CHAPTER IV

RESULTS AND DISCUSSIONS

4.1 STUDY AREA AND LOCATION OF RAZOR CLAM POPULATION DATA COLLECTION

The study area is the biggest sand dune of Don Hoi Lord, which is located at Mae Klong river mouth, at Mu 4 (Chu Chi village), Bangjakreng District, Amphur Muang, Samut Songkhram province. (Figure 4.1)

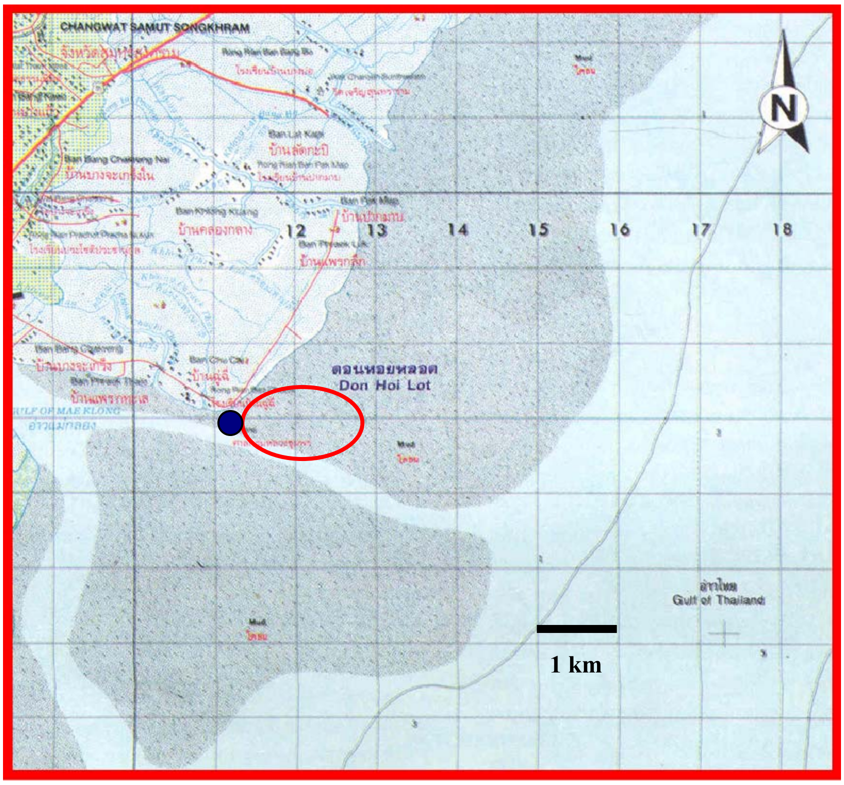


Figure 4.1 Study area in Don Hoi Lord (red eclipse) and Prince Chumporn Khedudomsak Memorial (dark blue spot)

At each of the 27 sampling stations along 4 line transects 4 1x1 m^2 quadrat were located for razor clam population data collection. There were 4 line transects (A, B, C and D) to run on the sand dune (Fig 4.2 and Table 4.1).

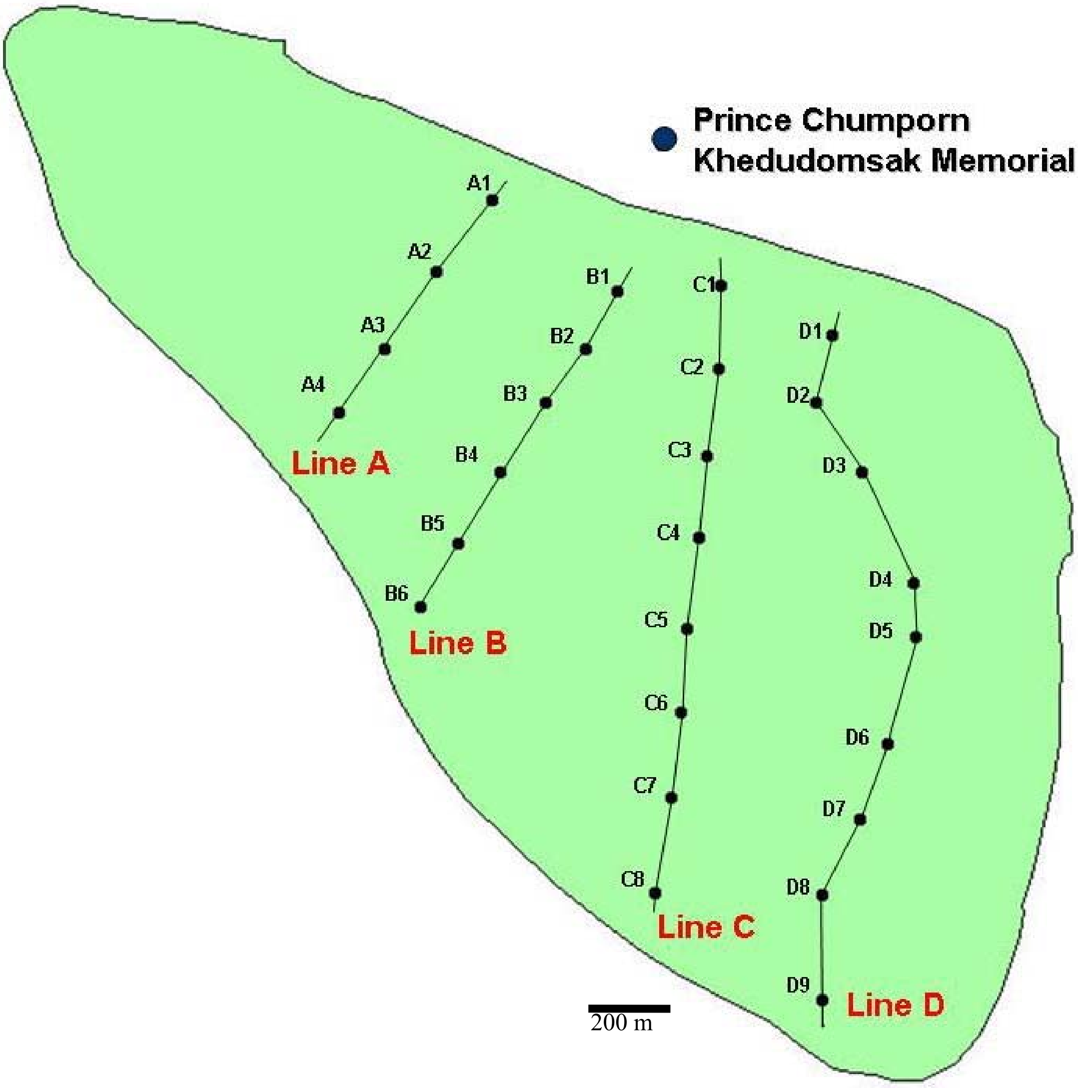


Figure 4.2 Study area with 4 line transects including 27 stations of razor clam population data collection.

From figure 4.2, all 27 sample stations located on 4 linetransects as the following:

Line A	4 stations (A1 to A4)
Line B	6 stations (B1 to B6)
Line C	8 stations (C1 to C6)
Line D	9 stations (D1 to D9)

* in each station comprise 3 replicates of 1 m^2 quadrat for data collection.

Table 4.1 Geographical position of each station in Don Hoi Lord represented in UTM Datum

Station	**Zone**	**East**	**North**
A1	47P	610646	1476909
A2	47P	610501	1476722
A3	47P	610365	1476518
A4	47P	610244	1476354
B1	47P	610968	1476668
B2	47P	610889	1476522
B3	47P	610783	1476381
B4	47P	610663	1476198
B5	47P	610557	1476013
B6	47P	610459	1475848
C1	47P	611240	1476688
C2	47P	611233	1476467
C3	47P	611202	1476238
C4	47P	611185	1476030
C5	47P	611149	1475787
C6	47P	611134	1475570
C7	47P	611112	1475350
C8	47P	611070	1475099
D1	47P	611529	1476557
D2	47P	611487	1476379
D3	47P	611606	1476197
D4	47P	611742	1475906
D5	47P	611747	1475768
D6	47P	611674	1475490
D7	47P	611604	1475290
D8	47P	611505	1475094
D9	47P	611504	1474818

4.2 PHYSICAL CHARACTERISTICS OF STUDY AREA

The biggest sand dune was selected for this study. The sand dune resembled a triangle pointed to the west (figure 4.2) and covers the area of 417 hectares including 2 gullies. It is located in southeast direction of Mae Klong river mouth and Chu Chi channel outlet, the north direction connect with Prince Chumporn Khedudomsak Memorial and area of Chu Chi village, the east and the south direction connect with another sand dune. Local fishermen usually call this sand dune is Don Nar Sarn.

The sand dune is under influence of tidal cycle. When the high tide is more than 1.4 m. from mean sea level, the sand dune will disappear with submerging under sea level. On the another hand, when the low tide less than 1.4 m. from mean sea level the sand dune will be exposed (Meteorological Division Hydrographic Department Royal Thai Navy, 2004-2005 and This study).

The sedimentary soil of this sand dune is consisted of 90% fine sand and around 10 % of clay(Art-Ong Pradatsundarasar, 1982). In addition, some area comprises more than 10 % of clay because that area located on the edge of sand dune connecting with gully. Water turbidity is high due to high values of suspended clay particle from the river.

Table 4.2 Sequential data collection by monthly.

Trip	Month	Date	Start Time	Min Low Tide Time	Min Low Tide (m)	Exposing duration (hr.)
1	March	27_03_04	2:00 PM	3:00-4:00 PM	1.2	3
		28_03_04	2:30 PM	3:00-4:00 PM	1.2	3.5
2	April	22_04_04	12:00 PM	2:00 PM	1.0	3.5
		23_04_04	12:30 PM	2:00-3:00 PM	1.0	4
3	May	20_05_04	10:30 AM	1:00 PM	0.8	5
		21_05_04	11:00 AM	2:00 PM	0.8	5
4	June	23_06_04	12:30 PM	3:00 PM	0.7	5.5
		24_06_04	1:00 PM	3:00-4:00 PM	0.9	5.5
5	July	21_07_04	12:00 PM	3:00 PM	0.6	6
		22_07_04	12:30 PM	3:00 PM	0.7	5
6	August	26_08_04	5:00 AM	7:00-8:00 AM	0.9	6
		27_08_04	6:00 AM	9:00 AM	0.8	5.5
7	September	22_09_04	2:30 AM	4:00-5:00 AM	1.0	5
		23_09_04	3:30 AM	5:00-6:00 AM	1.0	5
8	October	19_10_04	1:30 AM	3:00 AM	1.0	4
		20_10_04	2:00 AM	4:00 AM	1.0	4.5
9	November	16_11_04	12:00 AM	2:00 AM	1.0	4.5
		17_11_04	1:00 AM	3:00 AM	1.0	4.5
10	December	16_12_04	12:30 AM	3:00 AM	0.9	4.5
		17_12_04	1:30 AM	3:00-4:00 AM	1.0	4.5
11	January	26_01_05	11:30 PM	1:00-2:00 AM*	1.0	4
		28_01_05	12:00 AM	2:00 AM*	1.0	4
12	February	23_02_05	10:30 PM	12:00-1:00 AM*	1.0	3.5
		24_02_05	11:00 PM	1:00 AM*	1.0	3.5

* Time on next day

Source of tidal time: Division Hydrographic Department Royal Thai Navy (2004-2005).

From table 4.2 shows the date of monthly razor clam data collection, minimum low tide, low tide interval time. Finally, the duration of sand dune exposure was calculated which is the available time for razor clam harvesting per day.

As a data represented in table 4.2 between March and July, the low tide was at daytime while August low tide was in the early morning. Local fishermen have to use a head-flashlight as an accessory device because after August until February low tide was occurred at night-time.

During 12 months of the study, the minimum low tide level was 0.6 m. from the mean sea level at daytime low tide in July and the maximum interval low tide time was 6 hours at daytime low tide in July.

4.3 RAZOR CLAM POPULATION

4.3.1 Density of razor clam

The density of razor clam during 12 months of study from March 2004 to February 2005 was presented in individual/m^2 in figure 4.3

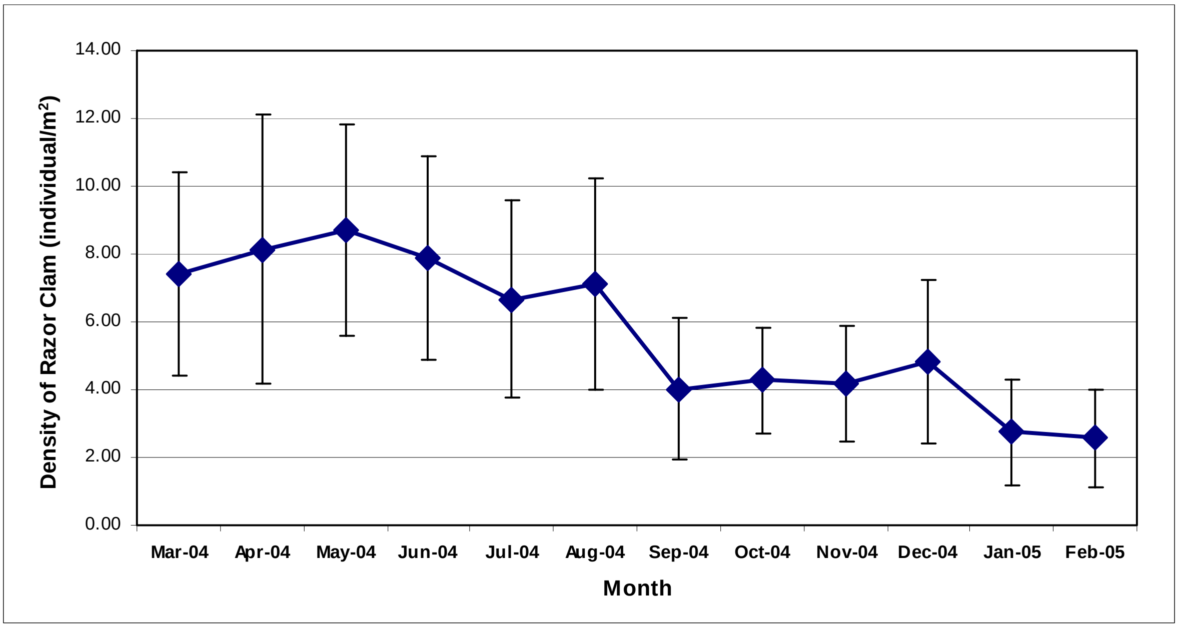


Figure 4.3 Mean of razor clam density (individual/m^2) in this study

Table 4.3 Density of razor clam in each station (individual/m^2) in 12 months

Month / Station	Mean Density ± SD (Individual/m^2)											
	Mar-04	**Apr-04**	**May-04**	**Jun-04**	**Jul-04**	**Aug-04**	**Sep-04**	**Oct-04**	**Nov-04**	**Dec-04**	**Jan-05**	**Feb-05**
A1	5.33 ± 3.21	5.33 ± 1.53	3.67 ± 1.53	3.00 ± 1.00	4.00 ± 3.46	12.00 ± 5.29	3.67 ± 2.08	4.00 ± 1.00	4.33 ± 3.21	0.67 ± 0.58	1.67 ± 0.58	1.00 ± 0.00
A2	15.00 ± 5.00	12.00 ± 5.20	7.00 ± 1.00	9.33 ± 4.93	5.00 ± 2.00	5.33 ± 1.53	2.67 ± 1.53	2.00 ± 2.08	2.00 ± 1.00	2.00 ± 1.00	1.33 ± 1.15	1.67 ± 0.58
A3	3.67 ± 3.06	6.33 ± 2.89	14.33 ± 5.51	9.33 ± 5.13	9.00 ± 1.73	10.33 ± 6.35	4.67 ± 0.58	3.33 ± 0.58	2.67 ± 2.08	3.00 ± 2.00	5.00 ± 4.36	2.33 ± 1.15
A4	1.33 ± 0.58	1.00 ± 0.00	2.00 ± 1.00	1.33 ± 0.58	1.33 ± 0.58	1.33 ± 0.58	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.33 ± 0.58	0.33 ± 0.58
B1	13.33 ± 1.15	18.67 ± 15.03	12.33 ± 2.08	14.33 ± 6.51	6.67 ± 4.04	11.67 ± 3.21	7.33 ± 0.58	4.00 ± 1.00	5.33 ± 2.52	7.00 ± 4.00	4.33 ± 3.21	3.00 ± 2.65
B2	6.33 ± 1.15	13.00 ± 1.00	10.00 ± 2.65	15.67 ± 6.81	6.00 ± 2.65	5.67 ± 2.08	3.67 ± 1.53	4.33 ± 0.58	4.33 ± 1.15	4.76 ± 2.52	2.33 ± 1.53	3.33 ± 0.58
B3	17.33 ± 10.69	15.00 ± 3.61	17.67 ± 4.93	15.33 ± 3.06	16.33 ± 4.73	16.00 ± 3.00	7.67 ± 6.43	5.33 ± 2.52	3.00 ± 1.00	3.67 ± 1.53	5.00 ± 1.00	2.33 ± 0.58
B4	7.00 ± 3.46	7.33 ± 3.51	10.67 ± 2.31	10.67 ± 2.52	8.67 ± 4.16	6.33 ± 0.58	5.00 ± 3.61	4.00 ± 2.00	3.67 ± 2.52	5.33 ± 3.21	2.00 ± 1.73	3.33 ± 1.53
B5	8.67 ± 4.73	7.67 ± 4.62	11.33 ± 7.57	7.67 ± 0.58	3.00 ± 1.73	4.00 ± 2.65	5.00 ± 0.58	3.00 ± 1.00	2.67 ± 0.58	3.67 ± 1.53	2.00 ± 1.00	2.33 ± 0.58
B6	1.33 ± 0.58	1.00 ± 0.00	1.33 ± 1.15	1.33 ± 0.58	0.67 ± 0.58	1.33 ± 0.58	0.33 ± 0.58	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
C1	18.33 ± 8.39	13.33 ± 6.24	16.00 ± 7.21	12.67 ± 5.86	8.00 ± 10.39	8.00 ± 7.94	8.33 ± 8.74	4.67 ± 0.58	3.33 ± 2.08	11.00 ± 3.00	3.67 ± 2.08	2.33 ± 0.58
C2	7.33 ± 1.53	11.00 ± 5.29	10.67 ± 6.51	9.00 ± 6.93	8.00 ± 2.65	5.67 ± 3.06	5.33 ± 0.58	2.67 ± 2.08	4.00 ± 1.00	2.67 ± 1.53	3.67 ± 0.58	5.00 ± 3.61
C3	17.67 ± 7.09	13.00 ± 6.08	**27.33 ± 7.51**	19.00 ± 6.24	19.00 ± 7.81	10.33 ± 2.08	7.33 ± 4.04	10.00 ± 2.00	7.67 ± 1.15	**8.33** ± 3.06	**4.00** ± 1.73	**4.00** ± 1.00
C4	16.33 ± 9.45	16.33 ± 10.12	27.00 ± 6.08	25.67 ± 8.74	14.67 ± 7.37	9.00 ± 4.00	3.00 ± 2.65	4.00 ± 1.00	3.67 ± 3.06	1.67 ± 2.08/	3.00 ± 2.65	1.67 ± 1.53

