INTEGRATED AND COLLABORATIVE ECOLOGICAL AND SOCIO-ECONOMIC MODELLING FOR SUSTAINABLE RAZOR CLAM MANAGEMENT AT DON HOI LORD RAMSAR SITE, THAILAND

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การสร้างแบบจำลองความร่วมมือเชิงบูรณาการด้านนิเวศวิทยา เศรษฐกิจและสังคม เพื่อการจัดการหอยหลอดอย่างยั่งยืนที่พื้นที่ชุ่มน้ำที่มีความสำคัญระหว่างประเทศดอนหอยหลอด ประเทศไทย

นายกอบชัย วรพิมพงษ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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Thesis Title	INTEGRATED AND COLLABORATIVE ECOLOGICAL AND SOCIO-ECONOMIC MODELLING FOR SUSTAINABLE RAZOR CLAM MANAGEMENT AT DON HOI LORD RAMSAR SITE, THAILAND
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กอบชัย วรพิมพงษ์: การสร้างแบบจำลองความร่วมมือเชิงบูรณาการด้านนิเวศวิทยา เศรษฐกิจและสังคมเพื่อการจัดการหอยหลอดอย่างยั่งยืนที่พื้นที่ชุ่มน้ำที่มีความสำคัญระหว่างประเทศดอนหอยหลอด ประเทศไทย (INTEGRATED AND COLLABORATIVE ECOLOGICAL AND SOCIO-ECONOMIC MODELLING FOR SUSTAINABLE RAZOR CLAM MANAGEMENT AT DON HOI LORD RAMSAR SITE, THAILAND) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: รองศาสตราจารย์ ดร. นันทนา คชเสนี, อ. ที่ปรึกษาวิทยานิพนธ์ร่วม: Christophe Le Page, Ph.D., 255หน้า.

