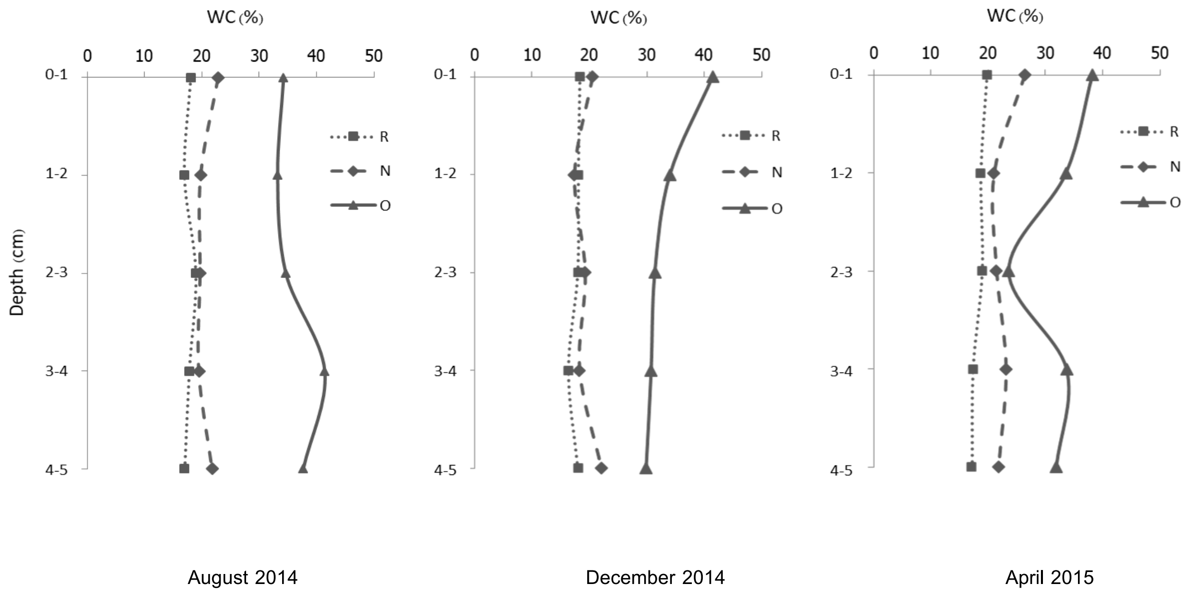

Figure 3 Water Content (WC) among the three sampling station.

Grain size

The grain size among the area where green mussel raft culture activities are shown in fig. 4. The results showed that the sediment of the area where no green mussel raft culture activity was present, the area where green mussel raft culture activities was just performed for 1-2 years and the area where green mussel raft culture has been performed for over 10 years were dominated by fine sand, coarse sand and a mix of three sand size (coarse sand, medium sand and fine sand), respectively. The sediment grain structure was also different among the stations. The percentage of silt & clay were higher in the area where green mussel raft culture has been performed for over 10 years than the area where green mussel raft culture activities was just performed for 1-2 years and the area where no green mussel raft culture activity was present, respectively. Grain size in sediment depth has no clear vertical and seasonal changes. Statistical analysis indicated that grain size were significantly different among the stations ($p<0.05$) but insignificantly different among depth and seasons ($p>0.05$).