Table 4.3 Density of razor clam in each station (individual/m^2) in 12 months (continued)

C5	6.67±2.52	9.00±4.36	10.00±3.61	10.33±4.93	7.33±1.15	9.00±5.57	4.00±1.73	8.00±2.00	4.67±3.79	4.00±3.46	5.00±2.65	1.33±0.58
C6	5.00±1.73	4.33±2.31	6.00±1.00	4.67±1.15	7.00±3.46	4.67±2.31	4.33±1.53	4.67±1.15	5.00±2.65	5.00±1.00	4.67±0.58	1.00±0.00
C7	3.00±1.00	3.67±0.58	3.00±2.65	4.33±2.08	7.67±2.31	3.33±1.53	3.00±1.00	4.67±1.53	3.00±1.00	4.33±2.52	2.67±0.58	2.33±1.53
C8	6.33±1.53	4.67±1.53	6.33±2.52	3.33±0.58	8.67±3.79	3.67±2.08	2.67±2.08	5.00±1.00	4.33±2.31	4.67±2.31	4.00±2.65	1.33±0.58
D1	7.67±1.15	13.67±6.03	9.67±4.93	5.33±1.53	3.67±1.53	7.00±1.00	2.33±2.52	4.33±2.08	6.00±2.65	3.67±1.53	1.67±0.58	3.33±3.21
D2	5.33±2.08	7.33±3.79	4.00±2.00	4.67±3.79	3.00±3.00	8.00±5.29	2.00±1.00	4.33±1.53	2.67±2.08	5.33±1.53	2.33±1.53	1.67±1.15
D3	3.67±1.15	6.33±3.51	3.33±3.21	1.33±0.58	5.33±1.15	4.67±2.08	3.33±1.53	5.00±2.00	1.00±0.00	2.67±1.15	2.00±1.00	6.00±3.46
D4	4.67±1.53	8.33±5.03	2.67±0.58	4.67±0.58	5.00±1.00	10.67±4.51	4.33±0.58	8.00±4.36	7.33±2.52	9.33±1.53	3.00±1.73	3.67±2.52
D5	2.00±2.00	6.00±5.20	5.33±1.53	5.67±1.15	6.00±2.65	13.33±7.09	4.33±1.15	8.00±1.00	15.67±2.52	20.67±16.26	3.67±1.53	8.33±3.51
D6	3.00±0.00	4.00±1.00	4.67±1.15	3.00±1.73	2.33±0.58	4.33±1.53	5.33±2.31	4.00±2.65	2.00±1.73	4.00±1.73	0.33±0.58	2.33±3.21
D7	5.00±3.61	4.67±3.79	2.67±0.58	4.33±0.58	6.67±1.53	8.33±4.04	5.33±2.08	4.67±2.52	4.00±1.73	3.00±1.73	2.33±2.31	1.67±0.58
D8	3.00±0.00	4.33±3.21	3.67±2.08	3.00±1.00	4.00±2.00	5.67±3.51	2.00±2.65	3.00±2.65	4.33±1.15	5.00±1.00	2.33±2.52	1.67±0.58
D9	5.67±2.08	2.33±1.15	2.67±1.53	3.67±1.53	2.67±0.58	2.33±1.15	3.33±3.21	1.00±1.00	5.33±0.58	4.67±3.21	1.67±2.08	2.00±2.65
Average±SD	**7.41±2.98**	**8.12±3.97**	**8.72±3.13**	**7.88±3.13**	**6.65±2.91**	**7.11±3.13**	**4.02±2.11**	**4.28±1.55**	**4.15±1.71**	**4.81±2.41**	**2.74±1.57**	**2.57±1.43**

From figure 4.3 shown that mean density of razor clam had increased since March 2004 to May 2004, during daytime low tide and reported as the first breeding season razor clam (Art-Ong Pradatsundarasar et al., 1989). After that May 2004, the mean density of razor clam decreased until August 2004 which razor clam population started a little increase again because of approaching the second breeding season (Art-Ong Pradatsundarasar et al., 1989). After August 2004 low tide was at night-time, mean density of razor clam decreased until Dec 2004 mean density of razor clam increased a little.

From statistical analysis month by month by Independence t-test at $P < 0.05$ (Kanlaya VAnitbancha, 2003) under SPSS program (Table 4.4) showed that density of razor clam was different between each month except August 2004 to September 2004 and December 2004 to January 2005 .

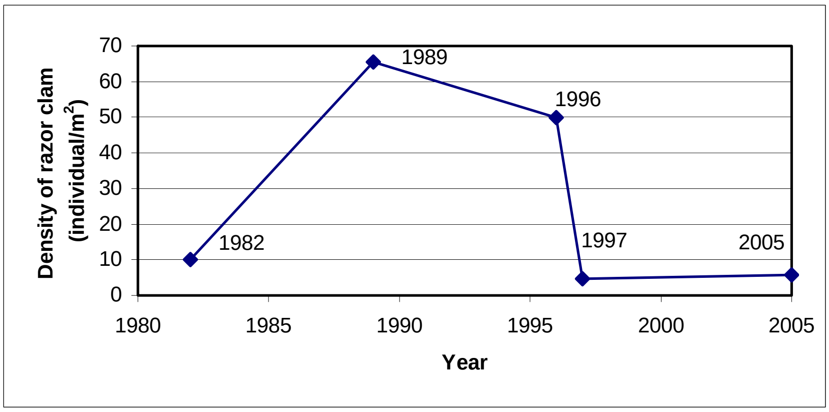
Table 4.4 Statistical analysis of razor clam density (Independent Sample T-Test at $P < 0.05$)

Month-to-month	Density test (Sig. (2-tailed) value in SPSS)
March 2004 vs April 2004	0.467
April 2004 vs May 2004	0.590
May 2004 vs June 2004	0.458
June 2004 vs July 2004	0.226
July 2004 vs August 2004	0.619
August 2004 vs September 2004	**0.000**
September 2004 vs October 2004	0.570
October 2004 vs November 2004	0.777
November 2004 vs December 2004	0.324
December 2004 vs January 2005	**0.001**
January 2005 vs February 2005	0.618

Mean density of razor clam of this study was 5.71 ± 2.49 individual/m^2. Maximum of density was 8.72 ± 3.13 individual/m^2 in May 04, during the daytime low tide and it just passed the first breeding season 2 months ago. On the other hand, minimum of density was 2.57 ± 1.43 individual/m^2 in February 2005, in the last night-time low tide which the climatic condition was fluctuated as low air and water temperature. In addition, this month is closed to the first breeding season and daytime low tide, which environmental would change dramatically in the following month. Thus, density of razor clam should be increased in March 2005 correspond with last year pattern in this study. There were some differences between density of razor clam in each month, the main reason might be harvesting pressure from fisherman all year long while razor clam can breed all year but there are only 2 massive breeding periods in one year. The production of razor clam may not enough to local fisherman harvesting demand. Another reason may be the different period of low tide because the low tide during night-time fisherman and researcher has to use a flashlight as accessory device to harvest razor clam that may be some difficulties to catch or harvest razor clam.

From table 4.3 has shown some differences of density of razor clam in each station, some stations has a little bit high number of density less difference in number through the study. For example, Station A4 and B6 these were located at the edge of sand dune closed with furrow. The highest density of razor clam in this study was 27.33 ± 7.51 individual/m^2 in C3 station in May 2004 and the lowest density of razor clam in this study was 0 individual/m^2 in A4 station in September 2004 to December 2004 and B6 station in October 04 to February 2005.

Mean density of this study was 5.71 ± 2.49 individual/m^2, it is different the previous studies as. 10.00 individual/m^2 (Art-Ong Pradatsundarasar, 1982), 65.50 individual/m^2 (Art-Ong Pradatsundarasar et al., 1989), 49.9 individual/m^2 (Sriburi and Gajaseni, 1996), 4.6 individual/m^2 (Rangsimant Bauthong, 1997) in figure 4.4.



(Art-ong Pradatsundarasar, 1982, Art-ong Pradatsundarasar et al., 1989, Thaviongse Sriburi and Nantana Gajaseni, 1996, Rangsimant Bautong, 1997 and this study 2005)

Figure 4.4 Comparison of mean density of razor clam from previous studies to this study

Table 4.5 Comparison of mean density of razor clam between previous studies and this study

Month	Year & Density (individual/m^2)				
	I (1981)	II (1988)	III (1996)	IV (1997)	**V (2004)**
March	9.5	17.3	N/A	3.4	**7.4**
April	N/A	30.9	12.6	10.6	**8.1**
May	11.7	33.7	49.5	7.4	**8.7**
June	N/A	37.0	18.9	2.7	**7.9**
July	N/A	29.9	129.1	9.4	**6.7**
August	8.8	102.9	87.1	7.9	**7.1**
September	N/A	40.9	N/A	N/A	**4.0**
October	N/A	N/A	84.7	2.8	**4.3**
November	N/A	87.5	31.6	1.5	**4.1**
December	N/A	209.6	24.1	4.5	**4.8**
January	N/A	N/A	N/A	0.2	**2.7**
February	N/A	N/A	8.1	0.1	**2.6**
Mean	**10**	**65.5**	**49.5**	**4.6**	**5.7**

I Art-ong Pradatsundarasar, 1982

II Art-ong Pradatsundarasar et al., 1989

III Thaviongse Sriburi and Nantana Gajaseni, 1996

IV Rangsimant Bautong, 1997

V this study, 2005

From previous studies (Figure 4.4 and Table 4.4), since 1982 density of razor clam was increased from 10 to 65.5 individual/m^2 until 1989 then it was decreased from 65.5 to 4.6 individual/m^2 until 1997 and this study density of razor calm has a small increase from 4.6 to 5.7 individual/m^2. The main causes of razor clam density reduction might be harvesting pressure from local fisherman and changing of environment in Don Hoi Lord (Art-Ong Pradatsundarasar et al., 1989)

Applying lime solution on the razor clam habitat for harvest razor clam (Nantana Gajaseni et al., 2004) was the one favorite method around 10 years ago; this method has more powerful to harvest razor clam because every razor clam in dressing area will jumping from hole and fisherman can catch all of razor clam but in reality they selected the big size (since 5 cm) only. This method may the main cause to reduced razor clam population because razor clam size less than 5 cm were discarded and die from lime poison or eat by another animal on sand dune later. Now a day, this harvesting method are prohibited from local government so density of this study may start recovering from effect of Dressing lime solution method when compare with Rangsimant Bautong (1997).

The reduction of razor clam population may also be caused by environmental deterioration around Don Hoi Lord. The area has changed from mangroves to shrimp aqua-culture at approximately 20 years ago (Art-Ong Pradatsundarasar et al., 1989). Nowadays, most of shrimp aqua-culture has been abandoned. In addition, infrastructure (for example restaurant, car park) was constructed to replace the mangrove area around the sand dune due to tourist promoting by provincial government.

4.3.2 Razor clam weight

Mean value of razor clam weight during 12 months of the study from March 2004 to February 2005 are presented in g/individual in figure 4.5

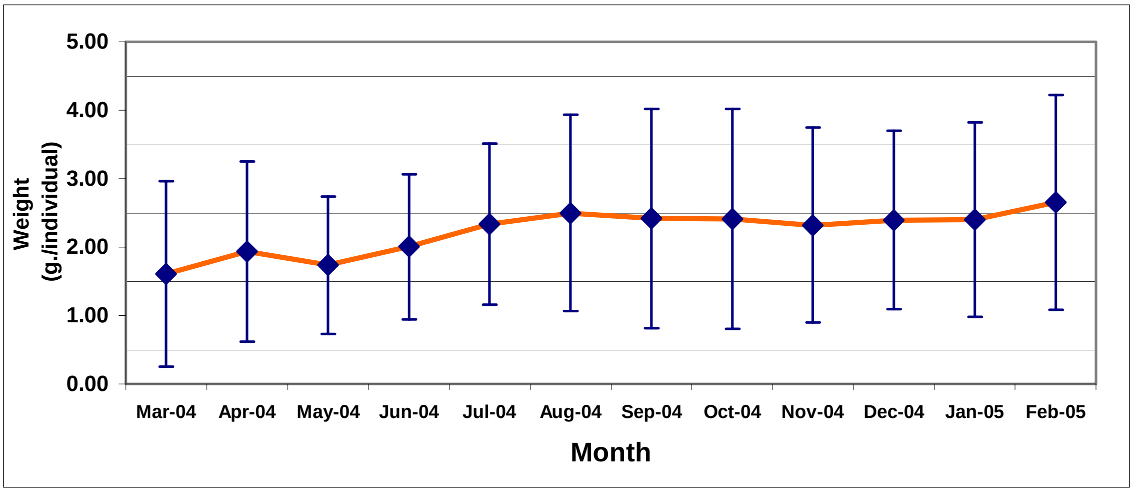


Figure 4.5 Mean of razor clam weight (g/individual) in this study

Table 4.6 Mean of razor clam weight by monthly

Mean of razor clam weight ± SD (g./individual)												
Month	**Mar-04**	**Apr-04**	**May-04**	**Jun-04**	**Jul-04**	**Aug-04**	**Sep-04**	**Oct-04**	**Nov-04**	**Dec-04**	**Jan-05**	**Feb-05**
Weight	1.61 ± 1.35	1.93 ± 1.32	1.74 ± 1.01	2.01 ± 1.06	2.34 ± 1.18	2.50 ± 1.44	2.42 ± 1.61	2.41 ± 1.61	2.32 ± 1.42	2.40 ± 1.30	2.40 ± 1.42	2.65 ± 1.57

From figure 4.5, mean of razor clam weight increased from March 2004 to August 2004 then it gradually decreased until November 2004 and then it increased again until February 2005. Mean of razor clam weight in this study was 2.14±0.33 g/individual, maximum of mean razor clam weight was 2.65 ± 1.57 g/individual in February 2005 and minimum of mean razor clam weight was 1.61±1.35 g/individual in March 2004.

Independence t-test at $P < 0.05$ of monthly mean weight data under SPSS program (Table 4.5) shows that razor clam weight is different between from month to month between March 2004 to August 2004 and then razor clam weight is not different until end of the study.

Table 4.7 Statistical analysis of razor clam weight (Independent Sample T-Test at $P < 0.05$)

Month-to-month	**Weight test (Sig. (2-tailed) value in SPSS)**
March 2004 vs April 2004	0.000
April 2004 vs May 2004	0.002
May 2004 vs June 2004	0.000
June 2004 vs July 2004	0.000
July 2004 vs August 2004	0.041
August 2004 vs September 2004	**0.444**
September 2004 vs October 2004	**0.946**
October 2004 vs November 2004	**0.454**
November 2004 vs December 2004	**0.463**
December 2004 vs January 2005	**0.971**
January 2005 vs February 2005	**0.081**

In August 2004 and February 05, there were 2 peaks of highest of mean razor clam weight as 2.50±1.44 and 2.65±1.57 g/individual respectively which are closed the breeding season of razor clam, the first in March and April, the second in July and August (Art-Ong Pradatsundarasar et al., 1989).

Sunan Tuaycharoen and Panit Voraingtara (1991) reported mean of razor clam weight in Ban Bangboo, Samut Songkhram province was 4.46 g/individual. When compare with this study, mean of razor clam weight reduced to 50 %. It may reflect the declining of razor clam population.

4.3.3 Razor clam size

Mean of razor clam Length along 12 months of study from March 2004 to February 2005 represented in cm/individual as figure 4.6

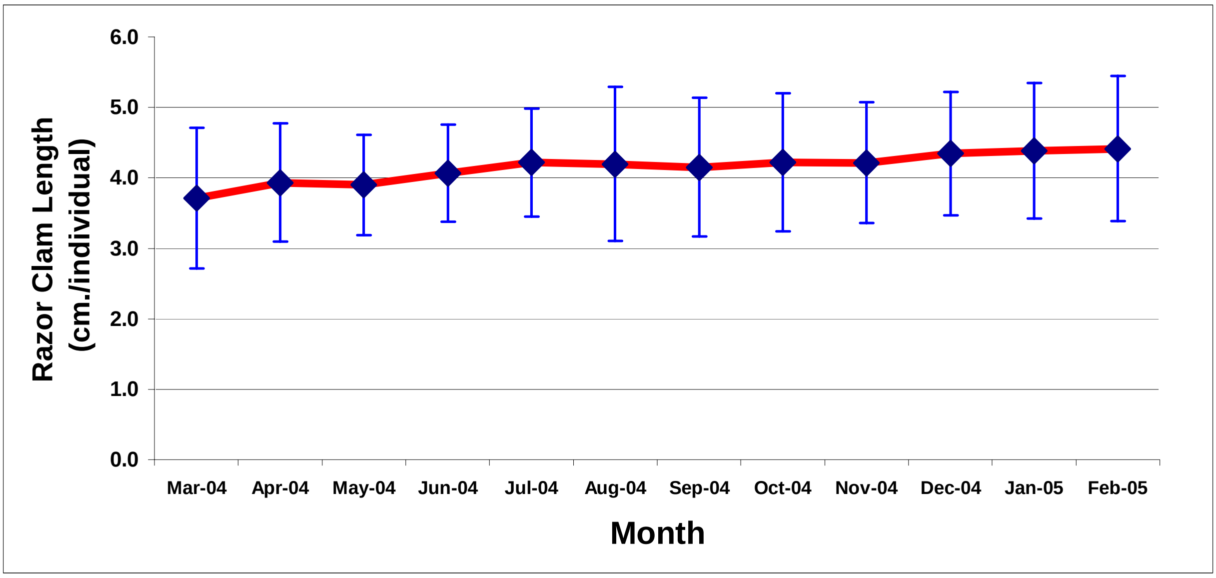


Figure 4.6 Mean of razor clam size (cm/individual) in this study

Table 4.8 Mean of razor clam length by monthly

Mean of Razor clam Size ± SD (cm./individual)												
Month	**Mar-04**	**Apr-04**	**May-04**	**Jun-04**	**Jul-04**	**Aug-04**	**Sep-04**	**Oct-04**	**Nov-04**	**Dec-04**	**Jan-05**	**Feb-05**
Clam size	3.7 ± 1.00	3.9 ± 0.80	3.9 ± 0.70	4.1 ± 0.70	4.2 ± 0.80	4.2 ± 1.10	4.1 ± 1.00	4.2 ± 1.00	4.2 ± 0.90	4.3 ± 0.9	4.4 ± 1.0	4.4 ± 1.0

From figure 4.6, mean of razor clam size seemed to increase through out the study period. Nevertheless, there was only one month in September 2004 that mean of razor clam size was decreased. Mean of razor clam size in this study was 4.15±0.90 cm./individual, maximum mean of razor clam size was 4.4±1.0 cm./individual in January and February 2005 and minimum mean of razor clam size was 3.7±1.0 cm./individual in March 2004.