การศึกษาครั้งนี้มีจุดประสงค์เพื่อหาวิธีการการจัดการทรัพยากรหอยหลอดอย่างยั่งยืน โดยการใช้แบบจำลองเพื่อนคู่เคียง (ComMod) ซึ่งประกอบด้วย 2 ส่วนหลักคือ แบบจำลองพหุภาคี (ABM) และการประชุมเชิงปฏิบัติการเพื่อการจำลองสถานการณ์ร่วมกัน (Participatory Simulation Workshop) เพื่อการเข้าถึงส่วนหลักของแบบจำลองเพื่อนคู่เคียง การศึกษาจึงแบ่งออกเป็น 3 ส่วน ดังนี้ 1) การศึกษาประชากรของหอยหลอด และค่าปัจจัยสิ่งแวดล้อมบางประการ โดยเฉพาะดินตะกอนและปริมาณอินทรีย์คาร์บอนแขวนลอยในน้ำ (POC) ช่วงมิถุนายน 2551-พฤษภาคม 2552; 2) การศึกษาระบบเศรษฐสังคมของการประมงหอยหลอด เพื่อเข้าใจพฤติกรรมการจับหอยหลอดของชาวประมง และกลไกทางการตลาดของหอยหลอด; 3) การพัฒนาแบบจำลองพหุภาคีจากข้อมูลภาคสนาม และการทดสอบสถานการณ์สมมุติในการจัดการหอยหลอด หลังจากนั้นนำแบบจำลองพหุภาคีและผลการทดสอบ ไปใช้ในการประชุมเชิงปฏิบัติการเพื่อการจำลองสถานการณ์ร่วมกันเพื่อแลกเปลี่ยนและอภิปรายถึงแนวทางการจัดการที่เหมาะสม ผลการศึกษาพบว่า สถานภาพของประชากรหอยหลอดอยู่ในขั้นวิกฤตเนื่องจากความหนาแน่นเฉลี่ยของหอยหลอดในการศึกษามีเพียง 0.51±0.30 ตัว/ตร.ม. ซึ่งเป็นความหนาแน่นน้อยที่สุดตั้งแต่มีการศึกษาในปี 2524 การวิเคราะห์ความสัมพันธ์ทางสถิติพบว่า ความหนาแน่นของหอยหลอดมีความสัมพันธ์เชิงลบกับปริมาณอินทรีย์วัตถุในดินและตะกอนแขวนลอยในน้ำ (p<0.05) แต่ไม่พบความสัมพันธ์กับ POC ในส่วนของกลไกทางการตลาดของหอยหลอดได้รับการผลักดันโดยพ่อค้าคนกลางที่รับซื้อหอยหลอดทั้งหมดจากชาวประมง และกระจายเข้าสู่ตลาดในเขตจังหวัดสมุทรสงครามและจังหวัดใกล้เคียง ปัจจัยที่ส่งผลต่อการขึ้นลงราคาของหอยหลอดขึ้นอยู่กับปริมาณหอยหลอดที่พ่อค้าคนกลางกักตุนไว้ และความต้องการของตลาด ซึ่งจะเพิ่มขึ้นในช่วงวันหยุดราชการ และปิดภาคการศึกษา การตัดสินใจจับหอยหลอดของชาวประมงมี 2 ปัจจัยที่ส่งผล คือ ความหนาแน่นของหอยหลอด และราคาขายหอยหลอด ในการพัฒนาแบบจำลองพหุภาคีมีการเพิ่ม i-stage distribution ในแบบจำลอง และทำการปรับแต่ง (calibration) จนแบบจำลองแสดงผลได้สอดคล้องกับความเป็นจริง การทดสอบสถานการณ์สมมุติในการจัดการทรัพยากรหอยหลอดพบว่า การหมุนเวียนพื้นที่บางส่วนเพื่อห้ามหยอดหอยหลอดร่วมกับระบบโควต้า เป็นแนวทางการจัดการที่ดีที่สุดต่อประชากรหอยหลอด จากนั้นมีการเพิ่มแผนที่การหยอดหอยหลอดลงไปในแบบจำลอง เพื่อใช้แบบจำลองเป็นสื่อกลางในการอภิปรายในการประชุมเชิงปฏิบัติการเพื่อจำลองสถานการณ์ร่วมกันกับผู้มีส่วนเกี่ยวข้องในพื้นที่ดอนหอยหลอด ผู้มีส่วนเกี่ยวข้องได้ยอมรับความเสมือนจริงของแบบจำลองพหุภาคี และบ่งชี้การใช้ประโยชน์ของแบบจำลองเพื่อให้การศึกษาแก่เยาวชนในพื้นที่ดอนหอยหลอดและประชาชนที่สนใจ แบบจำลองเพื่อนคู่เคียงเพื่อการอนุรักษ์หอยหลอดนี้สามารถช่วยเพิ่มพูนประสบการณ์ผู้มีส่วนได้เสียในพื้นที่ผ่านการแลกเปลี่ยนและทำงานร่วมกันในพื้นที่ศึกษา ทำให้มีการรวมกลุ่มกันของชาวประมงและผู้มีส่วนได้เสียอื่น ในการอนุรักษ์หอยหลอดด้วยการกำหนดเขตพื้นที่บางส่วนบนสันดอนทรายตั้งแต่เดือนตุลาคม 2552 เป็นพื้นที่ห้ามจับหอยหลอด

สาขาวิชา เทคโนโลยีการเกษตร	ลายมือชื่อนิสิต..
ปีการศึกษา 2553	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก..
	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม..

4873876323 : MAJOR AGRICULTURAL TECHNOLOGY
KEYWORDS : COMPANION MODELLING / RAROR CLAM / POPULATION DYNAMICS / DON HOI LORD / RAMSAR SITE

KOBCHAI WORRAPIMPHONG : INTEGRATED AND COLLABORATIVE ECOLOGICAL AND SOCIO-ECONOMIC MODELLING FOR SUSTAINABLE RAZOR CLAM MANAGEMENT AT DON HOI LORD RAMSAR SITE, THAILAND . THESIS ADVISOR : ASSOCIATE PROFESSOR NANTANA GAJASENI, Ph.D., THESIS CO-ADVISOR : CHRISTOPHE LE PAGE, Ph.D., 255 pp.

