Razor Clam (*Solen* spp.) Production and Future Trend of Don Hoi Lord, the Largest Tidal Flat of Thailand: Evidences from Aquatic Environment and Resources Utilization Impacts

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Introduction

Don Hoi lord, the *International Ramsar Site* situated closed to the Mae Klong river mouth, Samut Songkhram Province, covered an area *ca* 875 km^2 (Ramsar, 2010) along the coastal site. Most area of Don Hoi Lord is coastal wetland and sub-tidal flats formed by accumulation of sediment around the Mae Klong river mouth. It has unique characteristic of natural wetland in Thailand (Worrapimphong *et al*, 2007). Here razor clams are the most abundant clam species with the local name called "Hoi Lord". This species is filter feeder and lives buried in sand and/or muddy sand in sub-tidal areas. It had very important roles on economic status of local fisherman community. However, razor clam production became decreased by the time. Many evidences such as severe harvesting, effect of unsuitable harvesting methods, impacts from otter trawl, and deterioration of aquatic environment have been discussed as its decreasing reasons (PCD, 2007). According to REO8 (2007), the deterioration of water quality induced mainly by sewage and domestic discharges and agricultural utilization had revealed to contribute phytoplankton blooming phenomenon along the coastal zone of this area. This study was thus aimed to assess the razor clam status, impacts of aquatic environmental factors and related impacts by utilization from local fisherman community. The whole knowledge could be applied to develop the scheme for conservation and sustainable utilization of razor clam resources.

Materials and methods

Study site and survey plan
Don Hoi Lord is a very large tidal flat situated at the Mae Klong river mouth, Samut Songkhram Province, where was recorded as the region of high population density (472 people per square kilometer). This province had the agricultural area covering more than 83% of the whole province's area (REO8, 2007) with a lot of fishery activities. The investigation for status assessment of the razor clam (*Solen* spp.) population, its production potential, and related aquatic environmental factors were designed to cover 3 sub-tidal flats, where was the important harvesting sites (Figure 1). This surveys were conducted 4 times during May 2006, September 2006, November 2006, and August 2007.

Sampling and analysis
The sampling stations of razor clam were designed at 34 major stations, in where the clams were collected in 5 m^2 of quadrat size by local fisherman. Some more minor stations (*ca* 190 stations) were carried out within 1 m^2 of quadrat size, along the distance (every 100 m-

interval) between the major ones. The environmental surveys were conducted during high tides. Temperature, dissolved oxygen, salinity and pH were measured on board by using the Multi-parameter probe (YSI-6600 Sonde instrument). Surface (30 cm-depth) water samples were collected for analyses of nutrients concentrations; ammonium nitrogen (NH_4^+-N), nitrite and nitrate nitrogen (NO_2^-+NO_3^--N), silicate silicon ($Si(OH)_4$–Si) and orthophosphate phosphorus (PO_4^{3-} -P) by SKALAR segmented flow. The samples for chlorophyll *a* and total suspended solids were analyzed according to spectrophotometric method and freeze-dryer technique, respectively.