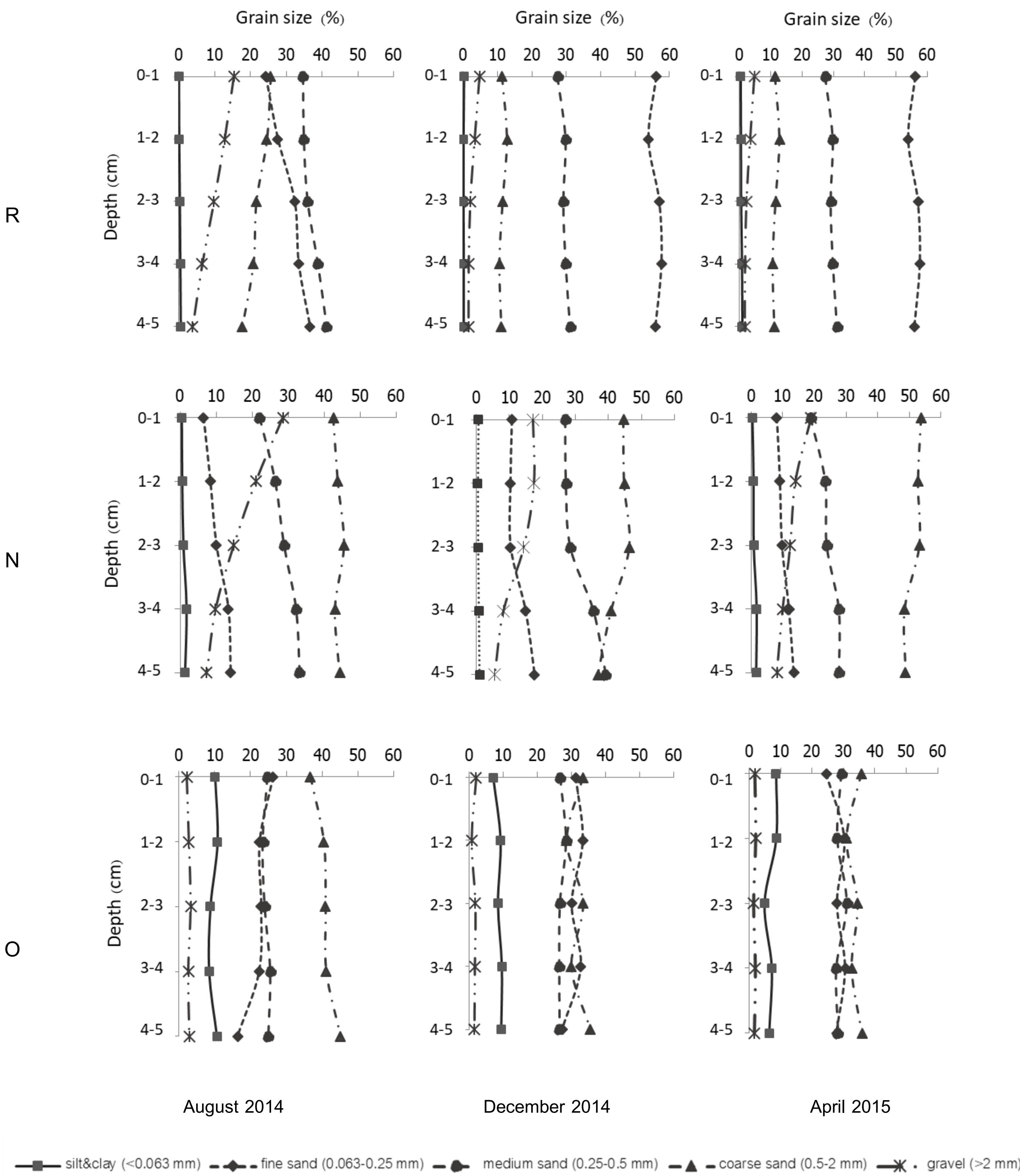

Figure 4 Grain size among the three sampling station.

DIN concentrations in the overlying water

The concentrations of DIN in overlying water were higher in the green mussel raft culture area than those in the area where no green mussel raft culture activity was present. The highest value of DIN in overlying water was found in the area where green mussel raft culture has been performed for over 10 years. The concentrations of DIN in overlying water were increasing with the increase of time of incubations (Table 3).

The results of the statistical data analysis showed that the DIN concentrations in overlying water were significantly between stations (p<0.05), nitrite and ammonia concentrations were significantly between seasons (p<0.05) but nitrate concentrations but insignificantly different among the seasons (p>0.05).

Table 3 Nitrite, nitrate and ammonia concentrations (μmol·L^{-1}) in the bottom water (0 h) and the overlying water (6-24 h) among the three sampling station.