Independence t-test at P < 0.05 of monthly mean length data under SPSS program (Table 4.6) shows that most of razor clam length in each month are not different between month except March 2004-April 2004, May 2004-June 2004, June 2004-July 2004 and November 2004-December 2004.

Table 4.9 Statistical analysis of razor clam length ((Independent Sample T-Test at P < 0.05)

Month-to-month	**Length test (Sig. (2-tailed) value in SPSS)**
March 2004 vs April 2004	0.000
April 2004 vs May 2004	**4.373**
May 2004 vs June 2004	0.000
June 2004 vs July 2004	0.000
July 2004 vs August 2004	**0.726**
August 2004 vs September 2004	**0.522**
September 2004 vs October 2004	**0.374**
October 2004 vs November 2004	**0.948**
November 2004 vs December 2004	0.048
December 2004 vs January 2005	**0.608**
January 2005 vs February 2005	**0.730**

Sunan Tuaycharoen and Panit Voraingtara, (1991) reported razor clam has mutuality and can reproduced at size over 4.24 cm. Whereas, Chanintorn Srithongsuk et al., (1990) reported that razor clam can produced gamete from initial size of 1.83 cm. However, mean razor clam size from this study was 4.15±0.90 cm/individual, implying that now razor clam can produce gamete but may not successfully reproduce until the size reach to 4.24 cm.

4.3.4 Population structure of razor clam

The study of razor clam population structure separated razor clam into 6 classes based on shell length and calculated number and percentage in each size class.

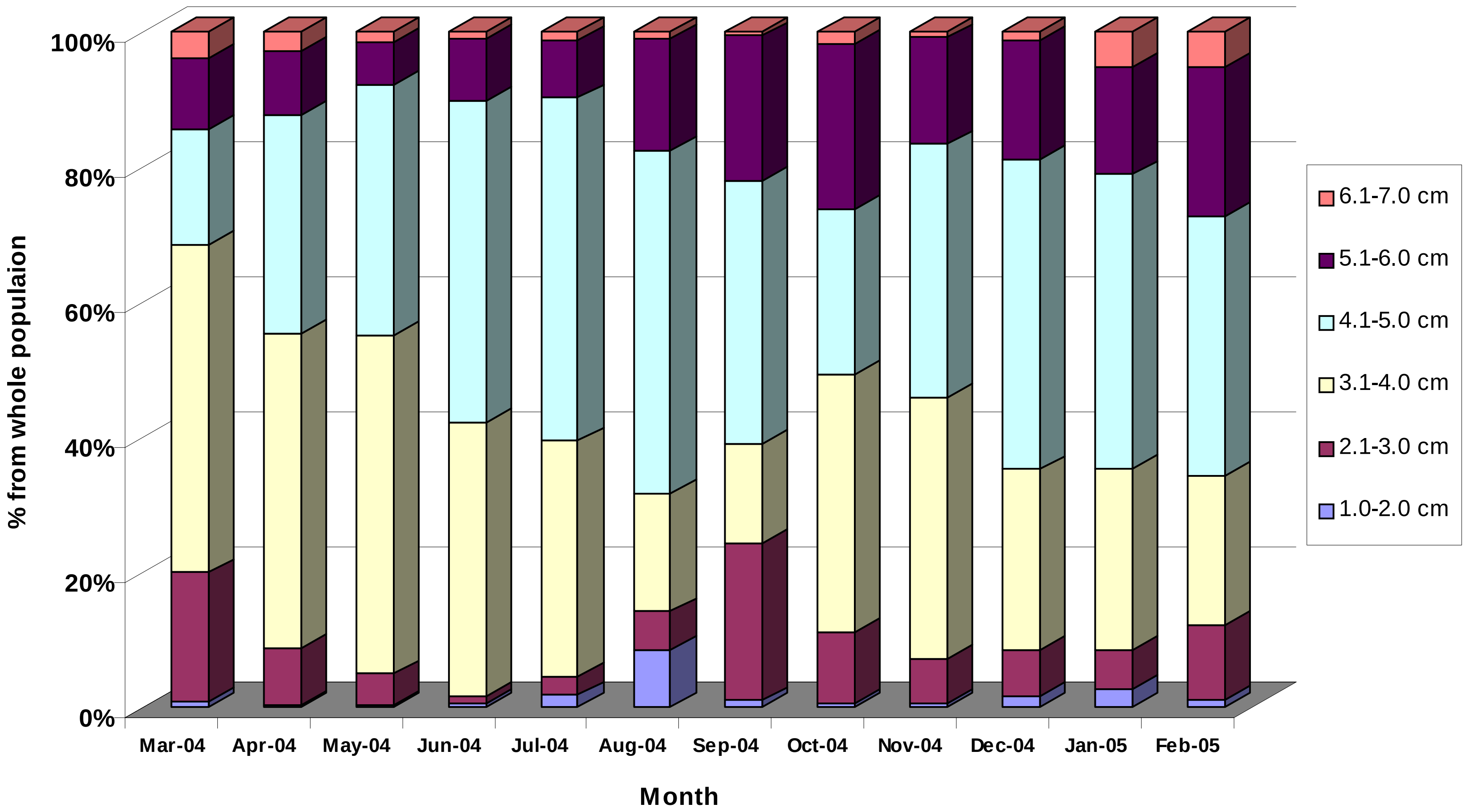


Figure 4.7 Total population structure of razor clam in percentage scale

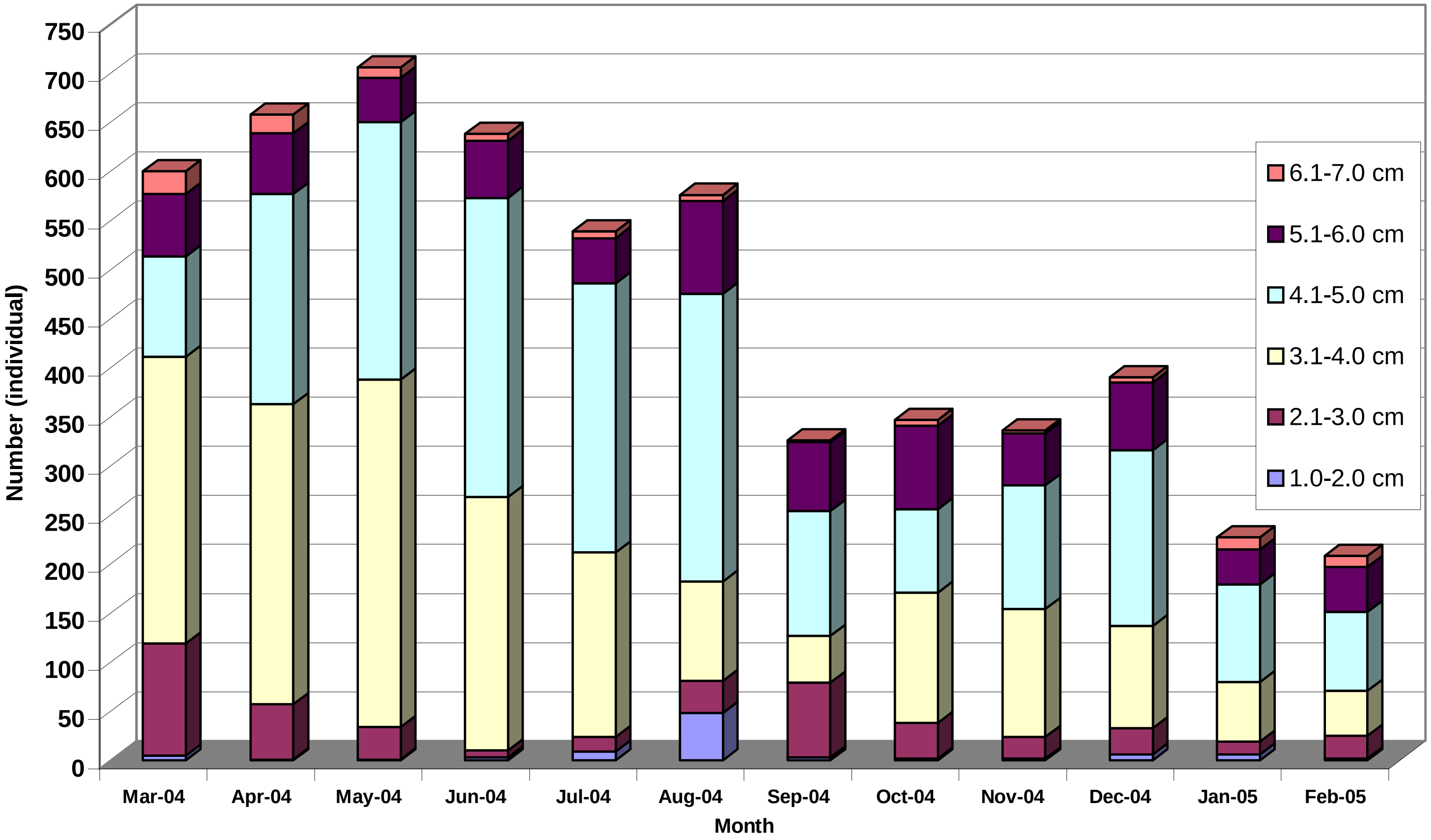


Figure 4.8 Total population structure of razor clam in number scale

Table 4.10 Number and percentage of razor clam in each size class

	Mar-04		Apr-04		May-04		Jun-04		Jul-04		Aug-04		Sep-04		Oct-04		Nov-04		Dec-04		Jan-05		Feb-05	
size	Num	%	Num	%	**Num**	**%**	**Num**	**%**	**Num**	**%**	**Num**	**%**	**Num**	**%**	**Num**	**%**	**Num**	**%**	**Num**	**%**	**Num**	**%**	**Num**	**%**
1-2 cm	5	0.83	1	0.15	1	0.14	3	0.47	9	1.67	48	8.33	3	0.92	2	0.58	2	0.60	6	1.54	6	2.64	2	0.96
2-3 cm	114	19.00	56	8.51	33	4.67	7	1.10	15	2.78	33	5.73	76	23.31	36	10.37	22	6.55	27	6.92	13	5.73	23	11.06
3-4 cm	292	48.67	306	46.50	354	50.14	258	40.44	188	34.88	101	17.53	48	14.72	133	38.33	130	38.69	104	26.67	61	26.87	46	22.12
4-5 cm	102	17.00	214	32.52	262	37.11	305	47.81	274	50.83	293	50.87	127	38.96	85	24.50	126	37.50	179	45.90	99	43.61	80	38.46
5-6 cm	64	10.67	62	9.42	45	6.37	58	9.09	46	8.53	95	16.49	70	21.47	85	24.50	53	15.77	69	17.69	36	15.86	46	22.12
6-7 cm	23	3.83	19	2.89	11	1.56	7	1.10	7	1.30	6	1.04	2	0.61	6	1.73	3	0.89	5	1.28	12	5.29	11	5.29
Total	**600**	**100**	**658**	**100**	**706**	**100**	**638**	**100**	**539**	**100**	**576**	**100**	**326**	**100**	**347**	**100**	**336**	**100**	**390**	**100**	**227**	**100**	**208**	**100**

Population structure, most of razor clam population was size 3 to 5 cm. and sizes from 4 cm. were caught by fisherman. Thus, this study found that population of razor clam size 5 cm. existed in small percentage. On the other hand, population of small razor clam (1 to 2 cm.) was found all year (Table 4.6) especially in August 2004 and January 2005 was 8.33 and 2.64 %. It was the first and the second rank in this study. Furthermore, if population of razor clam size over than 4 cm. was also found every month it can reproduce offspring all year long. Razor clam population size 2 to 3 cm. had decreased since March 04 to June 04 and started increasing again in the following month to September 2004 with maximum of razor clam population size 2 to 3 cm. (23.31%). After that it deceased from 23.31 % to 10.37% and had consistence until February 2005. Razor clam population size 5 to 6 cm. was corresponded with razor clam population size 2 to 3 cm. (Figure 4.8) when size 2 to 3 cm. decreased population size 5 to 6 cm. also decreased.

Breeding season of razor clam in this study occurred all year long because population of small razor clam (1 to 3 cm.) was found every month except June 04 was found in small percentage. It corresponded with Art-Ong Pradatsundarasar et al, (1989) in terms of razor clam can breed all year long. On the other hand, there were 2 peaks population of small razor clam in March 2004 and September 2004. Based on the growth rate of razor clam is 1 cm./month (Ruffolo et al., 1999), population of small razor clam in these month should be fertilized 3 month ago. Before small razor clam was found, it might imply that the peak of razor clam breeding season were around June to July and November to December.

The finding of this study also agreed with the previous study by Sunan Tuaycharoen and Panit Voraingtara (1991) in terms of peaks of breeding season November to April and June to October and small razor clams were found every month except June 2004 was found in small percentage, it might imply that the month before June or May razor clam breed in small percentage. Moreover, peak of razor clam breeding season in this study also corresponded to previous study by Art-Ong Pradatsundarasar *et al*. (1989) in that peak of razor clam breeding season was March to April and July to August, Thaviongse Sriburi and Nantana Gajaseni (1996) in that peak of razor clam breeding season was April to July.

However, the differences in the peaks of razor clam breeding season in the study maybe caused by some ecological factors. Wong et al. (1986) indicated that temperature was an important factor to induce maturation of gametes and consequential breeding even if temperature higher or lower than normal. The first peak of razor calm breeding season in this study (June to July) occurred at daytime low tide during June to July, sand dune exposed to sunlight quite many hours so temperature on sand dune was high. It may activate razor clam gamete, while tidal time will differences in every year therefore peak of razor clam breeding season can change due to tidal time in each year. In general, breeding season of marine invertebrate is usually influenced by change of temperature in each season and lunar period or tidal cycle in each month. These effects on gamete maturation to right season and gamete releasing right tidal cycle to effective fertilization (Levinton, 1982).

The second peak of breeding season occurred during November to December at night-time low tide due to the constraints of temperature which is big change from previous month. During September to February, it was a night-time low tide and small razor clam (size $\geq$ 3 cm) was found in every month in steady percentage. In the comparison between daytime low tide (March to August) and night-time low tide, razor clam might breed at night-time low tide in longer period than at daytime low tide. Art-Ong Pradatsundarasar ea al. (1989) found that one razor clam in December had gamete in spermatozoa stage, confirming the second peak of breeding season in this study. However, the second peak of breeding season was also influenced from temperature change; the temperature was rapidly dropped compare with the daytime low tide. In addition, during the night-time low tide in the rainy season, a lot of nutrients will coming with flood then there are unlimited factor for phytoplankton and high tide occurred in daytime. It promoted photosynthesis of phytoplankton. Rangsimant Bautong (1997) reported that composition of plankton in razor clam stomach contents was phytoplankton only. Thus, phytoplankton might be a one of ecological factor for razor clam breeding season because from figure 4.8 razor clam size ≥ 3 were found every month during night-time low tide.

4.3.5 Relationship between weight and length of razor clam

Length-weight relationship (LWR) (Park and Oh, 2002)) of razor clam in this study is shown in figure 4.10

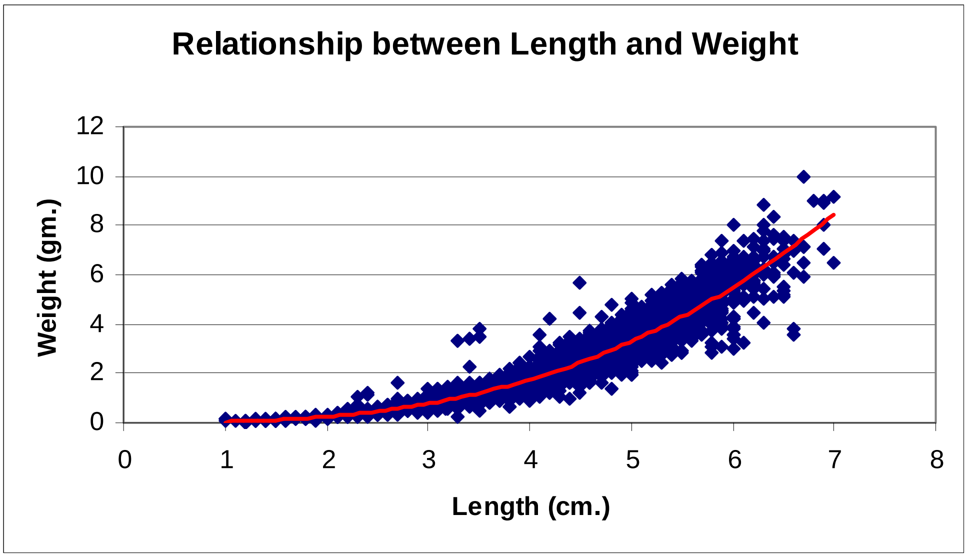


Figure 4.9 Length-weight relationship (LWR) of razor clam in this study

The relationship between length and weight of razor clam is represented in power function:

$$W = aL^b$$

When W = razor clam weight

L = razor clam length

a = specific gravity or intercept

b = growth constant or slope

Source: Thanitha Thapanand (2000), Park and Oh (2002)

Thus, power function of LWR of razor calm in this study is **$W = 0.0356L^{2.8118}$**

Correlation coefficient (r^2) = 0.935, n=5551

The exponent (*b*) is 2.8118, and can imply that razor clam has allometric growth pattern because the growth is equal to 3 (Thanitha Thapanand, 2000). In addition, LWR of razor clam was estimated by regression curve and ANOVA using SPSS for Windows version 11.5 to assess their relationship. The result shows that length and weight have a power function relationship (F test from ANOVA and t-test from curve estimation regression at $p<0.01$) and the parameters in function correspond the previous parameters.

Correlation coefficient (r^2) in this study is 0.935, meaning that length of razor clam can explain variation of razor clam weight at 93.5 % (Kanlaya Vanichbancha, 2003) or the correction of the power equation of razor clam LWR in this study is 93.5%.

Park and Oh (2002) studied LWR of bivalves (17 species included Genus *Solen*) from coastal waters of Korea and reported that *b* value in the power function has ranged from 2.44 to 3.31, mean of *b* value was 2.89±0.212 and r^2 of all species were over 0.9 at significant $p<0.001$. These parameters correspond with this study ($b = 2.8118$, $r^2 = 0.935$).

4.4 HUMAN ACTIVITIES

4.4.1 Number of local fisherman

Number of local fishermen who goes to harvest razor clam in the study during March 2004-Februny 2005 is shows in figure 4.10.