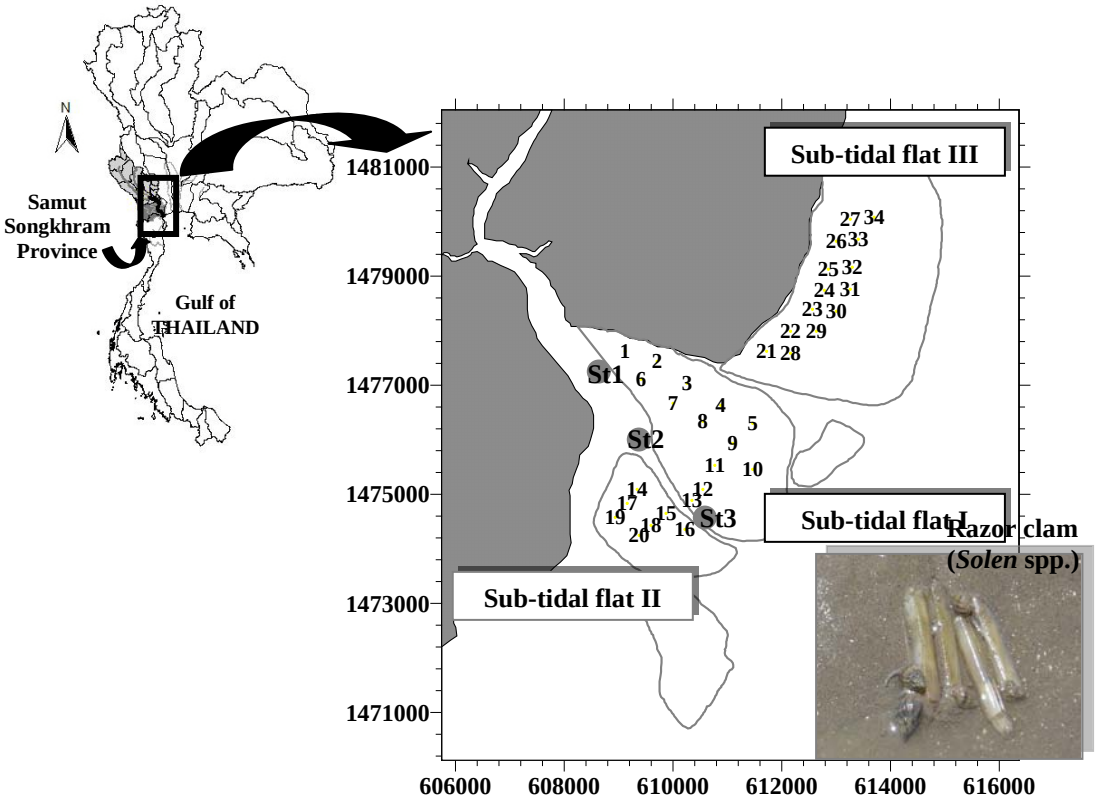

Figure 1 Survey stations of razor clam population (1-34 stations) within three sub-tidal flats (I-III) of Don Hoi Lord, Mae Klong river mouth, Samut Songkhram Province (St1, 2, and 3 with circles indicated the water quality survey stations).

Results and Discussions

Biomass distribution

In 2006, biomass of razor clams in Sub-tidal flats I, and II were in ranges of 965-3,084 kg/km^2 and 746-5,260 kg/km^2, respectively. Figure 2 showed that razor clam density of Sub-tidal flat I increased (368-1,075 10^3individuals/km^2) by time. Although, the density decreased during early-rainy season (May to September 2006), it increased during late-rainy season (September to November 2006) in Sub-tidal flat II (348-802 10^3individuals/km^2). In 2007, biomass and density tended to increase. The biomass of Sub-tidal flats I, and II were 19,666 and 3,217 kg/km^2 (with the densities of 3,760 and 1,609 10^3individuals/km^2), respectively. This evidence demonstrated that the razor clam biomass was varied by sub-tidal flat area and changed over the year. Such occurrence could be induced by temporal variation of related aquatic environments and anthropogenic activities.

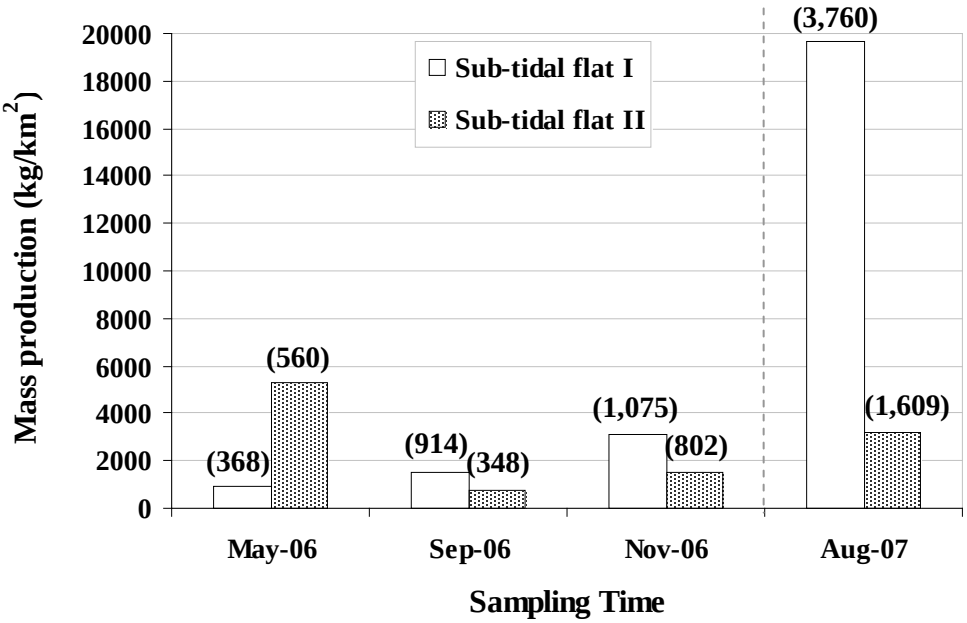

Figure 2 Variation of razor clam mass production (kg/km^2) and density (in parenthesis; 10^3individuals/km^2) in Sub-tidal flats I, and II during the study periods.