Don Hoi Lord wetland located near Mae Klong river mouth in the area of Samut Songkhram province, upper the Gulf of Thailand. The wetland was registered as the 1099th Ramsar site. Razor clam (*Solen spp.*) is an important species in the sandbars which are a part of this wetland. Fisherman has harvested razor clam for generating income more than 2 generations. Due to the previous studies, razor clam population has decreased through the time. The objective of this study aims to explore possible sustainable management policies for Don Hoi Lord by using Companion Modelling approach (ComMod). The approach mainly consists of Agent-based simulation model (ABM) and participatory simulation workshop with stakeholders involvement. To achieve the aim of the study, there are 3 parts including: 1) ecological study of razor clam population and its environmental factors especially sediment and particulate organic carbon (POC) between June 2008 – May 2009; 2) socio-economic study to understand fisherman harvesting behavior and razor clam market mechanism; and 3) ABM development from field study finding and test the management scenarios with the ABM. Moreover, the ABM was used in participatory simulation workshop to validate the ABM and to exchange and discuss on razor clam sustainable management.The results from ecological study showed that razor clam population was in crisis due to the decreasing of population. Mean density of razor clam was 0.51±0.30 clam/m^2 which has been the lowest record among previous scientific studies since 1982. In addition, razor clam density had negative correlation with %organic matter in soil sediment and particulate sediment in water column ($p < 0.05$) but it was not correlated with POC. Razor clam market is being driven by a trader who buys all razor clam from a fisherman and processed razor clam as clam meat before distributing to market. The trader set razor clam buying price from fisherman independently based on their razor clam stock and a current market demand. Razor clam demand usually was increased during weekend and, presently the trader distributing processed razor clam to a restaurant and a merchant in fresh market. Regarding fisherman, there were 2 factors affected fisherman's decision to harvest razor clam, firstly the density of razor clam and secondly razor clam price. Due to the low razor clam density, fisherman had to harvest on other species instead of razor clam but razor clam is still the first priority. The ABM development was done by added i-stage distribution model and re-calibrated until the simulation model represented system behavior. Then, the management scenarios were tested with the ABM and it was found that reserved zoning accompany with quota system was the best scenario for sustaining razor clam population. Next, spatial interface of the ABM was upgraded based on socio-economic finding and the upgraded ABM was used in participatory simulation workshop with stakeholders. The workshop can be a forum for discussion among stakeholders by using ABM as mediator and stakeholders in the workshop which could share their representations for collective agreement to achieve the goal.

Finally, the whole process of ComMod at Don Hoi Lord by communicating and co-working between researcher and stakeholders in the field study could help them instituted the group to working on sustainable management by implementing a reserved or forbidden zone on the sandbar at Don Hoi Lord.

Field of Study : Agricultural Technology Student's Signature ....

Academic Year : 2010.................. Advisor's Signature ....

Co-Advisor's Signature ....

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ABBREVIATIONS

ABM	=	Agent-based simulation model
ComMod	=	Companion modelling
DMCR	=	Department of Marine and Coastal Resources
DO	=	Dissolve oxygen
Gov	=	Local government
LWR	=	Length and weight relationship
MSL	=	Mean sea level
OM	=	Percentage of soil organic matter
PCD	=	Pollution Control Department
POC	=	Particulate organic carbon
PS	=	Particulate sediment
RPG	=	Role-playing game
RZ group	=	Razor clam Conservation Group
TAO	=	Tambon Administrative Organization

CHAPTER I

INTRODUCTION

1.1 Problems and rationale

Fisheries make a major contribution to the human food supply (FAO, 1984). Capture fisheries and aquaculture supplied the world with around 110 million tones of food fish in 2006, providing an apparent per capita supply of 16.7 kg (live weight equivalent) (FAO, 2009). Beside, the human populations in the world most are living in coastal line with in 100 km from shoreline (3 times higher density than average total world population density) (Small and Nicholls, 2003). Thus, the coastal fisheries are one of important food production for mankind.