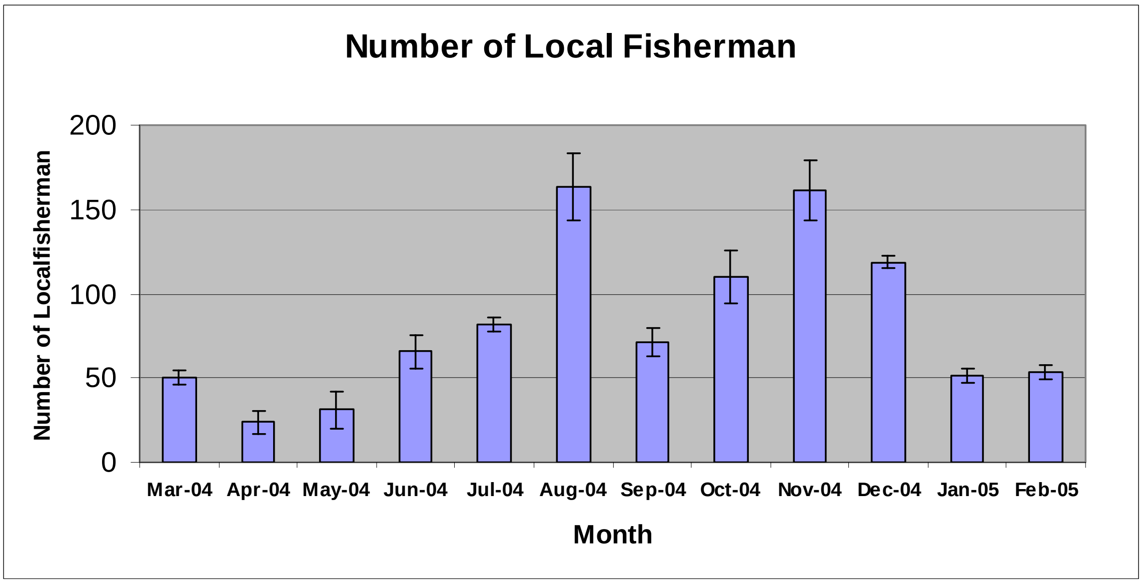


Figure 4.10 Mean of number of local fisherman (person/day) in study area in each month

Table 4.11 Mean of local fisherman number in the study area

Mean of number of local fisherman in the study area with SD (person/day)												
Month	**Mar-04**	**Apr-04**	**May-04**	**Jun-04**	**Jul-04**	**Aug-04**	**Sep-04**	**Oct-04**	**Nov-04**	**Dec-04**	**Jan-05**	**Feb-05**
number	50	24	31	66	81	163	71	110	161	119	51	53
sd	4	7	11	10	4	20	9	16	18	4	4	4

The number of local fishermen harvesting razor clam in the study area, differed in each month. Mean number of local fishermen was 82±9 persons/day, maximum number of local fisherman was 163±20 persons/day in August 2004 and minimum number of local fisherman was 24±7 persons/day in April 2004.

The difference in local fisherman number might be explained by many factors which affected local fisherman decision to go to harvesting razor clam in the study area, For example, density of razor clam, climate, season and opportunity of additional job. The main reason from interview which affected to local fisherman decision is density of razor clam because there is another razor clam source near the study area to access due to the razor clam reduction. Therefore, local fisherman will go to harvest in another razor clam area and make a decision to move or still stay in the study area.

The second reason from interview was opportunity of additional job, Natsucha Oiamsomboon (2000) reported that 34.4 % of villager around Don Hoi Lord have a second job which agreed the interview data. In some month, the density of razor clam is low and some labor wage in fishery is high (for example, crab fishery) so they decide to earn income from labor in fishery instead of harvesting razor clam.

4.4.2 Fisherman harvesting rate and interval time to catch razor clam

Fisherman harvesting rate and interval time to catch razor clam (both of them from local fisherman interview) in each month have shown together in figure 4.11

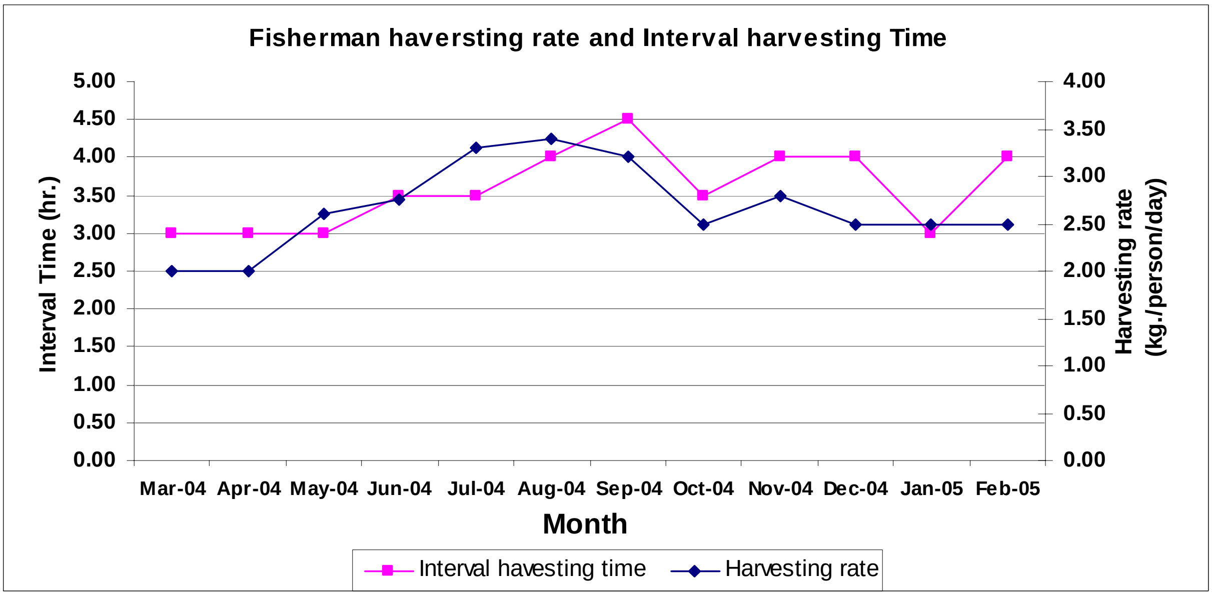


Figure 4.11 Fisherman harvesting rate and interval time to catch razor clam
(Note: Harvesting rate on right X axis and interval time on left X axis)

Maximum razor clam harvesting rate was around 3.4 kg./person/day in August 2004 and minimum razor clam harvesting rate was around 2 kg./person/day in March and April 2004. Furthermore, the longest interval time this spent by fisherman to catch razor clam was around 4.5 hours in September 2004 , beside the shortest interval time around 3 hours in March, April, May 2004 and January 2005.

Figure 4.11 represented the relationship between fisherman harvesting rate and estimated interval time to catch razor cam from local fisherman interview in each month. From the graph shown the positive relationship between harvesting rate and interval time, the harvesting production depended on the time that local fisherman spent to catch razor clam. However, the main factor influencing harvesting rate might be the density of razor clam because in some months the low tide period long but the harvesting rate is not much due to the interval time. For example, in September 2004 the interval time was longest around 4.5 hrs but the harvesting rate did not reach maximum. In addition, the private interviewing of local fisherman shown that "In some month if the density of razor clam was not too much and I could not get razor clam much enough then I preferred to go back home and get some rest" said local fisherman (Rungruang Artayagul, interviewed, July 1st, 2004). Moreover, there are other jobs in some month which help local fisherman increase their income. For example, in January 2005 with night-time low tide the interval time to catch razor clam was shorter than other month while the harvesting rate stills the same. At that moment, there was blue crab season then local fisherman could go to work in crab fishery or to do individual crab harvesting in the day time so they could earn enough income and prefer to take a rest at home instead of going out again for razor clam harvesting during the night-time (Sutin Aim-augsorn, interviewed, February 11th , 2005). In addition, there are many reasons affecting the time of razor clam harvesting such as abnormal climate, wave and wind in the sea, social festival (songkran festival,for instance).

4.4.3 Razor clam price

Dynamics of razor clam price was set up by the trader throughout the year are shown in figure 4.12

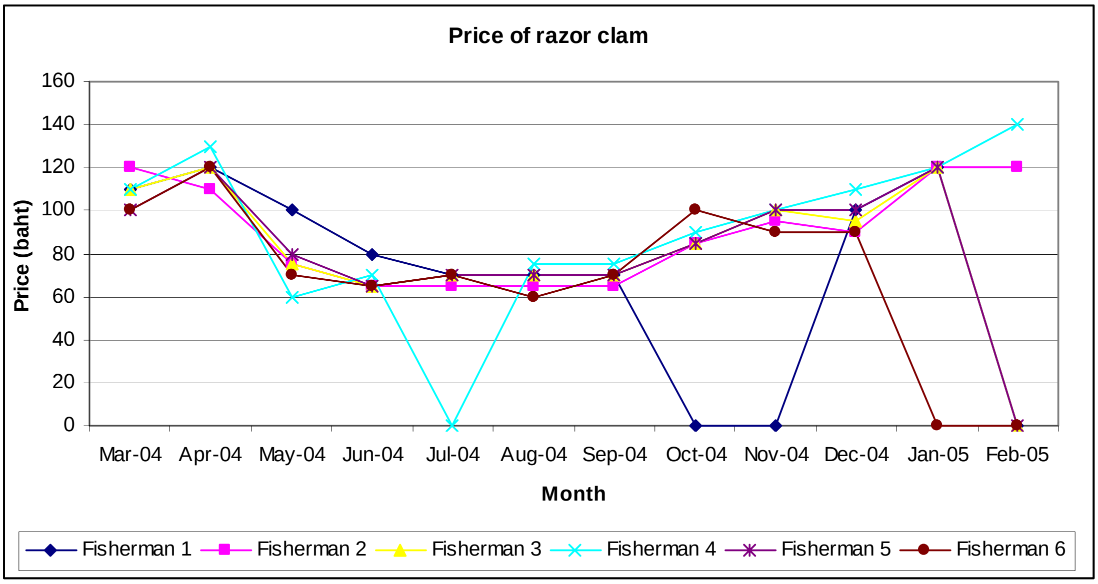


Figure 4.12 Dynamics of razor clam price in one year from 6 local fishermen

(* price = 0 mean local fisherman decided to get additional job in that month)

From figure 4.12, razor clam price set up by various trader who local fisherman regularly sell was increased one month in April after low tide occurred during the day time (March-August) and after that the price had decreased and started increasing again when the low tide occurred at the night-time (September-February). Maximum of razor clam price was 140 baht/kg. in February 2005 and Minimum price was 65 baht/kg. in June 2004.

The maximum price of razor clam was in the last month of night-time low tide. During December 2004 to February 2005 there was a crab season in which some fishermen preferred to go to work for crab fishery, making the total amount of razor clam harvesting was decreased so the trader raised up the price to accelerate razor clam harvesting rate to meet market demand. The minimum price of razor clam was occurred during the daytime low tide during March 2004 to August 2004. Figure 4.12 shows that the price of razor clam during daytime low tide was rather low when compared to the price of night-time low tide, from the trader interview shown the simple mechanism of buying razor clam price that "when the low tide occur at daytime, there are more local fisherman than other time go to harvest razor clam and the harvesting rate was higher. Therefore, the more daily razor clam production was the less price was set up by trader regarding surplus of market demand." (Ram (trader), interviewed, March 3rd 2005)

4.4.4 Number of tourist

Mean of tourist number who visited the sand dune in each month is shown in figure 4.13

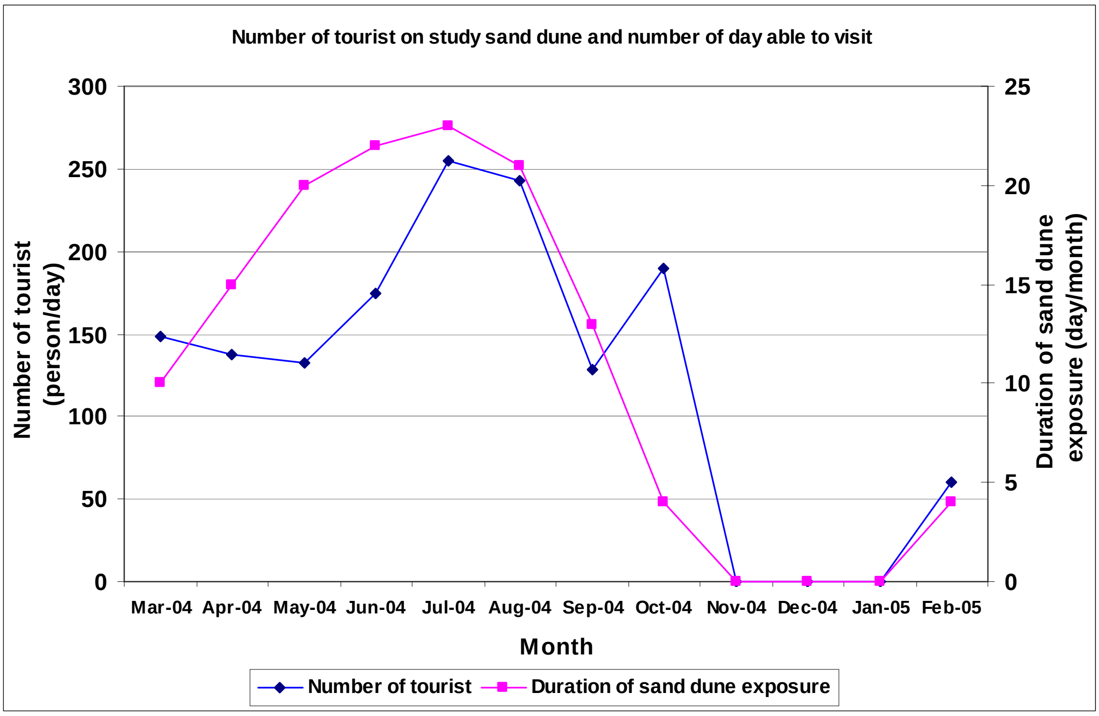


Figure 4.13 Mean of tourist number on the study sand dune and duration of sand dune exposure.

Tourist number on the study sand dune at the daytime low tide was over 100 persons per day especially in June-August 2004. The number of tourist increased because the daily interval time of low tide and the duration of sand dune exposure per month were longer than other month. On the other hand, the night-time low tide was occurred after August 2004, then the number of tourist visit on sand dune decreased because the sand dune expose only at night. Therefore, the seasonal condition caused tourist visit decline, they could visit for other purpose such as having seafood, shopping, natural appreciation etc.

4.4.5 Tourist behavior

Tourist general information and behaviors from questionnaire (N=146) were analyzed by SPSS 11.5 for Windows and the results are as following:

General characteristics of tourist

Sex

Tourist population consisted of female=54.1% and male=45.9%

Age

There are 5 groups of age range in this study. The first age range was 20-30 years old of 34.5%, the second was 31-40 years old of 26.2 %, the third was < 20 years old of 18.6%, the forth was 41-50 years old of 12.4% and the fifth was >50 years old of 8.3%.

Type of occupation

The occupations of tourist of this study consisted of 36.9% of employer, 23.3% of student, 20.5 % of merchant, 18.5% of government officer and other occupation was 0.7%.

Income

Total income of tourist from questionnaire were separated into 7 groups, the highest mode of tourist income was range 8,001-10,000 bath/month of 16.7%, second mode was range 6,001-10,000 bath/month 16.0%, third mode was <2000 bath/month 14.6%, forth mode was range 2,001-4000 bath/month and 4,001-6,000 bath/month both of 13.9%, sixth mode was > 14,000 bath/month 13.2 % and finally, the lowest mode of tourist income was range 10,001-14,000 bath/month 11.8%.

Visit to Don Hoi Lord

From the questionnaire most tourists used to visited Don Hoi Lord (79.5%) and retured to visit again and 20.5% of tourist visited Don Hoi Lord for the first time.

Table 4.12 Number and percentage of general characteristics of tourist

General characters		Number	Percentage
Sex			
Male		67	45.9
Female		79	54.1
	total	146	100.0
Age			
< 20 years		27	18.6
20-30 years		50	34.5
31-40 years		38	26.2
41-50 years		18	12.4
>50 year		12	8.3
	total	145	100.0
Occupation			
student		34	23.3
merchant		30	20.5
government officer		27	18.5
employee		54	36.9
other		1	0.8
	total	146	100.0
Income per month			
<2,000 bath		21	14.5
2,001-4,000 bath		20	13.9
4,001-6,000 bath		20	13.9
6,001-8,000 bath		23	16.0
8,001-10,000 bath		24	16.7
10,001-14,000 bath		17	11.8
>14,000 bath		19	13.2
	total	144	100.0
missing 2*			
Visit to Don Hoi Lord			
no		30	20.5
yes		116	79.5
	total	146	100.0

Purposes to visit Don Hoi Lord

From table 4.10, the questionnaires for tourist were design to their purposes to Don Hoi Lord as follows:

Look around area

84.9% of tourists expressed their expression that they like atmosphere at Don Hoi Lord area and other tourist (15.1%) they did not like.

Have a meal

64.4% of tourists they liked to have a meal at Don Hoi Lord and other tourist (25.6 %) they did not like.

Pay respect to Prince Chumporn Khedudomsak memorial

61% of tourists they liked to come and pay their respect to Prince Chumporn Khedudomsak Memorial (PCKM) at Don Hoi Lord based on personal spiritual belief and other tourist (39%) they did not like.

Buy seafood product

41.1% of tourists they like tod buy seafood product from Don Hoi Lord and other tourist (58.9%) they did not like to buy.

Traveling on sand dune

82.2 % of tourists liked to go to traveling on sand dune and other tourist (17.8%) they did not like.

Table 4.13 Frequency of purpose to visit Don Hoi Lord

Purpose to visit Don Hoi Lord	**Number**	**Percentage**
Look around area		
No	22	15.1
Yes	124	84.9
total	146	100.0
Have a meal		
No	52	35.6
Yes	94	64.4
total	146	100.0
Pay respect to PCKM		
No	57	39.0
Yes	89	61.0
total	146	100.0
Buy seafood product		
No	86	58.9
Yes	60	41.1
total	146	100.0
Traveling sand dune		
No	26	17.8
Yes	120	82.2
total	146	100.0

Tourist behavior on razor clam population

From table 4.11 shown tourist behavior potentially affected to razor clam population due to their activities as follow:

Catch razor clam

100% of tourist who liked to go on sand dune preferred to catch razor clam by themselves.

Razor clam catching ability of tourist

81.7% of tourists who went on sand dune and could catch razor clam by themselves but in small number and other tourist (18.3%) could not catch.

<u>Left lime on sand dune</u>

15.8% of tourists who went on sand dune and left a cup of lime and bamboo stick as tools for catching on sand dune and other tourist (84.2%) they had brought it back to main land.