station	time (h)	August 2014			December 2014			April 2015		
		nitrite	nitrate	ammonia	nitrite	nitrate	ammonia	nitrite	nitrate	ammonia
R	0	2.58±0.47	17.06±2.43	17.96±4.33	3.66±0.72	15.42±3.53	26.22±5.12	4.78±0.74	19.02±2.81	26.21±3.22
	6	2.83±0.31	17.56±3.62	18.30±2.52	3.87±1.24	15.98±2.35	26.76±4.88	4.81±1.41	19.34±2.42	27.02±3.26
	12	2.91±0.72	17.75±4.20	18.42±4.94	3.94±0.71	16.24±3.71	26.92±4.76	4.90±1.83	19.55±2.76	27.34±2.90
	18	3.45±0.46	17.82±2.67	18.71±3.03	4.17±2.26	16.72±2.64	27.18±5.80	5.37±2.50	19.70±2.62	27.45±3.04
	24	3.50±0.44	18.09±4.81	19.04±4.79	4.40±1.11	16.80±5.03	27.34±6.42	5.31±2.21	19.74±3.40	27.80±2.71
N	0	2.46±0.20	24.14±4.46	19.38±4.62	6.27±1.07	26.41±2.31	39.68±3.23	5.26±1.41	29.81±4.13	39.20±4.01
	6	2.59±0.37	25.32±3.72	19.44±2.48	6.54±1.43	26.98±4.53	40.08±7.14	5.38±1.33	30.24±3.81	40.56±5.19
	12	2.63±0.41	25.7±3.21	19.87±5.07	6.78±0.92	27.23±5.74	43.21±6.50	5.67±0.50	30.67±4.66	41.68±4.82
	18	2.76±0.73	27.12±2.57	20.25±3.82	6.86±1.74	27.54±4.91	43.56±8.32	5.72±1.49	30.82±6.90	42.90±4.53
	24	2.88±0.62	28.96±4.02	22.12±3.14	7.22±2.30	27.9±7.22	46.28±5.77	5.81±1.82	31.03±6.50	43.60±3.71
O	0	5.55±0.77	35.43±5.31	22.58±4.03	14.79±1.33	38.10±2.68	40.02±2.33	11.03±2.32	28.40±4.08	40.06±3.20
	6	5.91±0.72	36.41±6.41	23.11±5.08	15.11±2.43	38.76±3.51	43.19±5.24	11.36±1.83	29.74±4.43	42.10±2.78
	12	6.22±0.40	39.76±4.72	23.24±4.70	15.32±4.71	39.03±4.11	44.32±4.71	11.48±3.30	29.83±5.71	45.38±4.52
	18	6.40±1.14	43.60±3.64	23.58±3.61	15.87±3.62	39.75±4.54	47.16±2.60	11.86±3.71	30.65±5.45	46.21±6.19
	24	6.72±2.32	45.48±4.90	23.90±5.32	16.09±5.40	40.17±3.83	48.06±5.46	12.12±4.75	30.84±6.44	48.53±5.93

Flux of DIN

DIN fluxes at the water-sediment interface measured from laboratory incubations were displayed in fig. 5. Fluxes of DIN were positive and indicated that DIN moves from the sediment to the water column. Nitrite flux in all stations and all season are among the same flux. While station O, Nitrate and Ammonia flux are different in season and among station. DIN fluxes were higher in the area where green mussel raft culture activities were present than the area where no green mussel raft culture activity was present. The highest values of DIN fluxes were found at the area where green mussel raft culture has been performed for over 10 years. Fluxes of nitrite, nitrate and ammonia in the area where green mussel raft culture has been performed for over 10 years were 7.97, 32.60 and 39.92 $\mu mol \cdot m^{-2} \cdot h^{-1}$, respectively. Fluxes of nitrite, nitrate and ammonia in the area where green mussel raft culture activities were just performed for 1-2 years were 4.30, 16.86 and 30.76 $\mu mol \cdot m^{-2} \cdot h^{-1}$, respectively. Fluxes of nitrite, nitrate and ammonia in the area where no green mussel raft culture activity was present were 4.90, 7.01 and 8.48 $\mu mol \cdot m^{-2} \cdot h^{-1}$, respectively.