Production potential

Both sub-tidal flats were important areas with high utilization in both of fisheries and tourism aspects. In this study, razor clam sizes in each sub-tidal area varied from 1.0-6.7 cm, while the weights varied from 0.01-9.70 g per individual. Length (L; cm) – weight (W; g) relationship was proposed to be $W = 0.0173e^{1.0413L}$ *(n=310, r=0.94)* as showed in Figure 3.

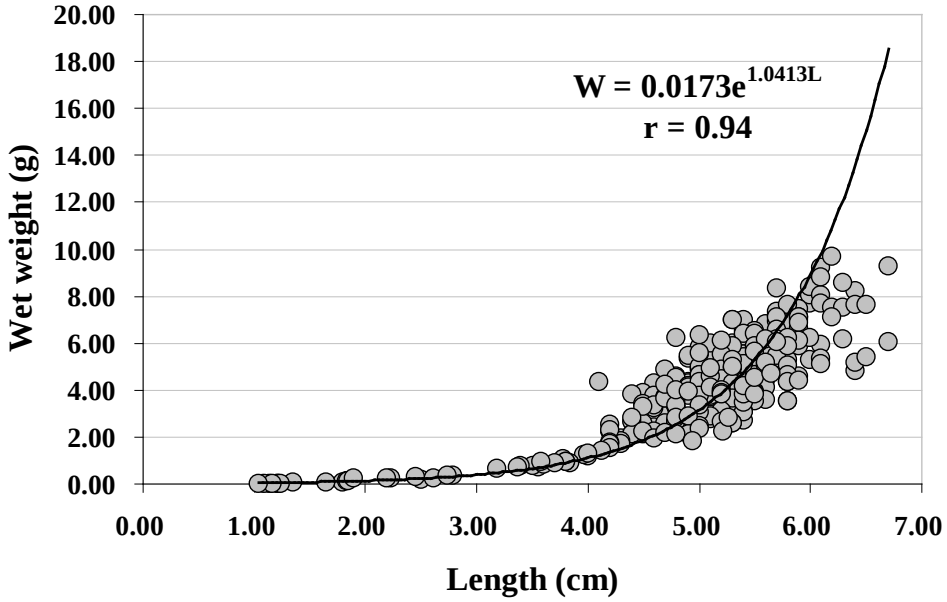

Figure 3 Relationship between length (L; cm) and weight (W; g) of razor clams (*Solen* spp.) observed in Don Hoi Lord tidal flat during the study periods of 2006-2007.

Densities of the razor clam ranged in 368-1,075 and 348-802 10^3individuals/km^2 for the Sub-tidal flats I, and II, respectively (Table 1). The densities of both areas were lower in September 2006. Consideration of razor clam size composition (%) classified by the market demand sizes, the results reflected that the small size (<4 cm) decreased by the time in both of

the sub-tidal areas. Normally, proportion of the economic size (4-8 cm) was greater than the proportion of small razor clam size. The small size had found apparently only during May 2006. Therefore, the proportion of the economic size became higher. Such changes of the razor clam size structure implied the problems in development of small-size population and/or nearly settled population in the same area. This result should be coincided with aquatic environmental deterioration that should be clarified further.

Production potential of razor clam of the Sub-tidal flat I during early- (May to September 2006) and late-rainy seasons (September to November 2006) were 135 and 789 kg/km^2/month, respectively. In 2007, the results had revealed that the production potential became increased (in the ranges of 135 to 1,397 kg/km^2/month). Increasing rate of production was relatively low. Such occurrence should be due to the harvesting impact and related changes of habitats induced by land reclaimation along the surrounding area (Worrapimphong *et al*., 2007). In addition, the tidal flat closed to the household areas had received nutrient loads and thus the phytoplankton bloom often occurred in the area.

Table 1 Density (10^3individuals/km^2) and size composition (%) of razor clam in the Sub-tidal flats I, and II and the production potentials (kg WW/km^2/month) of Sub-tidal flat I in Don Hoi Lord during the study periods.