Table 4.14 Frequency of tourist behavior on razor clam population

Tourist behavior on razor clam population	**Number**	**Percentage**
<u>Catch razor clam</u>		
Like to catch	120	100.0
Don't like to catch	0	0.0
total	120	100.0
<u>Razor clam catching ability of tourist</u>		
Can not catch	98	81.7
Can catch	22	18.3
total	120	100.0
<u>Left lime on sand dune</u>		
No	101	84.2
Yes	19	15.8
total	120	100.0

* total number calculated from number of tourist who like to traveling on sand dune

Don Hoi Lord has been promoted as a tourist attraction by provincial and local government and it has unique characteristics and many attractive activities on Don Hoi Lord. From the socio-economic data, gender of tourist was not different between male and female, the mode of tourist age was less than 20 years old up to 40 years old (79.3%) it may imply that young tourists were appreciated to visit Don Hoi Lord. The main occupations of tourist were employment and student (36.9% and 23.3%). The income of tourist were not differenced between each range, it around 10-17% in each range. Finally, almost tourist have ever visited Don Hoi Lord and came back to visit again that the mean of interesting point for sustainable management. If the management at Don Hoi Lord is still appropriate, the tourist will come back to visit again (Pongsak Kumpheng (tourist), interviewed, July 22nd 2004).

The major purpose of tourist was prioritized as nature appreciation (84.9%), sand dune visit (82.2%), sea food appreciation (64.4%). Lastly, they would like to pay respect to PCKM for their spiritual belief (61.0%)

Tourism which makes impact on razor clam population is tourists who went to sand dune and attempted to catch razor clam. From table 4.11, the result indicate just 18.3% of them could catch razor clam. However, there were 15.8% of them left cup of lime and bamboo stick which is equipment for catching razor clam on the sand dune. It possible causes an impact on razor clam population and its habitat by dissolving in water and dispersing during the high tide. Its impact is similar to the applying lime solution method to catch razor clam in the past.

4.5 MULTI-AGENT SIMULATION MODEL CONSTRUCTION

Multi-agent simulation model was constructed by integrating razor clam population data and local fisherman behavior data into the MAS concept on the Cormas platform. It makes better understanding in the interaction between razor clam and local fisherman in Don Hoi Lord system. The main objective of this model is to simulate the real situation of razor clam population based on scientific data and try to make it more reality. The constructed model called "Don Hoi Lord Model" with respecting and relating name of the study area. The overview of the process of the multi-agent simulation model construction is shown in figure 4.15.

The process started from creating a conceptual model to represent ideas and components of the system study, and then transform conceptual model into Unified Modelling Language (UML). The UML is necessary for construction of the model on Cormas platform. Thus, in process of implement UML on Cormas platform we first implemented razor clam model into Cormas platform and define parameters for razor clam model. Sensitivity analysis was carried out to justify parameters of razor clam population which fit with razor clam model. It can represent the reality of model when compared with real data. Then, the implementation of local fisherman was added and parameters were defined in the current Cormas platform, which already had razor clam population model. The relationship between razor clam population and local fisherman model was identified as harvest (Razor clam population harvested by local fisherman). Again, sensitivity analysis was carried out to justify parameters of local fisherman, corresponding to available data. Both razor clam and local fisherman models were in the same Cormas platform and became “Don Hoi Lord model”.

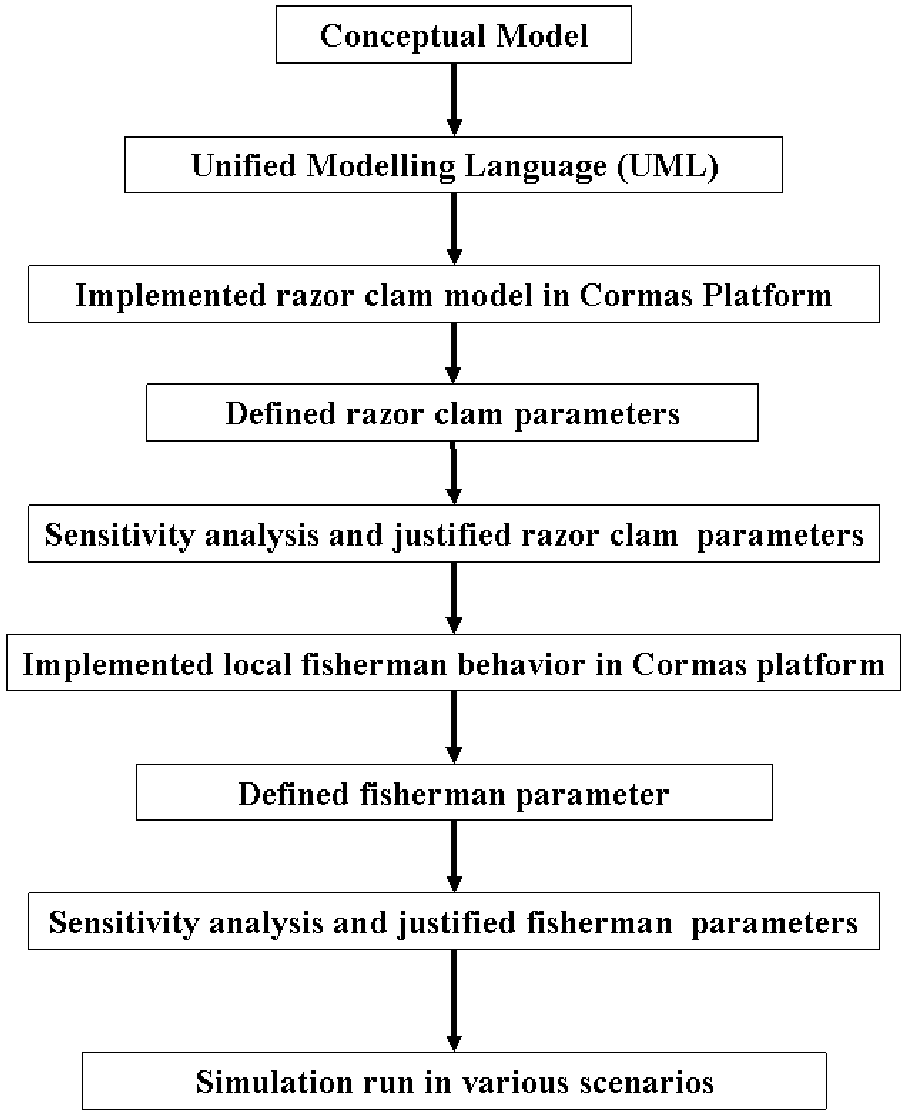


Figure 4.14 Overview of the multi-agent simulation model construction

4.5.1 Conceptual model and UML class diagram

- Conceptual model

The conceptual model of this study is shows in figure 4.15. which represents a simple entities and relations in the system study.

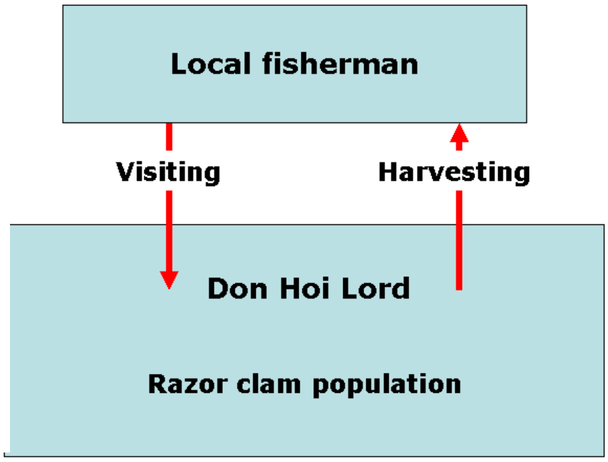


Figure 4.15 Conceptual model for model construction

The conceptual model shows a simple relationship between local fisherman and Razor clam population as follow: Local fisherman visits on Don Hoi Lord according to habitat of razor clam population and harvest razor clam population from Don Hoi Lord.

- UML class diagram

Unified Modelling Language class diagram of Don Hoi Lord model is shown in figure 4.16. It represents both of spatial entity (Cell and razor clam population) and social entity (Local fisherman).Each of them has a specific parameter, operation and tasks to connect together.

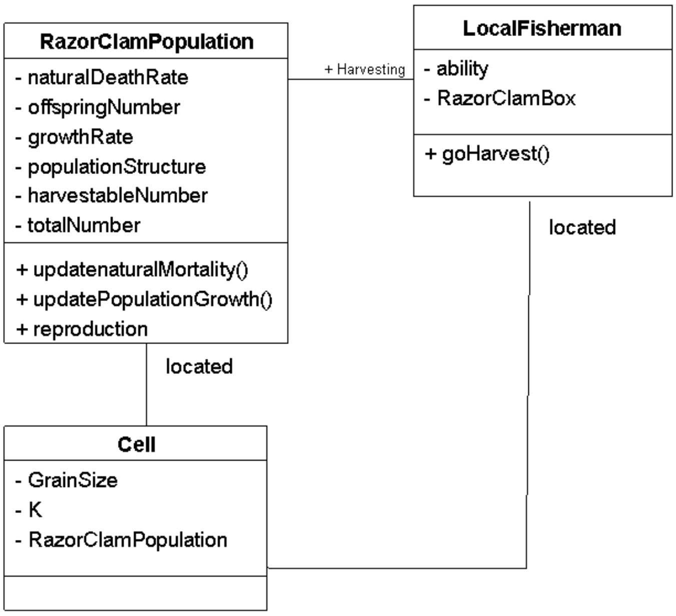


Figure 4.16 UML class diagram of Don Hoi Lord model

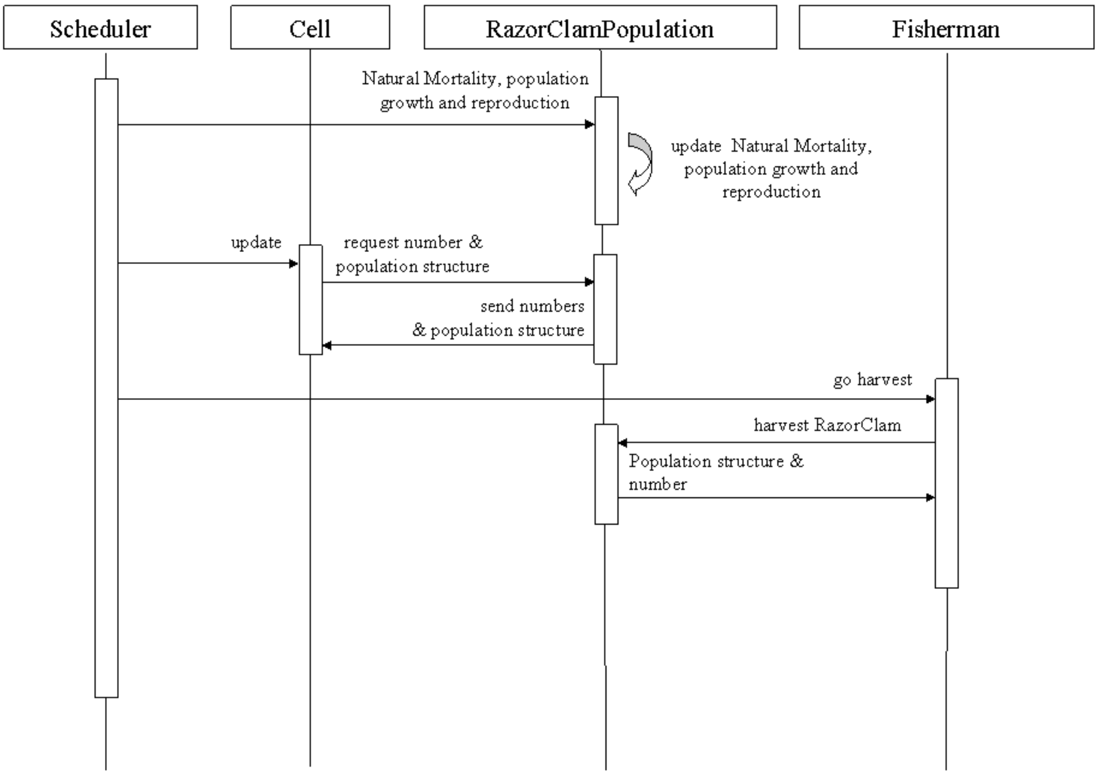


Figure 4.17 Sequential diagram of Don Hoi Lord model

From figure 4.17 represents the activity and operation of model in one step. It starts from Scheduler induced RazorClamPopulation calculating razor clam population data and update a new population data. Then, Scheduler induced Cell to update RazorClamPopulation which locate in the Cell by sending request to RazorClamPopulation. After that Schedule will induce Fisherman (local fisherman) go harvesting razor clam from RazorClamPopulation.

4.5.2 Parameters

The parameters in the model are shown in table 4.15. There are three sets of parameters; spatial grid or cell area parameters, razor clam parameters, and local fisherman parameters.

Table 4.15 Don Hoi Lord model parameters

Parameter	Value	Reference
Spatial grid		
- Number of cell	11x11 in Razor clam population 141x141 in Razor clam population and local fisherman	
- Cell area	1 m^2	Field data collection
- Carrying capacity in equation (K)	30-50	Field data collection sensitivity analysis
- Grain size	1-3	SPSS Cluster analysis from density of razor clam *** see appendix B3**
Razor clam parameters		
- Growth rate	1 cm/30 day	Ruffolo et at., 1999
- Natural mortality (M)	0.02/day	Ruffolo et al.,1999 and Sensitivity analysis
- Sex ratio	1:1	Sunan Tuaycharoean and Panit Voraingtara, 1991 and Baron et al., 2004

Table 4.15 continue

Parameter	Value	Reference
- Breeding size	4 cm	Sunan Tuaycharoean and Panit Voraingtara, 1991
- Percentage of breeding clam/day (1^{st}-12^{th} month) start from March	3.2, 2.6, 3.0, 1.0, 4.0, 3.1, 3.2, 0.2, 1.4, 1.6, 1.6 and 1.8	Sunan Tuaycharoean and Panit Voraingtara, 1991
- Offspring number (OS)	30 from 1 female	Wanpen Sriprathumwong et al., 2545 and sensitivity analysis
Local fisherman parameters		
- Harvesting ability	random 30-100%	Field data collection
- Harvesting movement	random150-250 m^2	Field data collection, Personal interviewed

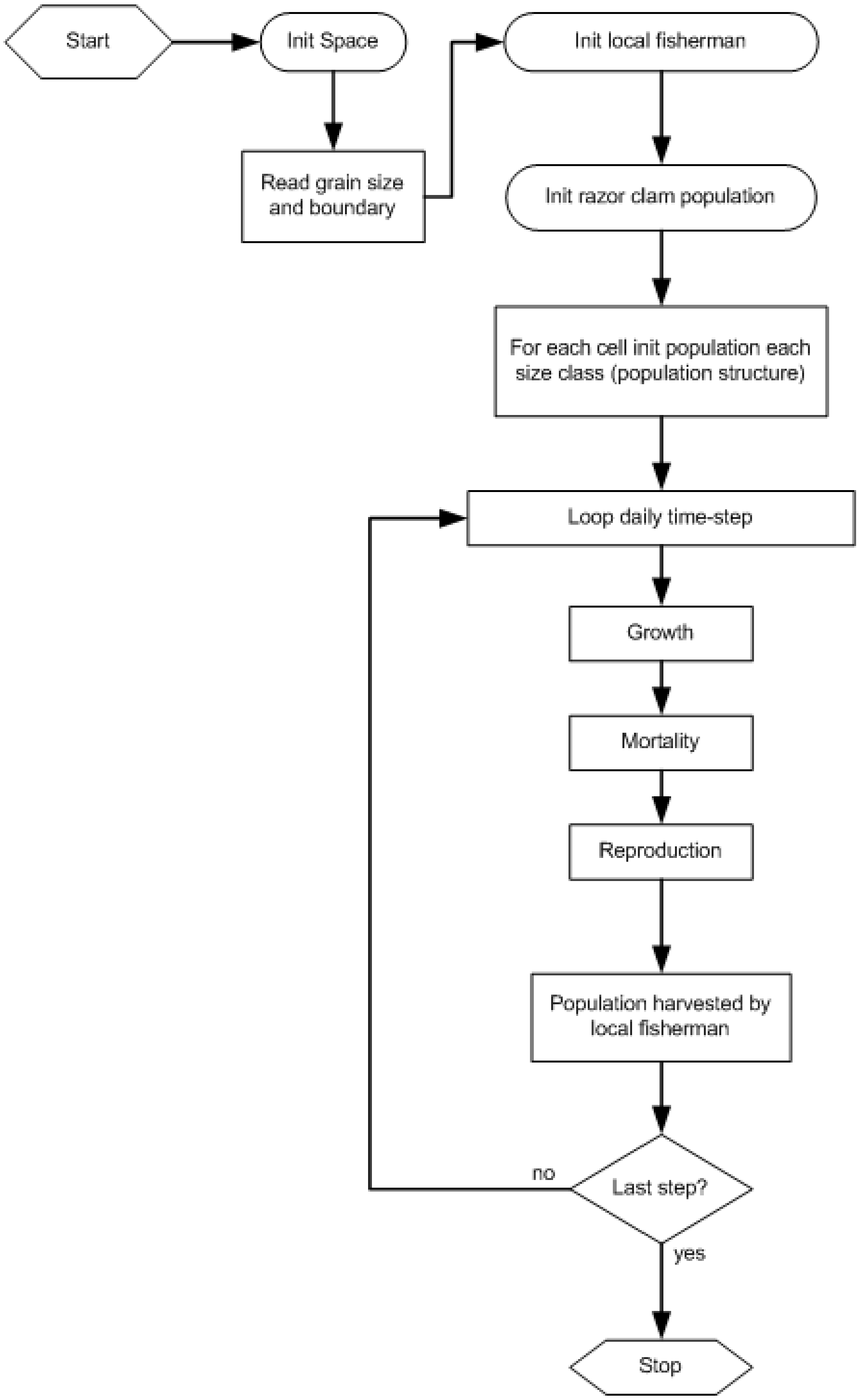


Figure 4.18 Overall flow chart of Don Hoi Lord model

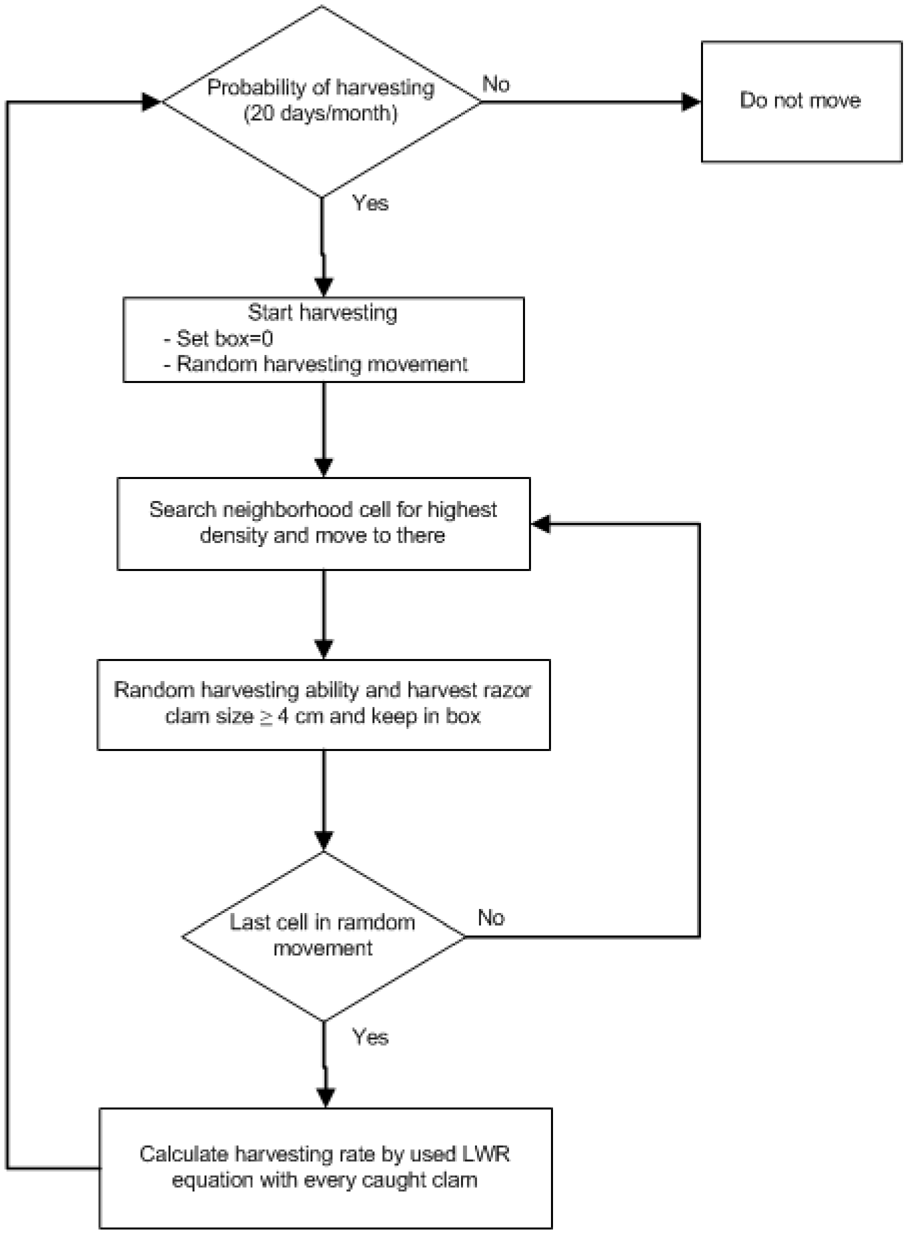


Figure 4.19 Flow chart of local fisherman activity (*LWR see chapter 4.3.5)

Figure 4.18 and 4.19 show the overall flow of Don Hoi Lord model under computer simulation including biological model (figure 4.18) and local fisherman harvesting activity (figure 4.19).