Due to Pauly, et al. (2002), fisheries induce serial depletion of resources and global catches declining since the late of 1980s and aquaculture cannot compensate because of many constrains over the regions in the world. Thailand is the one of top ten capture fishery in the world (FAO, 2009) and also facing with resource declined especially the common marine resources in coastal area which are important for local fisherman livelihood along shoreline.

Don Hoi Lord is a coastal wetland ecosystem and located near Mae Klong river mouth in Samut Songkhram province, where is around 90 km west of Bangkok. It is a special habitat of razor clam that names “Hoi Lord” in Thai. By taxonomic characteristic, the razor clam is a bivalve that lives in fine sand habitat at coastal wetland under tidal influence. Don Hoi Lord is likely distinguished and famous for razor clam because it is seemingly a largest habitat of razor clam population that is most potentially harvested by local fishermen in Thailand.

The razor clam at Don Hoi Lord is a common-pool of resource among local fishermen who have been ever harvesting the clams for more than 80 years without any control regulation. Until 1987, the population of razor clam has declined continuously then the provincial government announced a regulation on the appropriate harvesting method to be implemented. Even now, according to the fishermen’s perception, the density of the razor clam population is still decreasing, and the mean size of the clams also decrease noticeably (Ruffolo, Charusiri, Gajaseni et al., 1999). On other the hand, the demand of razor clams consumption is still increasing without any concern to the reduction of razor clam population and put more pressure on harvesting rate. Moreover, the promotion of tourism policy of the provincial government is seemingly accelerating more consumption demand from tourists who visit Don Hoi Lord and wish to test "hoi lord" as a special local delicacy food. In this connection, it is urgently to do research on how to solve the rapid decline of razor clam population through many possible methods or approaches to integrate conservation and sustainability concept for protecting razor clam from extinction.

Most of previous studies at Don Hoi Lord mainly focused on life history of the clams (Tuaycharoen and Worra-in, 1991), environmental conditions in relation to razor clam population (Pradatsundarasar, Saichuae, Teerakup et al., 1989), and the study of social awareness related to the importance of Razor clam for the local community (Oiamsomboon, 2000). These existing studies were oriented towards conservation aspect from either a biological or a social perspective, but none of them provided an integrated approach to investigate options for a better or appropriate management towards sustainability. Presently, numerous scientists now believe that the study of ecosystems requires a multi-disciplinary or holistic approach in order to integrate biological, environmental and social components within the same research framework. By taking the abovementioned concept into account, the social dynamics is particularly important factor in the field of renewable resource management. Beyond the standard concept of "integrated renewable resource management", the challenge is now to develop a new "integrative science for resilience and sustainability" focusing on the interactions between ecological and social components and taking into account the heterogeneity and interdependent dynamics of these components (Berkes and Folke, 1998). Meanwhile, modelling is becoming an essential tool for the study of ecological systems. Models provide an opportunity to explore ideas regarding ecological systems that is not be possible to do a field-test for logistical, political, or financial reasons (Jackson, Trebitz and Cottingham, 2000).

Thus, more integrated and collaborative research is needed to raise the awareness of stakeholders about the necessity to communicate and ultimately coordinate themselves towards a sustainable use of the razor clam resource. Discussions about razor clam management options need to integrate ecological and socio-economic information. The Companion Modelling approach or ComMod (Barreteau, Antona, d'Aquino et al., 2003b) aims at providing a communication platform.

ComMod is an iterative process based on successive cycles of conducting field studies and developing simulation models. This study intends to explore in parallel by implementing ecological aspect and ComMod approach to provide information of razor clam towards a sustainable renewable resource management.