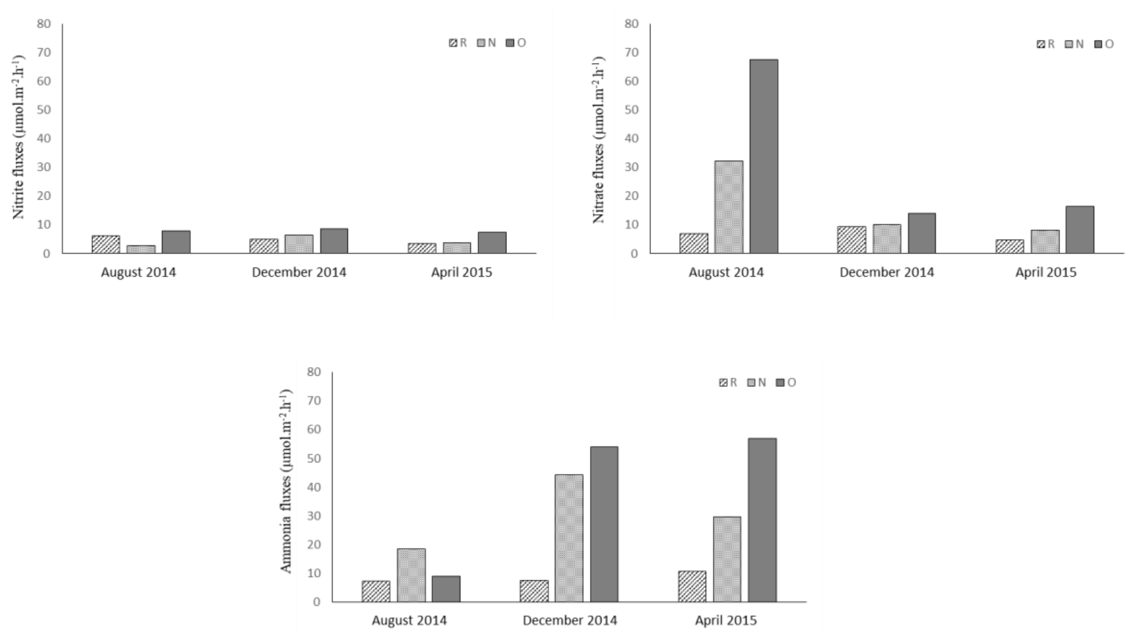

Figure 5 Nitrite, nitrate and ammonia fluxes at the water-sediment interface in Sriracha Bay among the three sampling station.

Discussion

Total organic matter (TOM), water content (WC) and grain size

The results from the investigation showed that the TOM was released to the WC and the grain size of the sediments (Table 2). TOM and WC were higher in the area where green mussel raft culture activities were present than in the area where no green mussel raft culture activity was present. TOM in surface sediments was found to be the most robust indicator of impact of the long green mussel raft culture, thus suggesting that TOM and WC enrichment could derive from the accumulation of faeces in sediment. The mussel raft culture could induce sedimentation to surface sediment and also alter bottom sediment characteristics and water qualities (Vichkovitten *et al*., 2020).

The sediment grain structure was also different among the stations. The percentage of silt & clay were higher in the area where green mussel raft culture activities were present than in the area where no green mussel raft culture activity was present. The long green mussel raft culture caused a major effect of change in the sediment texture including in the components of the sediment. The results were found to be similar to the previous studies (Intarachart, 2008; Intarachart & Khaodon, 2008). This was an important factor of accumulated WC and TOM.

DIN concentrations in overlying water

The DIN concentrations in overlying water were higher in the area where green mussel raft culture activities were present than in the area where no green mussel raft culture activity was present. The highest value of DIN in the overlying water was found at area where green mussel raft culture has been performed for over 10 years. The prolonged green mussel raft culture effectively released nutrients into the water and sediment. Mussels released nutrients into the marine environment through their feces and soluble excretion (Srisunont & Babel, 2015).

The concentrations of DIN in overlying water were higher in final time of incubations than initial time of incubations, indicating DIN diffused from sediment to water column. Ammonia was the main form of DIN in the overlying water. Ammonia mainly derived from the remineralization of sedimentary OM. Bacteria changed the organic nitrogen to ammonia, and then ammonia entered into the overlying water. Maybe the more remineralization due to the decreasing dissolved oxygen anoxic, inferred that anoxic can occur in surface sediment. Which is similar to the nutrient characteristic in the estuary (Zhang *et al*., 2013).

Flux of DIN

Flux of DIN at the water-sediment interface moving from the sediment to the water, indicated that the sediment in the green mussel culture acted as a source of nitrite, nitrate and ammonia. The highest fluxes of DIN at the water-sediment interface were found at the prolonged green mussel raft culture area. This results is similar to that observed in different areas such as the pearl oyster culture area (Mazouni *et al*., 2012). Our results suggested that ammonia generally diffused from sediment to water column and the sediment was the source of ammonia, which is similar to the fluxes across the sediment in the Pearl River estuary (Zhang *et al*., 2013). Our results indicated the green mussel raft culture activity released nutrient into the water and sediment. This nutrient stimulate bacterial growth in water due to the dissolved nutrients (Srisunont & Babel, 2015). Nitrite, nitrate and ammonia are the dissolved inorganic forms of nitrogen were found across the overlying water.

Conclusions

Our data suggest that the highest values of TOM were found at area where has been cultured more than 10 years (5.71±2.44 %). The long green mussel raft culture caused a major effect of the change of sediment texture including component of sediment. This was an important factor of accumulated WC and TOM. The sediment interface in the green mussel culture in Sriracha Bay serves as a source of nitrite, nitrate and ammonia. The values of DIN fluxes were higher in the area of the prolonged culture for over 10 years than the one of 1-2 years. The lowest DIN fluxes was fund the area of no mussel raft culture activity. Fluxes of nitrite, nitrate and ammonia at the water-sediment interface in the area where green mussel raft culture has been performed for over 10 years were 7.97, 32.60 and 39.92 $\mu mol \cdot m^{-2} \cdot h^{-1}$, respectively.

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