According to table 4.15, some of the parameters were included in the sensitivity analysis which was an important process in modelling approach. The sensitivity analysis helps researcher to justify uncertain parameter. Sensitivity analysis seeks to rank input variables by their influences on predictions of a model (Jager and King, 2004) and then selects the parameters which affect corrective behavior of model when compared with the reality in system study.

After process of implemented razor clam model in Cormas platform, sensitivity analysis was carried out to justify the parameter in the razor clam model. Three kinds of parameter as carrying capacity (K), natural mortality (M) and Offspring number (OS) were run in the difference set of value (K=30, 40, 50 M=0.01, 0.02, 0.03, 0.04, 0.05 OS= 25, 35, 45). Each value set was tested in sensitivity analysis function on Cormas platform.

Forty-five simulation graphs and 39 comparing value graphs in the period of 20 years of razor clam density were produced from sensitivity analysis are shown in Appendix D1 and D2. The decision was made to select in correspond to reality depending on 3 categories:

- Maximum density of razor clam is around 200 individual/sq. m *
- Minimum density of razor clam population is not closed 0 individual/sq m
- There are 2 peaks of density in one year and difference between peaks is not too much. These represent 2 breeding seasons of razor clam in year round*

(*Art-Ong Pradatsundarasar et al., 1989)

From the razor clam sensitivity analysis, based on natural mortality rate (M) had more effects on razor clam population because it reflected fluctuations of razor clam population graph. Carrying capacity (K) and Offspring number (OS) had effects on razor clam population in smaller degree when compared with natural mortality rate in sensitivity analysis. Therefore, natural mortality rate played an important role in razor clam population in Don Hoi Lord model.

Selected parameters from sensitivity analysis were K=30, M= 0.02, OS=25 and density of razor clam graph from these parameter has shown in figure 4.19

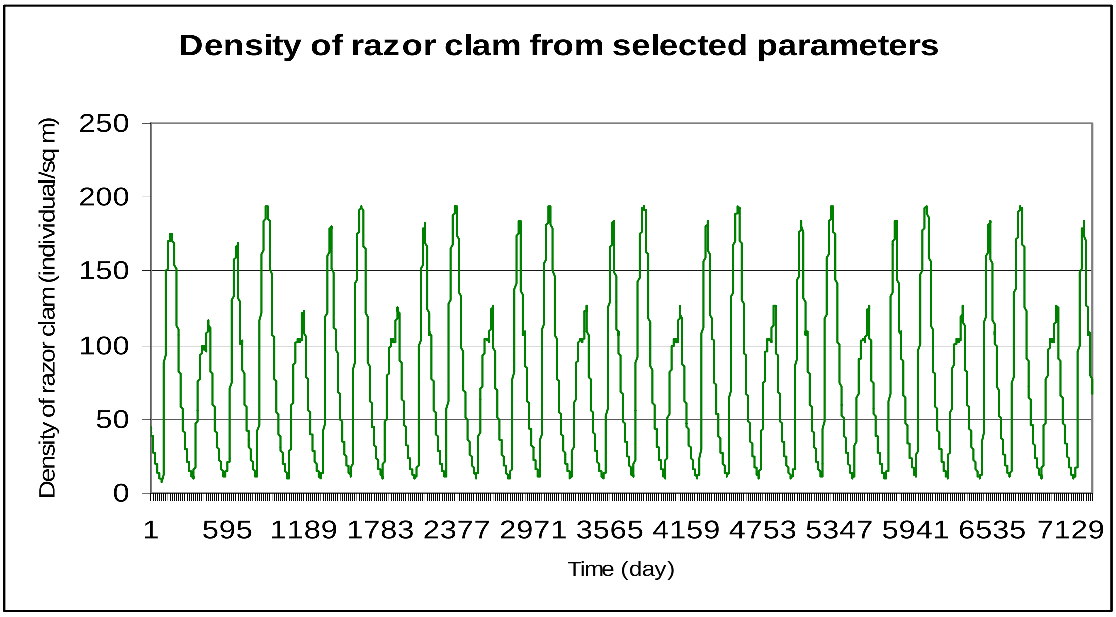


Figure 4.20 Density of razor clam from selected parameters (20 years simulation run)

Local fisherman behavior was implemented into Cormas platform after sensitivity analysis and justified razor clam parameters. Parameters for local fisherman behavior have show in table 4.15.

4.5.3 Scenarios

There are two scenarios in this study, the first scenario came from the real situation at present and the second came from the agreement during collective discussion of local fisherman in the RPG session.

- Scenario I: Non-reserve zoning, freely harvesting every local fisherman can go everywhere on the artificial sand dune in the model.
- Scenario II: Mobile reserve zoning, total area on the artificial sand dune is separated into four equal parts. One of four parts will be closed as protected area for 3 months in year round and do not allowed local

fishermen go there for harvesting razor clam. After 3 months, the protected area have move to other part and protected area from last 3 month ago will be open to access. Therefore, in year round every part will be closed for 3 month in rotation pattern for population of razor clam conservation.

4.5.4 Results from simulation model run

Based on the razor clam distribution is "Clump distribution" (Art-Ong Pradatsundarasar, 1982, and this study). It means that not all area of sand dune have the razor clam. Thus, in the multi-agent simulation model has used space around 20,000 m^2 to explore the interaction between razor clam population and local fisherman harvesting pressure.

In addition, the space in simulation model is separated into 3 zones which is corresponding to the groups of razor clam density by cluster analysis in program SPSS 11.5 for Windows. The groups of razor clam density calculated from the density of razor clam in every station during one year were separated into 3 groups (low density, medium density, high density). The differences of density were put in the simulation model as the quality of gain size (1= low density, 2=medium density and 3=high density) because the observations indicated some differences on razor clam density due to soil texture property.

Figure 4.21 Multi-agent simulation interface represent the difference 3 zones in the model

From figure 4.21,the simulation interface was separated into 3 different zone the dark color area at center of picture represents the high density of razor clam population as gain size = 3, the around dark color represents medium density of razor clam population as gain size=2, lastly the pale color area at corner of picture represent low density of razor clam population as gain size = 1.

The simulation runs were carried out two scenarios (non-reserve zoning and mobile reserve zoning) and also tested in each scenario with difference number of local fishermen (5, 7, 11, 13 and 15 local fishermen). Time step of each simulation run was 10 years and local fishermen start harvest at the 2nd year. Results of the simulations show follows:

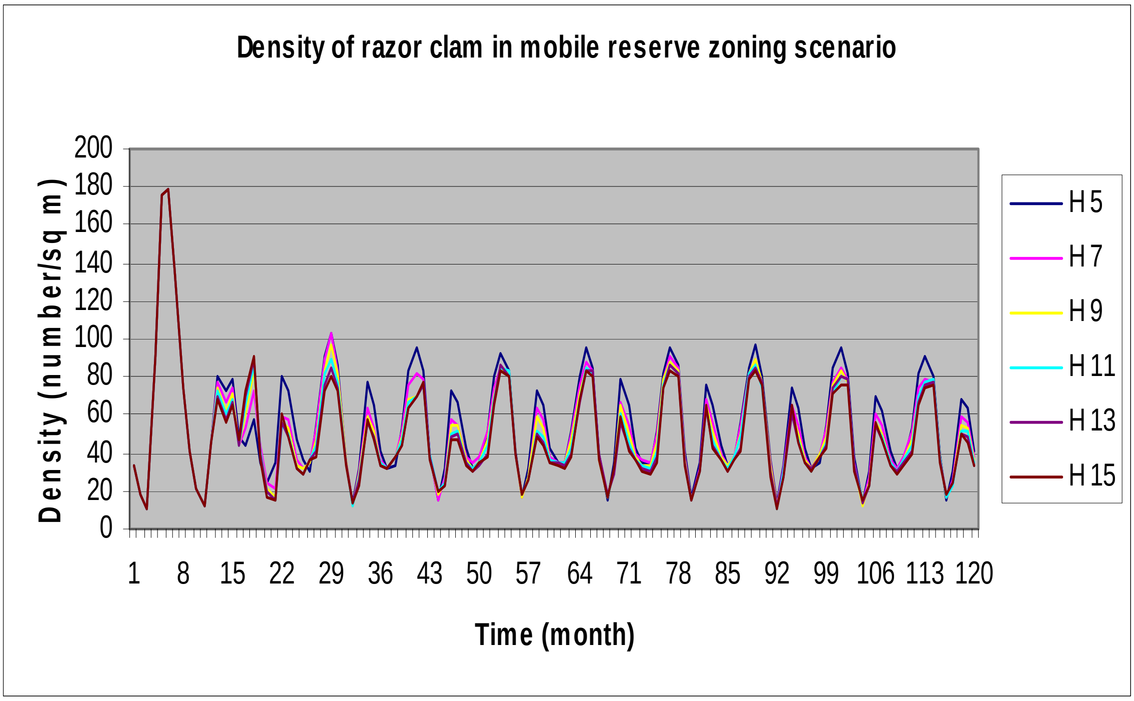


Figure 4.22 Simulation run in density of razor clam in mobile reserve zoning scenario with difference local fisherman number (H5-H15=Density at 5-15 fishermen)

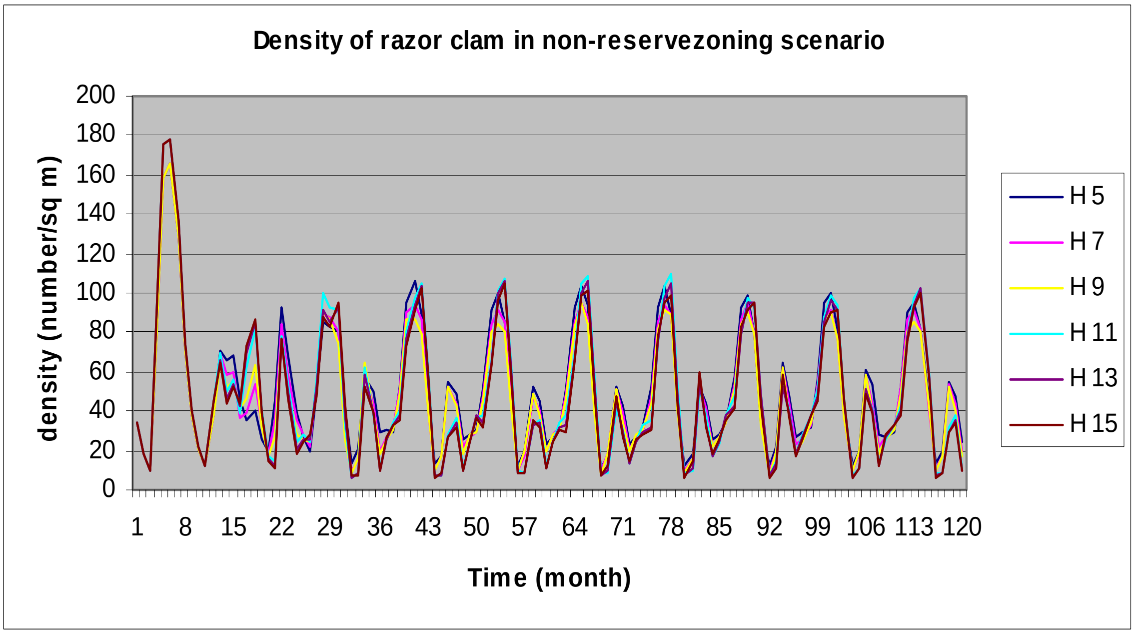


Figure 4.23 Simulation run in density of razor clam in non-reserve zoning scenario with difference local fisherman number (H5-H15=Density at 5-15 fishermen)

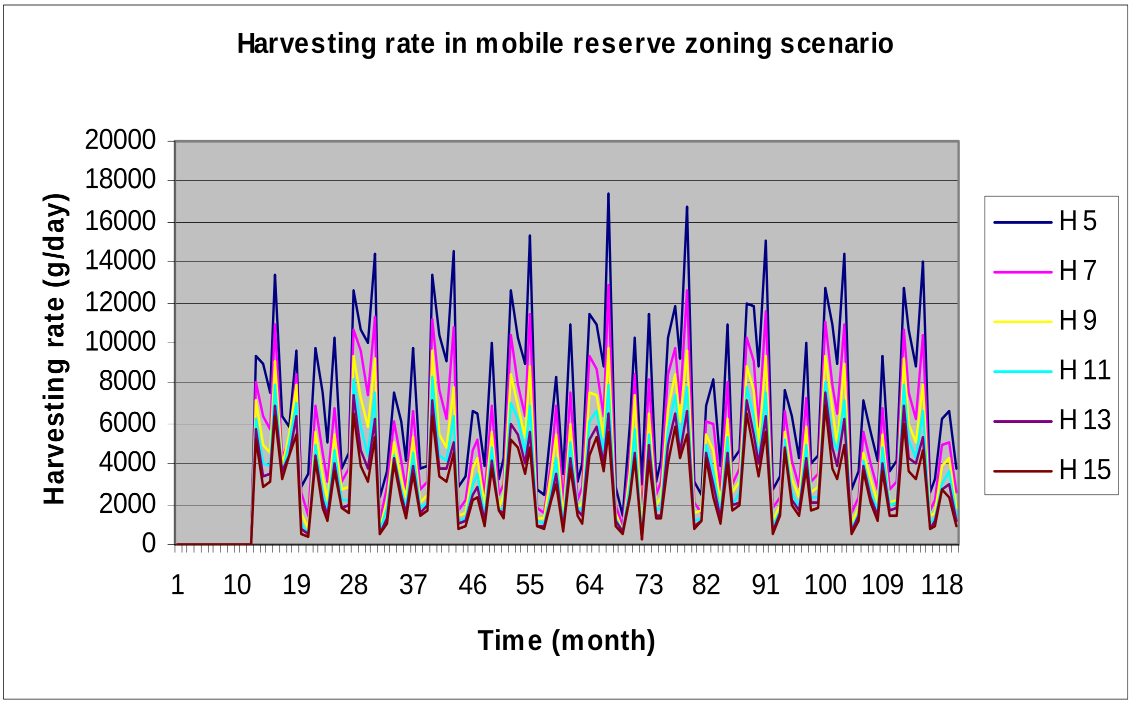


Figure 4.24 Simulation run of harvesting rate in mobile reserve zoning scenario with difference number of fisherman. (H5-H15=Harvesting at 5-15 fishermen)

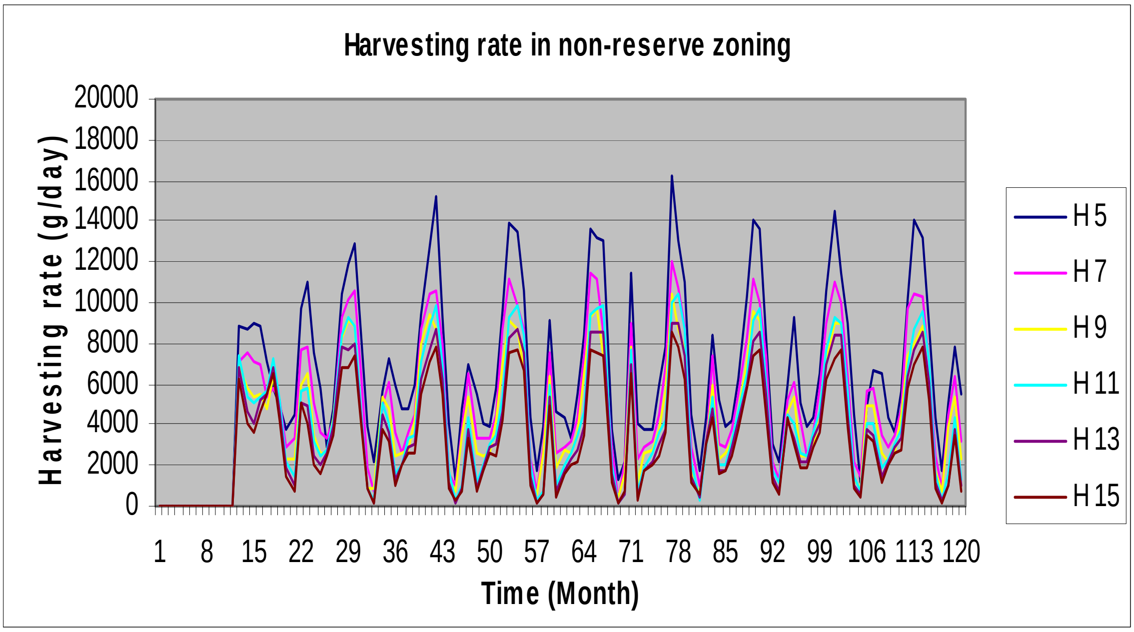


Figure 4.25 Simulation run of harvesting rate in non-reserve zoning scenario with difference number of fisherman. (H5-H15=Harvesting at 5-15 fishermen)

(* see more detail both scenarios at appendix D2)

The results from 10 years simulation run in each scenario indicated differences of razor clam population density and local fisherman harvesting rate also.