1.2 Objectives of the study

The general objective of the study is to explore possible sustainable management policies for Don Hoi Lord Ramsar site by integrated and collaborative ecological and socio-economic modelling. To achieve this general objective, some complementary specific objectives are:

I. To study ecological factors affecting razor clam population in relation to variation of sediment and particulate organic carbon.

II. To study socio-economic aspect of fishermen depending on razor clam and, to understand razor clam market mechanism, including fishermen harvesting behaviors and their decisions making process.

III. To design and implement a companion modelling approach by combining Agent–based models (ABM) and participatory simulation workshop to share, exchange and disseminate knowledge on sustainable razor clam management.

1.3 Scope of the study

The largest sandbar at Don Hoi Lord was selected as a study site. This sandbar is closed to local communities and has a high harvesting rate in relation to direct fisherman harvesting and indirect effect of tourism. This study was designed for a monthly data collection for one year including biological data of razor clam population and environmental data of water and soil such as soil texture, particulate organic carbon in water column, and organic carbon in soil. They were measured on site and some were prepared for analysis at university laboratory. For socio-economic data collection, the direct interview method was conducted with from various stakeholders who are involved with razor clam harvesting directly or indirectly. Besides, the Cormas (common-pool resources and multi-agent systems) platform was used in this study to build an agent-based simulation model (ABMS) for exploring the dynamics of razor clam population and its effected by harvesting. Finally, a participatory simulation workshop was used in a discussion session to share representation and experiences for razor clam conservation and management and lastly the model will be calibrated and verified with fishermen at Don Hoi Lord.