Parameters	Sub-tidal flat I				Sub-tidal flat II			
	May 2006	September 2006	November 2006	August 2007	May 2006	September 2006	November 2006	August 2007
Density (10^3 individuals/km^2)	368	914	1,075	3,760	560	348	802	1,609
Size composition								
% small size (<4 cm)	52	15	8	0	0	18	15	1
% economic size (4-8 cm)	48	85	92	100	100	82	85	99
Production potential (kg WW/km^2/month)	135 789 353 1,397				-			

Environmental factors

The results demonstrated that Don Hoi Lord area had received the influence from freshwater runoff with different water qualities by times. Table 2 showed that the salinity changed by each survey periods. During the rainy season, the salinity was comparatively low. Particularly during in September 2006, very low salinity was found and thus the razor clam density became lower than the other periods. The water temperature decreased slightly during November 2006 and December 2007. The pH levels were nearly constant in the study area. Dissolved oxygen concentrations (DO) had decreased to the unsuitable levels (<4 mg/l), especially during May 2007. Such low DO may probably cause by the decomposition of organic compounds contained in the water mass by bacterial functions. In the same period, the

levels of chlorophyll *a* and suspended solids were higher 54.79±47.64 μg/l and 40.49±60.66 mg/l, respectively). Chlorophyll *a* was recognized as a key factor in the food supply for razor clams growth (Cozta and Martínez-Patiño, 2009). Nevertheless, the chlorophyll *a* levels here reflected that Don Hoi Lord was in mesotrophic to hypertrophic status. Moreover, the incidents of *Noctiluca* red tide (with the maximum chlorophyll *a* of 136 μg/L) and very high ammonium-N concentration (58 μM) were noticed in the zones adjacent to household. Such eutrophication problems occurrences may impact to razor clam production in the near future.

Table 2 Level of water qualities (mean±SD) examined within Sub-tidal flat sites I and II during the study period.

Parameters	**Study periods**					
	May 2006	September 2006	November 2006	May 2007	September 2007	December 2007
Temperature (^oC)	30.06±0.21	30.43±2.37	28.78±0.08	30.39±0.03	31.19±0.29	27.30±0.26
Salinity (psu)	14.26±3.18	0.77±0.96	23.43±1.25	0.31±0.03	5.96±0.65	22.89±4.30
Dissolved oxygen (mg/l)	5.91±0.87	5.54±0.15	6.01±1.73	4.75±0.64	5.92±0.40	7.33±2.11
pH	7.81±0.15	8.29±0.36	8.67±0.22	7.52±0.22	7.44±0.09	8.63±0.07
Chlorophyll *a* (μg/l)	4.06±1.85	2.67±1.34	9.45±3.20	54.79±47.64	4.45±3.08	15.35±7.03
TSS (mg/l)	15.79±5.86	35.56±25.95	13.13±3.80	40.49±60.66	50.30±18.86	9.25±1.55
NH_4^+-N (μM)	37.00±0.90	11.69±11.39	13.59±10.58	10.33±0.54	28.88±7.71	25.87±10.35
NO_2^-+NO_3^--N (μM)	8.92±3.18	20.15±3.35	5.14±0.4	10.68±0.18	15.99±2.95	3.28±2.00
$Si(OH)_4$–Si (μM)	65.37±6.95	77.68±1.13	61.49±10.44	53.29±1.28	66.94±0.43	36.82±9.37
PO_4^{3-}-P (μM)	3.03±0.61	1.34±0.50	5.46±2.04	1.91±0.38	3.81±0.77	1.80±0.64

Levels of ammonium, nitrite and nitrate, silicate, and orthophosphate concentrations had changed differently study periods that should be probably as a result of contaminants from freshwater mass runoff from the Mae Klong river. Thus, monitoring of nutrient loads, particularly ammonium and orthophosphate induced by the anthropogenic activities such as domestic waste, agricultural and industrial wastes were of importance. The activities that caused impacts on aquatic resources and phytoplankton bloom phenomenon should be focused and deserved depth consideration. The community utilization activities such as harvesting method, moreover, showed also be integrated considered so as to enhance the population growth for conservation and sustainable utilization purpose.

Conclusions

This study showed that the composition of the small (<4cm) razor clam population was highest in May 2006. The small size portion of the razor clam here then gradually reduced by time. Razor clam biomass during year 2006 ranged between 746-5,260 kg/km^2. Production potential of the razor clam in Sub-tidal flat I, which had the highest resources utilization, was 135 and 789 kg/km^2/month in early- and late-rainy seasons in 2006. The results indicated that the razor clam growth in the late-rainy season had the higher rates. In addition, the results of aquatic environmental factors showed that salinity levels apparently decreased and chlorophyll *a* were increased to unsuitable levels. Such occurrences may impact to razor clam future population. Further study on resources utilization pattern should be focused in order to develop integrated scheme for conservation and sustainable utilization of the razor clam population.

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