Density of razor clam from two scenarios is different in maximum and minimum value in each fisherman number (figure 4.20-4.21). In the mobile reserve zoning scenario, razor clam population (represented in razor clam density value) under harvesting pressure fluctuated between 20 individual/m^2 to 90 individual/m^2. On the other hand, there was little difference between densities of razor clam in relation to the number of local fisherman. The small number of local fisherman could harvest more razor clam than the highest number of local fisherman. In the non-reserve zoning scenario, razor clam population under harvesting pressure in this scenario is similar in term of the graph of population behavior but the interval maximum and minimum of density are different with mobile reserve zoning scenario caused the razor clam population density between 5 individual/m^2 to 100 individual/m^2. In addition, the density of razor clam in relation to various numbers of local fisherman also causes the small difference between both scenarios. Overview of razor clam population density between two scenarios, the results indicate in the same pattern without harvesting pressure (figure 4.18) but only difference in density. Moreover, the influence of reserved area zoning on the razor clam density can made the small interval of minimum and maximum density through the running time.

Razor clam harvesting rate from two scenarios (figure 4.22-4.23) are also different in maximum and minimum values due to the fisherman number. Razor clam harvesting rate from both scenarios had unique values according to local fisherman number and the values decreased with the increasing of local fisherman number. It seem to corresponds to a resource-sharing concept that if the number of local fisherman who freely harvest razor clam is increasing while razor clam resource remains in a certain number. The razor clam resource must be shared among the local fisherman. Overview of razor clam harvesting rate in two scenarios at razor clam area around 20,000 m^2, the scenario I seems to benefit for a small number of local fisherman (5, 7 and 9 persons). Because the harvesting rate of those local fisherman number is higher than non-reserve zoning. On the other hand, razor clam harvesting rate from the higher local fisherman number 11, 13 and 15 persons are not appropriate when compare with the result of harvesting rate in non-reserve zoning scenario.

To summarize of the multi-agent simulation model, it can prove the hypothesis of the study in which the razor clam population responds to different scenario and different local fisherman number.

There are some discussions on the result of multi-agent simulation model with RPG as follows:

- The resilience of razor clam resource

Based on system stability regarding on resilience stability (Jiragorn Gajaseni, 1997), razor clam population in the model can recovery rapidly in shot time or razor clam population has more flexibility to current harvesting method (dipping lime) which is a selective method. So the local fisherman can select certain razor clam size and leave smaller size as a brood stock in the future. Nevertheless, razor clam population should have fast recovering rate in the nature but the model indicates the recovering rate higher than natural condition. It can discuss on resilience stability concept that in the past there was inappropriate harvesting method (for example: apply lime solution) which made nearly 100% harvesting or razor clam die. Thus, inappropriate methods may destroy razor clam population stock to level below resilience stability and it might cause the difference between the natural situation and simulation model.

- Multi-agent simulation model

Lack of complete life history especially natural mortality of razor clam that has more effect in the model.

Lack of complexity biological process on razor clam offspring dispersion in the model.

Lack of complexity local fisherman harvesting decision process between time-step in the model.

4.6 ROLE-PLAYING GAME (RPG)

4.6.1 Overviews of the game

Two rounds role-playing game in this study called “Don Hoi Lord role-playing game”. There were organized on March 28th and July 14th 2005 at Ban Chu Chi village which located near Don Hoi Lord area. As described in Chapter III, 12 local fishermen from one village were played in the first game and 10 local fishermen from 2 villages were played in the second game.

In the first game was separated into 2 sessions (Morning and afternoon session). In the morning session, the step of the game started from a simple scenario and played 3 steps in duration of 1 step per year. Firstly, the local fishermen could freely discuss about management method. After the first discussion, the game started again with new scenario based on the local fisherman agreement and 3 steps of the game were conducted. In the afternoon session, the simulation runs of 2 scenarios (3 steps/each) from collective agreement of local fisherman were performed. In addition, the results of each scenario were shown to local fisherman at the end of game.

Similarly, in the second game was separated into morning and afternoon session. The step of this game was similar with first role-playing game but the discussion details were more complex than the first game because local fishermen from another village, as well as a trader and fishery officer was participated in this game.

- <u>Simulation model accompany with both role-playing game</u>

Simulation model for Role-playing game was developed from the scientific model based on the idea of simple to fisherman understanding. The interface of simulation model has also used as a game board (figure 4.26). In each time step, the simulation model showned a number of fishermen in each zone during simulation run.

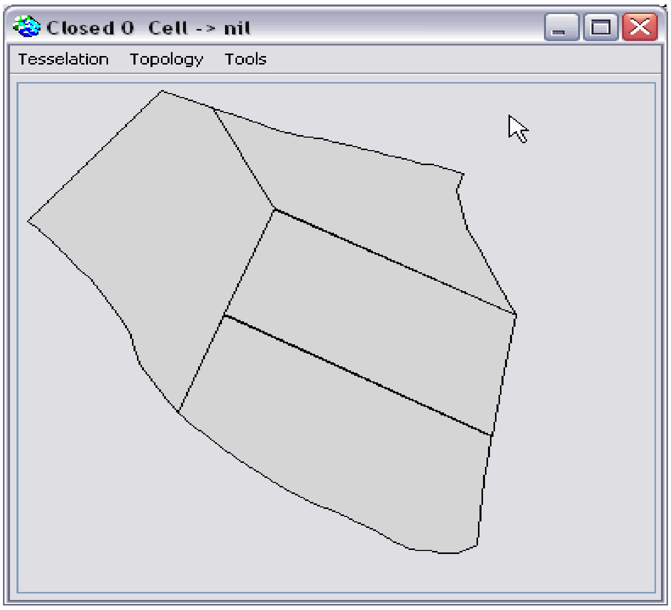


Figure 4.26 Interface of simulation model for RPG

- <u>Scenarios</u>

There were four scenarios in round of role-playing game: first scenario from real situation, second scenario from local fisherman agreement in freely discussion among them, third and fourth scenario from suggestion during freely discussion among fisherman in both rounds of the games.

First role-playing game

- Scenario I: general rule of this scenario was based on real situation. Local fisherman can go everywhere on the sand dune and can harvest razor clam as much as they can. Thus, general rule of this scenario is freely harvesting and local fisherman can go to every zone in the simulation model.

- Scenario II: the rule of this scenario was the outcome of local fisherman discussion after they finished the first scenario playing game. The general rule emphasized on closed zone rotation for 3 months and not allow local fisherman to harvest there. Closed zone rotation was agreed among local fisherman and after 3 months of closing the local fisherman can go to harvest in that area as well as another zone will be closed. Sequential of closing zone from agreement started from Zone 1, Zone 4. Zone 2 and Zone 3 and repeat again in next step or next year in the game.

- Scenario III: this scenario was based on some discussion from the local fisherman after the second scenario play. The general rule of this scenario is to close one zone permanently. The local fisherman suggested to close Zone 1, so during the game under the third scenario local fisherman can go any zone except zone 1.

- Scenario IV: this scenario was based on the same idea from the third scenario that close some zone annually and also rotate to another zone in the following year. Thus, the local fisherman suggested to close Zone 1 for 1^{st} year, Zone 4 for 2^{nd} year and Zone 1 again for 3^{rd} year.

Second role-playing game

- Scenario I: general rule of this scenario is similar with scenario I in first role-playing game. Local fisherman can go everywhere on the sand dune and can harvest razor clam as much as they can.

- Scenario II: the rule of this scenario is the outcome of local fisherman discussion after they finished the first scenario playing game. As the similar general rule of scenario II in first role-playing game general rule is emphasis on closed zone rotation for 3 months and not allow local fisherman to harvest there. Closed zone rotation was agreed among local fisherman and after 3 months of closing the local fisherman could to harvest in that area as well as another zone will be closed. Sequential of closing zone from agreement is different from first role-playing game by started from Zone 1, Zone 3, Zone 4 and Zone 2 and repeat again in next step or next year in the game.

- Scenario III: this scenario about local fisherman doubt in dressing lime solution method that was favored 2 decades ago and local fisherman believed that this method is good for razor clam reproduction. Nowadays, this method is prohibited by local government. The general rule in this scenario is similar with scenario I but different in detail of computer simulation model. The researcher programmed harvesting ability in local fisherman parameter at 100% all simulation run reflex 100% destroyed by lime solution method.

- Scenario IV: the idea of this scenario emerged from discussion between researcher and local fisherman. General rule about this scenario regarding a harvesting quota for every local fisherman. The harvesting quota from discussion was 3 kg/local fisherman. Thus researcher has programmed by limit total harvesting of local fisherman in each time step.

4.6.2 Understanding of the fisherman acting

- Local fisherman's zone selection

From observation and fisherman interviewed during the game, it was found that local fishermen have their patterns to select zone for harvesting. From observation, during decision step, local fishermen tried to compare months in the decision table with their experience about razor clam abundance in the nature. Furthermore, from interviews between changing scenarios it confirmed the idea of zone selection based on real local fisherman harvesting experience. In addition, in some month of year local fisherman decided to harvest razor clam in another area (nearest sand dune and Ban Bang Bor, Samut Prakarn province). The reason also based on their experience because they realize that in some month of the year where they should go to harvest razor clam. (Voice discussion in Appendix E)

In second role-playing game, local fisherman has learned how they maximize harvesting in scenario II by going to the closed zone when it was re-open and most of local fishermen in the game did this behavior. From direct interviews during the game, they said that they know from first role-playing game the closed zone has high density of razor clam so they should go to harvesting at there.

- Additional jobs

Results from local fisherman decision table, there are 2 kinds of jobs which a local fisherman has selected instead harvesting razor clam in some months. Firstly, during high season of crab production (December to early March), because one of additional job to make an income instead of razor clam harvesting. During this period, the razor clam harvesting is occurred at the night-time low tide and harvesting rate of fisherman is less than the daytime low tide so some of them prefer to going in crab fishery and they also express their behavior in the game. Another additional job is to sell some marine products to tourist at Don Hoi Lord. However, some local fishermen prefer stay home for 1-2 months during the night-time low tide. The reasons of this behavior from interview indicated that climate is the main reason because during that time the weather is unpredictable so they prefer to wait for opportunity to have another job or get some employments.

- Discussion session among local fisherman

In discussion session of local fisherman in both role-playing games, there are two kinds of discussion in the game, the first is discussion among them during the game and the second is discussion with researcher regarding razor clam conservation and management.

The first discussion session in both role-playing games, they shared experiences on harvesting place and information on total of harvesting number. Moreover, they consulted among their friends in terms of razor clam density before they made their decision.

During the second discussion in first role-playing game, they discussed among themselves in terms of the possibility of razor clam management and conservation method. Some of them expressed their perception about resource used and razor clam management and conservation. In summarize of second kind of discussion in the first role-playing game, razor clam management and conservation method represented in second scenarios and they also agreed in this method to apply in the real situation for razor clam management and conservation.

However, the results from scenario II in the second role-playing game was not good for razor clam conservation because local fisherman has learn how to maximize harvesting razor clam in this scenario and they admitted this scenario might not work in the future. In addition, some local fisherman discussed about the Applying lime solution method to harvest razor clam and inform their concerns to the researcher. Nevertheless, local fishermen still discuss among themselves to find another possible razor clam management and conservation method. The summarize of the second kind discussion in second role-playing game indicated that closed rotation zone in scenario II combined with quota rule in scenario IV can be use in the real situation if razor clam price is more than 100 baht/kg.

Figure 4.27 Discussion process among fisherman

Figure 4.28 Discussion process between local fisherman and research regarding on razor clam management and conservation in first role-playing game

Figure 4.29 Discussion process between local fisherman and research regarding on razor clam management and conservation in second role-playing game

4.6.3 Summary of the game

- Results from scenarios

First role-playing game

- First scenario: Freely harvesting

  Result from the game has shown in figure 4.30 and table 4.16.

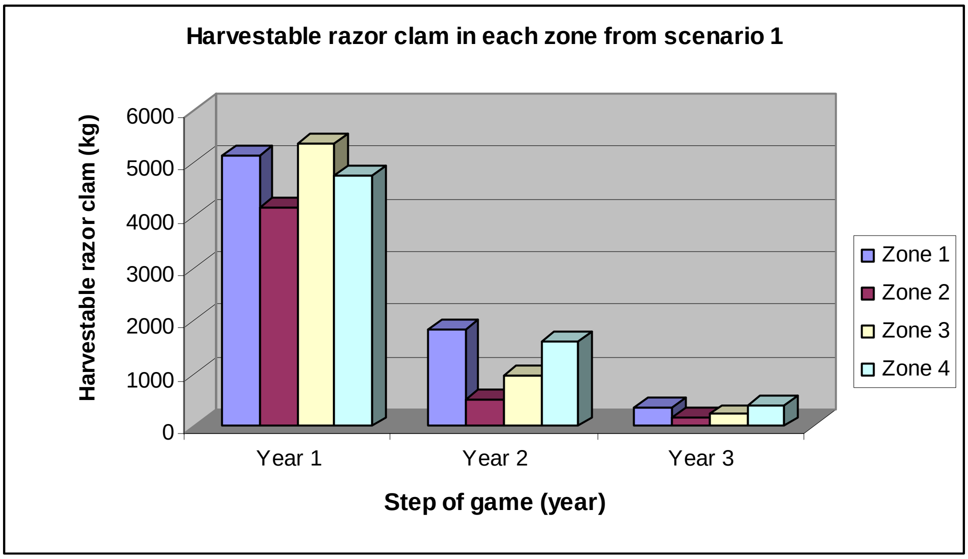


Figure 4.30 Harvestable razor clam in each zone in scenario I in 1st RPG

Table 4.16 Harvestable razor clam (kg) in each zone from scenario I in 1st RPG

Zone / Yr	Zone 1	Zone 2	Zone 3	Zone 4	Total
Year 1	5138	4153	5385	4755	19431
Year 2	1841	516	953	1605	4915
Year 3	359	179	227	395	1200

Razor clam production in scenario 1 has decreased every year (table 4.16) from 19,431 kg. in the first step to 1,200 kg. in the third step. The results indicated razor clam resource declining and at the end of scenario I local fishermen realize the negative impact of over harvesting. In zone 2, it seemed to have the worst impact when compare with other zone because zone 2 is located near main land and more disturbances from tourism and the local fisherman tried to avoid and selected other zone.

In summary of scenario I, local fisherman realized razor clam population decline and they had discussion and made agreement on razor clam management and conservation method. That becomes the general rule of scenario II.

- Scenario II: Closed zone rotation for 3 months/each

Results from the game in scenario II have shown in figure 4.31 and table 4.17.

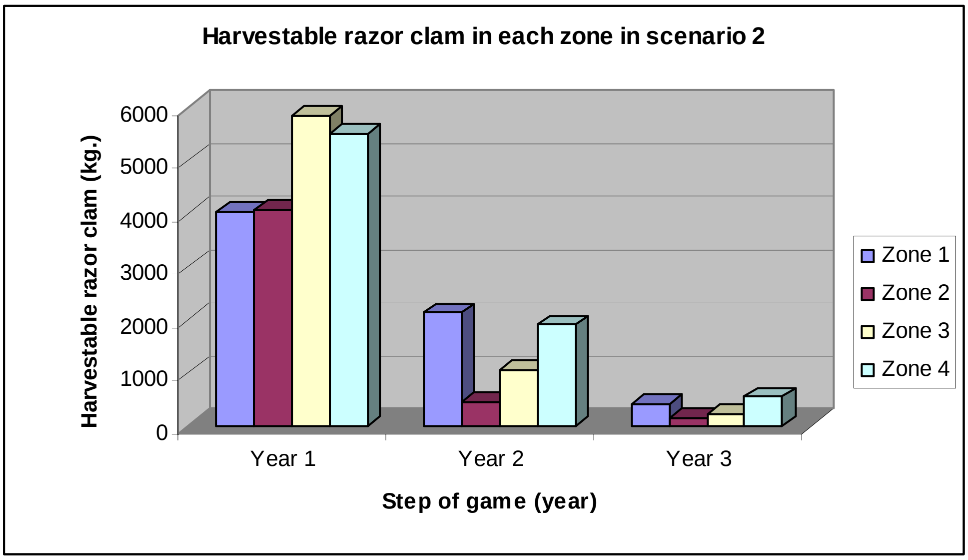


Figure 4.31 Harvestable razor clam in each zone in scenario II in 1st RPG

Table 4.17 Harvestable razor clam (kg) in each zone in scenario II in 1st RPG

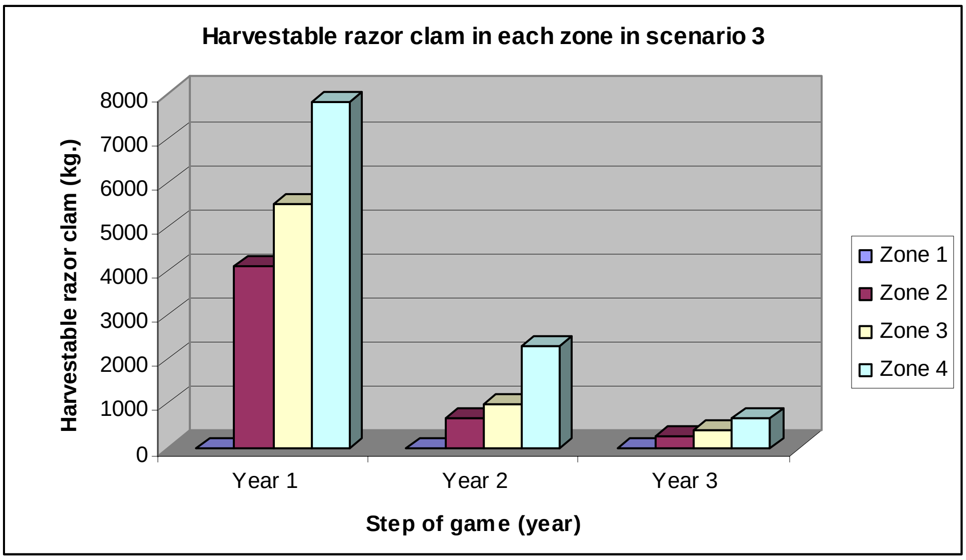
Zone / year	Zone 1	Zone 2	Zone 3	Zone 4	Total
Year 1	4044	4089	5845	5502	19480
Year 2	2133	434	1048	1906	5521
Year 3	420	135	238	545	1338

Razor clam production in scenario II decreased every year similar to scenario I. But there was a small difference due to the attempt of local fishermen in management and conservation. From discussion they realized that if they do some thing in management it would be improve the razor clam population in some way.