The overview of scope of study is illustrated as follow figure 1.1

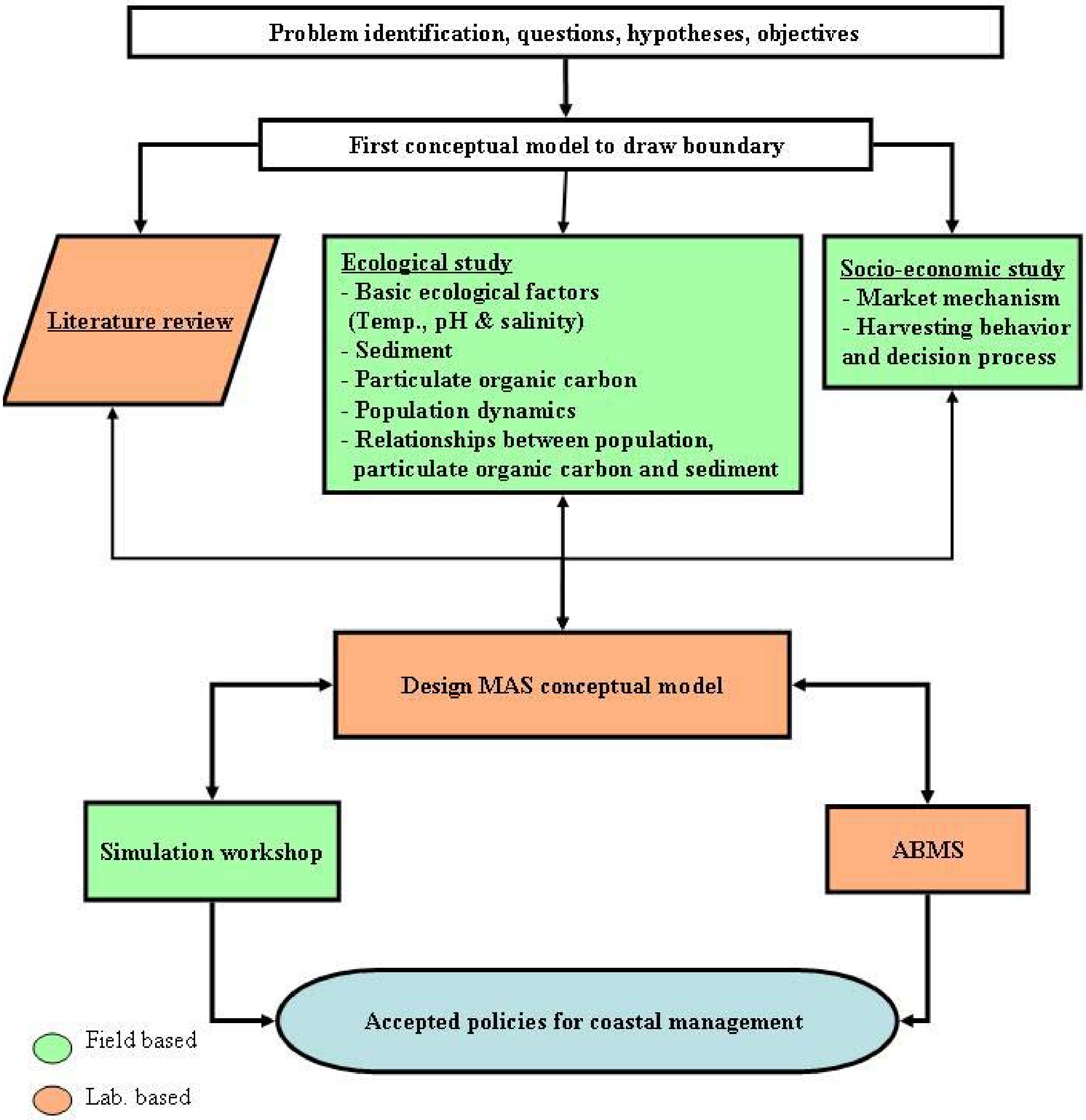


Figure 1.1 The scope of the study

1.4 Organization of the dissertation

This dissertation is organized into 6 chapters. In chapter 3, 4 and 5 are elaborated in the format of academic manuscript regarding a specific topic and also readily for submission to academic journal. Thus, organization in the dissertation consists of:

- Chapter one is introduction which provides the problematic and rationale, the objectives, the scope of study and the organization of this dissertation.

- Chapter two is literature reviews which described the background of razor clam and Don Hoi Lord following by fishery community at Don Hoi Lord and razor clam harvesting in Don Hoi Lord. Finally, the review of modeling for natural resource management is presented. The reviews of modeling consist of three major topics as follows; 1) the rational of modeling approach for natural resource management, 2) participatory modeling for sharing experiences and perception, and 3) companion modeling for collective learning and bring acceptable agreement..

- Chapter three is based on biological knowledge of razor clam population by describing razor clam population evolution from the past study until latest study under the current environmental factors in relation to razor clam population. This chapter is useful for understanding the dynamics of razor clam population over the time. It also provides a fundamental knowledge to manage razor clam population sustainably.

- Chapter four is focusing on human (fisherman) roles and their behavior effected on razor clam population that is the one of the major effects due to decreasing of razor clam population. Socio-economic study on razor clam harvesting at Don Hoi Lord is presented. This chapter is emphasis on razor clam harvesting by local fisherman around Don Hoi Lord area including the understanding of fisherman behavior regarding when they decide or where they go to harvest razor clam. In addition, razor clam market price characteristics are also described in this chapter.

- Chapter five is the modeling narration. It describes the collaborating of the content in chapter 3 and 4 in order to build the Agent-based simulation model. The simulation model was used to explore various scenarios based on razor clam management. Furthermore, the simulation model was used to discuss with various stakeholders by using workshop to validate some elements and simulation behavior in the model.

- Chapter six is the final chapter which concludes the relation of each chapter in the dissertation and to clarify the advantage from the study. The recommendations for a sustainable razor clam management also present in this chapter based on the results from all works in this dissertation.