In summary of scenario II, the idea of general rule in this scenario purely came from local fisherman discussion and agreement. Results of the game made them realize in the advantage of management and conservation method. Otherwise, local fisherman still behaves like scenario I but the discussion provided them some understanding of how important management and conservation method is. If every local fisherman from other villages and local government agree with them in management and conservation method and establish punishment for violator, the razor clam population is still reproducing sustainable in the future.

- Scenario III: Complete closing one zone (zone 1)

Results from the game in scenario III have shown in figure 4.32 and table 4.18.



*Complete closing zone 1

Figure 4.32 Harvestable razor clam in each zone in scenario III in 1st RPG

Table 4.18 Harvestable razor clam (kg) in each zone in scenario III in 1st RPG

Zone / year	Zone 1	Zone 2	Zone 3	Zone 4	Total
Year 1	0	4099	5511	7830	17440
Year 2	0	653	1005	2281	3939
Year 3	0	272	397	667	1336

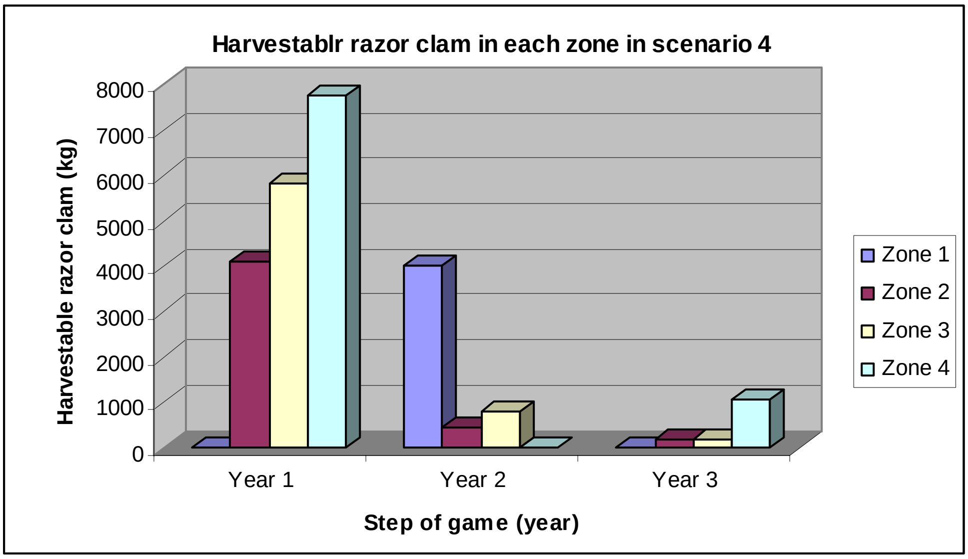
The idea of this scenario based on local fisherman idea during their discussion by complete closing zone 1 as preserved razor clam breeding ground. In this scenario local fisherman did not play by them self but researcher run the computer simulation and shown the result to them.

Again, the razor clam production decreased every year but there was a character of razor clam harvesting in each step. The maximum of harvestable zone was zone 4 in every step and the minimum of harvestable zone was zone 2.

In summary of scenario III, the results of the game in terms of total harvesting is not good when compare with scenario I and local fisherman did not agree with this management and conservation method.

- Scenario IV: Annual switch closing one zone

Results from the game in scenario IV have shown in figure 4.33 and table 4.19.



*Closed zone 1 in year 1, zone 4 in year 2 and zone 1 in year 3

Figure 4.33 Harvestable razor clam in each zone in scenario IV in 1st RPG

Table 4.19 Harvestable razor clam (kg.) in each zone in scenario IV in 1st RPG

Zone / year	Zone 1	Zone 2	Zone 3	Zone 4	Total
Year 1	0	4132	5813	7769	17714
Year 2	4038	438	809	0	5285
Year 3	0	173	205	1076	1454

Again, the idea of this scenario based on local fisherman during their discussion by closing zone 1 annually and switches to zone 4 in next year then back to the zone 1 again. In this scenario local fisherman did not play by them self but researcher run the computer simulation and shown the result to them.

The results from scenario IV seem to be a little better than scenario III but it's better than scenario I. Size class of harvestable razor clam are still the same pattern with scenario III except in the year 2 local fisherman can go to harvest in zone 1 that high density of razor clam and harvested from zone 1 is to be maximum in year 2.

In summary of scenario IV, the result of the game in terms of razor clam production decreases but the situations seemed to be better than scenario I and III. However, local fisherman still did not agree with this management and conservation method.

Second role-playing game

- Scenario I: Freely harvesting

Results from the game are shown in figure 4.34 and table 4.20

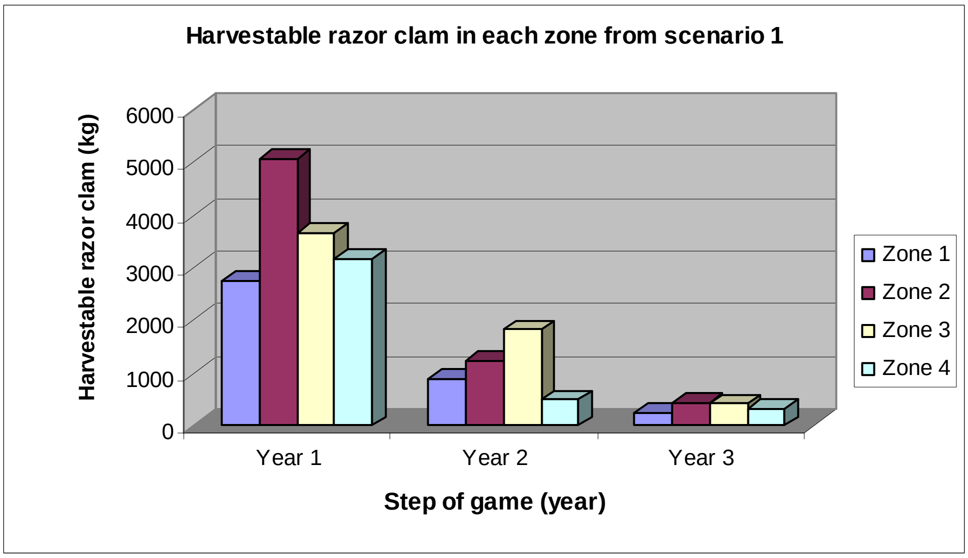


Figure 4.34 Harvestable razor clam in each zone in scenario I in 2^{nd} RPG

Table 4.20 Harvestable razor clam (kg.) in each zone in scenario I in 2nd RPG

Zone / year	Zone 1	Zone 2	Zone 3	Zone 4	Total
Year 1	2740	5085	3680	3162	14669
Year 2	890	1235	1821	490	4436
Year 3	256	420	415	320	1411

The result of this scenario was similar with first role-playing game because both of games have used the same rule.

In summary of scenario I, local fisherman from 2 villages realized razor clam population decline and they had discussion and made agreement similar first role-playing game. That becomes the rule of scenario II

- Scenario II: Closed zone rotation for 3 months/each

Result from the game have shown in figure 4.35 and table 4.21

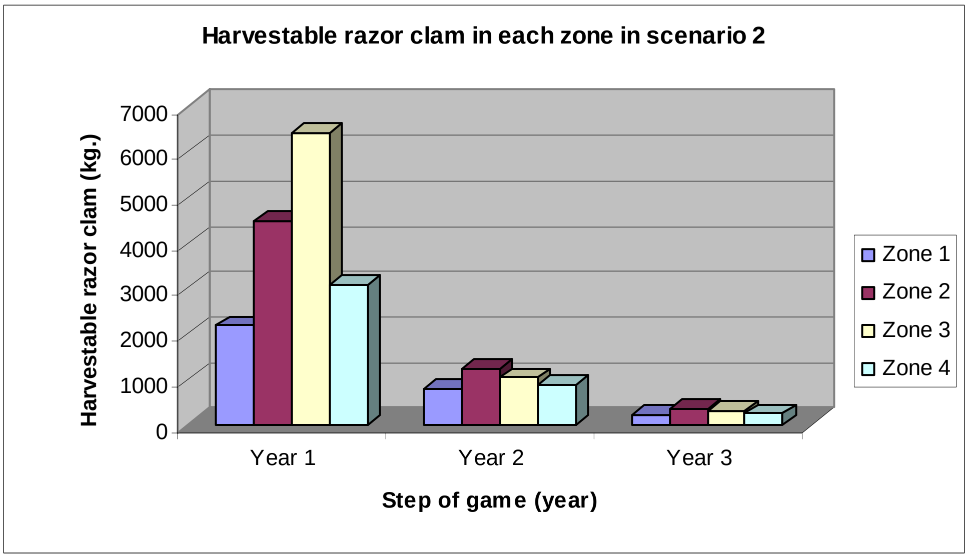


Figure 4.35 Harvestable razor clam in each zone in scenario II in 2nd RPG

Table 4.21 Harvestable razor clam (kg.) in each zone in scenario II in 2nd RPG

Zone / year	Zone 1	Zone 2	Zone 3	Zone 4	Total
Year 1	2178	4476	6449	3094	16197
Year 2	781	1211	1034	891	3917
Year 3	232	351	292	240	1115

The results from scenario II was not good when compare with scenario I even if the result from scenario II in first role-playing game was good for razor clam population and local fisherman suggested to use this scenario again in second role-playing game.

From direct interviewed and observe local fisherman during the game showed that they will go to closed zone when it re-open because they know that place has high razor clam density. That make local fisherman harvested more and more razor clam than scenario I and they confessed to research they tired to maximize harvesting by go to harvest at closed zone when it open.

In summary of scenario II, local fishermen from another village agree with general rule in this scenario can be apply to real situation. However, local fisherman from both village has learn how to maximize harvesting razor clam and they supposed that this scenario might be not work in long term management because other local fishermen can learn by themselves how to maximize harvesting razor clam like them. Finally, they still have discussion on other possible management and conservation method for razor clam after the scenario finished.

- Scenario III: Dressing lime solution method

Result from the game has shown in Figure 4.36 and table 4.22

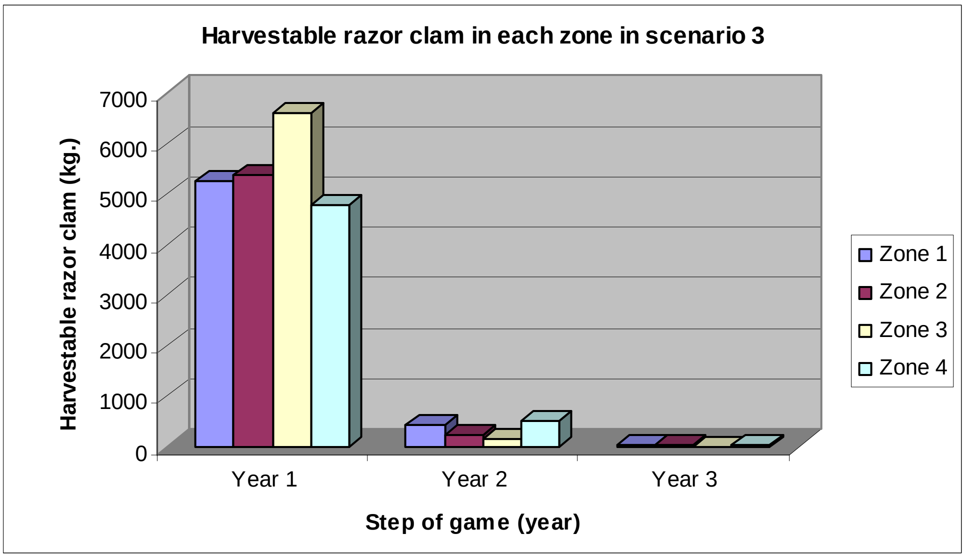


Figure 4.36 Harvestable razor clam in each zone in scenario III in 2nd RPG

Table 4.22 Harvestable razor clam (kg.) in each zone in scenario III in 2nd RPG

Zone / year	Zone 1	Zone 2	Zone 3	Zone 4	Total
Year 1	5279	5395	6595	4789	22058
Year 2	441	243	162	507	1353
Year 3	34	14	11	29	88

The idea of this scenario came from local fisherman doubt on dressing lime solution method and discuss with research about this method. Then researcher shown the results of this method by program the simulation model based on the real effect of dressing lime solution and run the simulation to show them.

In summary of scenario III, the results of the game regarding razor clam population is really not good for conservation when compared with any scenario because razor clam population has sharply decreased from fist step of game and become smallest number in last step. In addition, local fisherman has agreed with researcher in that this scenario or this method is not good for razor clam management and conservation.

- Scenario IV: Quota system

Result from the game has shown in Figure 4.37 and table 4.23

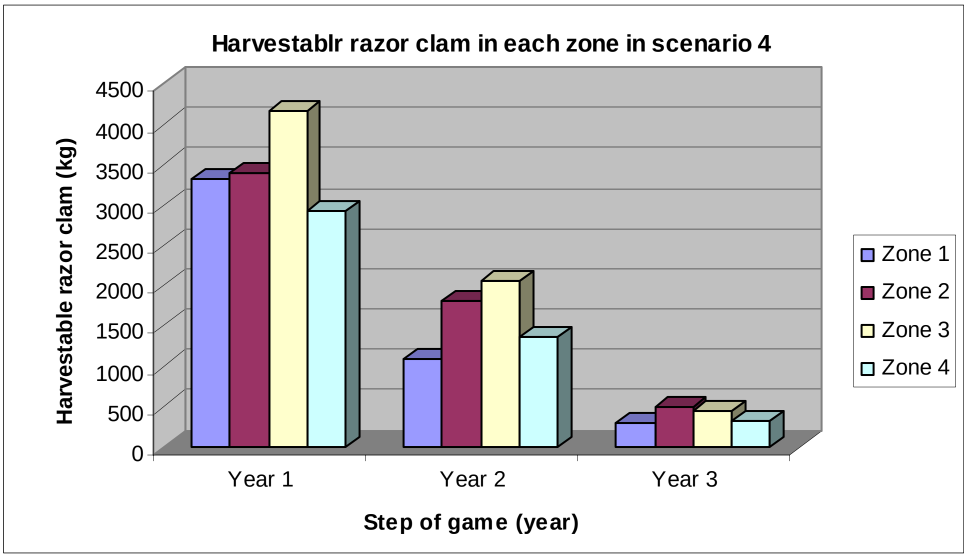


Figure 4.37 Harvestable razor clam in each zone in scenario IV in 2nd RPG

Table 4.23 Harvestable razor clam (kg.) in each zone in scenario IV in 2nd RPG

Zone / year	Zone 1	Zone 2	Zone 3	Zone 4	Total
Year 1	3318	3406	4173	2935	13832
Year 2	1093	1823	2069	1362	6347
Year 3	300	505	443	340	1588

The quota system in this scenario based on discussion between local fisherman and researcher after scenario II was not work in this role-playing game. The general rule in the scenario every local fisherman can harvest razor clam maximum 3 kg/person/day. In this scenario local fisherman did not play by themselves but research run the computer simulation and shown the result to them.

The results from this scenario seem to be better than other scenarios and local fisherman realized about razor clam population viability. On the other hands, all of local fisherman worried about their income because razor clam price are different during year round in the real world. Furthermore, the trader who participated in second role-playing game had worried about her income also because in real situation she can earn a lot of money when razor clam production exceed and price is low by stocking razor clam production in freezer and release to market if price is high.

In summary of scenario IV, the idea of this scenario was agreed upon by stakeholders in terms of razor clam management and conservation but some stakeholders (local fishermen and trader) worried about their income. However, the discussion in this scenario can negotiated that local fisherman can do the quota system if razor clam price is around 100 baht/kg all year round. Regarding the trader, she said she can do the quota system if local government assures her about razor clam market demand and razor clam retail price. On the other hands, trader bearing not so happy with this scenario because it can make her lost some money when compared with current situation. In addition, some of local fishermen suggested that should combine scenario II (Closed zone rotation for 3 months) from first RPG with this scenario because they believe that it can help razor clam population recovering fasten than do only this scenario.

- Lesson learned and advantage from Don Hoi Lord role-playing game

According to the objectives of Don Hoi Lord role-playing, it aim to understand local fisherman harvesting behavior, to share experience among stakeholders and to explore appropriate razor clam management and conservation method. The first objective was taking place in the morning session of the game; local fisherman decided for the place to go harvesting in 12 months. From personal interviews before RPG and observed local fisherman in the game are indicated that local fisherman tried to apply their experiences the game. In other ward, they knew by themselves where they should go to harvest razor clam each month. In addition, in some month local fisherman didn’t decide to go harvesting razor clam because in the reality they had another job for example labor in crab fishery or harvesting crab, harvesting razor clam in another sand dune. However, local fisherman harvesting behavior in reality is based on the density of razor clam availability and their communication. For example if some places on sand dune have more razor clam they will go there and suggest their friend to go to harvest razor clam as well. The second objective was carried out in the afternoon session, after the game finished; the collective discussion among stakeholders (local fisherman, local government, researcher and trader (in 2nd role-playing game)) was conducted in terms of harvestable razor clam in each scenario. The researcher indicated that the difference of harvestable razor clam production in different scenario was induced by local fisherman and expressed their opinion about razor clam management and conservation by consulting with local government and researcher. The agreement of stakeholders regarding appropriate razor clam management and conservation method is correspondent with scenario II in 1st game and scenario IV in 2nd game. In addition, after agreement the discussion was made, the local fisherman looking forward to how to take this agreement into implementation.

Don Hoi Lord Role-playing game could help researcher facilitate scientific knowledge from the simulation study to local fisherman and make them more understanding about dynamics of razor clam resource. Moreover, role-playing game can be a bridge between stakeholders in the Don Hoi Lord which can bring everybody into the negotiation process in particular to management and conservation purpose.

4.7 DISCUSSION ON COMPANION MODELLING

Following the main objective of Don Hoi Lord companion modelling that aims "to share experience among researcher and stakeholders and to carry out acceptable razor clam management and conservation method from stakeholders", this study can achieve the objective by organizing RPG and presenting the multi-agent simulation model to stakeholders and concluded the acceptable method for razor clam management and conservation through collective discussion those mention previously.

Companion modelling approach can be used in different fields of knowledge but it is perfectly based on the idea of renewable resource management and decision-making on the resource. Trébuil et al. (2002) conducted companion modelling approach with Akha village in upper northern Thailand. Objective of that study was to improve steep-land management by limiting land degradation in rapidly diversifying and market-integrated farming systems. They concluded that companion modelling approach helps to identify acceptable rule for improved regulation of collective uses of land resource. Gurung (2004) also used Companion modelling approach to improve irrigation water sharing in Bhutan and reported that companion modelling can be an efficient tool to mobilize communities to enhance their shared knowledge and facilitate knowledge-based decision-making in natural resource management.

Comparing between previous studies with Don Hoi Lord study, these are based on the same idea even if the different types of resource, race and components but companion modelling approach can help researcher achieve goal of study such as shared knowledge, collective discussion and identified acceptable or concluded agreement to manage natural resources.