CHAPTER II

LITERATURE REVIEW

2.1 Razor clams

In Thailand, the razor clams are called “Hoi Lord” in local name that are also well known as a delicacy food particularly in Samut Songkram province. In fact there are many river month ecosystems in Thailand where we can find the razor clams but it might be different species. However, this study is emphasized on the specific species, it is called *Solen regularis* Dunker.

2.1.1 Biological characteristics

2.1.1.1 Taxonomical characterisitcs

Razor clam is a common name of bivalve mollusk which has elongated shell shape like razor. Taxonomically, there are many kind of razor clam belong to:

Phylum Mollusca
Class Bivalvia
Order Veneroida

In this Order, the Veneroida or veneroids are bivalve mollusks. They have some familiar forms such as saltwater clams, cockles, and a number of freshwater bivalves including zebra mussels. Morphologically, Veneroids are generally thick-valved, equal valved, and isomyarian (that is, their adductor muscles are of equal size). Three main hinge teeth are the specific characteristics of the Subclass Heterodonta to which this order belongs. In term of movement, many species are active rather than sessile. However, they tend to be filter feeders, feeding through paired siphons, with a characteristic folded gill structure adapted to that way of life (Vaught, Tucker Abbott and Boss, 1989).

Among Families in Order Veneroida, there are two Families of razor clam which are Solenidae and Pharidae (Cosel, 1990). The majority of razor clam consist of four Genus which are; *Solen* belongs to Family Solenidae, *Ensis, Tagelus* and *Siliqua* belong to Family Pharidae (Fernandez-Tajes and Mendez, 2007), and (Wekell, Gauglitz Jr, Bamett et al., 1994). By contrast, (Brands, 2007) classified *Solen, Ensis* and *Siliqua* belong to Family Solenidae while *Tagelus* belong to Family Solecurtidae.

Table 2.1 Four genus of razor clam

Genus	Unique Characters	Picture
Siliqua sp.	- Razor shape and flat shell - Max shell length ~ 18 cm	
Tagelus sp.	- Razor shape and flat shell - Max shell length ~ 7 cm	
Ensis sp.	- Cylinder and curve shell - Max shell length ~ 20 cm	
Solen sp.	- Cylinder shell - Max shell length ~ 12 cm	

Source: *Siliqua* sp. ;www.wdfw.wa.gov, *Tagelus* sp. ; www.jaxshells.org, *Ensis* sp. ;www.aphotofauna.com

2.1.1.2 Morphological characteristics

Generally, the shell of razor clam has elongate, thin, flat and smooth forms. The shells covered with a glossy, yellowish and its hold by hinge teeth. However, shell shape may differ depend on taxonomic classification, *Solen* and *Ensis* have cylinder shell shape while *Siliqua* and *Tagelus* have flash shape (Table 2.1). There are two openings which anterior opening has two well developed siphons for filtering purpose and posterior opening has large and powerful foot for moving (Fisheries and Oceans

Canada, 2001). Razor clam foot is a group of muscle which it has shape like a pike and can retract-extend for movement. Usually, razor clam has muscle color white or light yellow or brown and pigmented in some species (Holland and Dean, 1977;Lassuy and Simons, 1989). *Siliqua*, *Tagelus* and *Ensis* have short siphon while *Solen* has bigger and longer siphon when compare with shell size (Barnes, 1987 ;Barth and Broshears, 1982;sited in Bautong, 1997).

Razor clams have a variation of adult size which depends on the species. For example, *Ensis directus* can grow up to length excess 20 cm (Kenchington, Duggan and Riddel, 1998), while *Solen regularis* in Thailand can grow up to 12 cm in length only (Pradatsundarasar, 1982). *Siliqua patula* can grow up to maximum of 18 cm. (Nelson, 1994), while *Tagelus plebeius* can grow up to 7 cm only (Abrahão, Cardoso, Yokoyama et al., 2010).

2.1.1.3 Reproductive characteristics

Razor clam is a sex separated animal and sex ratio is around 1:1 (Barón, Real, Ciocco et al., 2004;Lassuy and Simons, 1989). Reproduction of razor clam is an external fertilization by using its siphon that male releases sperms and female releases eggs into water. Bautong (1997) described the development of gamete cell of razor clam that is similar to other bivalves such as cockle, green mussel but it may differ in the interval of each stage or the size of gametes. There are six development stages of gamete cell are as follows:

1) Prefollicular development stage
2) Initial development stage
3) Developing stage
4) Mature stage
5) Partially spawned stage
6) Spent stage

After the external fertilization of eggs and sperms, razor clam embryo has a living form as plankton until its metamorphosis is ended as a mature shape and settle to soil surface (Bautong, 1997). However, even razor clam has much more sperms and eggs released into water with very low rate of successful fertilisation, but less than 50% of embryos can survive to be mature razor clam (Morton, 1979). Generally, razor clam has long period of spawning. In the Pacific Northwest, razor clams (*Siliqua patula*) can spawn in late spring or early summer around May–August depend on latitude (Lassuy and Simons, 1989). In Europe, razor clam (*Solen marginatus*) also has a long period of spawning like in the Pacific Northwest around May-August (Remacha-TRIVIÑO and Anadon, 2006). In addition, razor clam (*Ensis americanus*) in Europe also has the same period of spawning around May-September (Cardoso, Witte and Van der Veer, 2009). Meanwhile, razor clam (*Solen regularis*) in tropical zone has longer period of spawning all year round but there are some months between March and July in which are the peak of spawning (Pradatsundarasar et al., 1989 ;Sriburi and Gajaseni, 1996 ;and Srithongsuk, Ausawanggul, Tuycharoean et al., 1990).

Due to some studies indicated that some environmental factors such as salinity, food and temperature are playing an important role in razor clam reproduction. For instance, Pradatsundarasar et al. (1989) and Sriburi and Gajaseni (1996) revealed that the increasing of water temperature and salinity in summer can stimulate the reproductive system of razor clam (*Solen regularis*) to reach a peak of spawning. Furthermore, Wong, Lim and Wong (1986) reported that temperature between 32-33 can induce 80% of razor clam (*Solen brevis*) spawning 80% and the concentration of diatom at 0.9 million cell/ml can also induce 90% of razor clam spawning. In addition, Breese and Robinson (1981) found that marine algae *Pseudoisochrysis paradoxa* at 2-2.5 million cell/ml can make razor clam *Siliqua patula* spawning. Not only razor clam, but also other bivalves such as green mussel need suitable environmental factors to accomplish in spawning (Harvey and Vincent, 1990;and Kautsky, 1982).

2.1.1.4 Habitat and distribution characteristics

Descriptions of razor clam habitat consist of stable beach, near open sea or ocean, sandy or muddy flat especially sandy area with tidal system or exposed tidal flat near river mouth. It burrows into the sand or mud about 30 cm beneath the surface and live in its hole (Figure 2.1). Razor clam is semi-permanent living in its hole and with limited in lateral movement. However, rapid vertical movement is a character of razor clam (Lassuy and Simons, 1989). It moves vertically with extending its foot (digger) into the sand , then flattening out the tip of the foot like a rivet head. The clam then pulls itself down to its anchored foot. Moreover, when razor clam detects risky and stimulus sign, razor clam will throw of siphon and move itself into deeper level from surface. Moris, Abbot and Haderlie (1980) reported that *Siliqua* sp. can move its location more frequently than *Solen* sp. and the razor clam can move its location by using foot and siphon as swimming organ during high tide.

Holland and Dean (1977) explained the preference habitat of razor clam (*Tagelus slebeius*) that it does not inhabit in the area where sediment traps filled rapidly, but inhabits only the muddy-sand area where sediment traps filled slowly indicating more stable sediments. In addition, the proportion of soil texture is also importance to razor clam. *Ensis* sp. usually found in the area where the proportion of sand much more than slit and clay while *Solen* sp. usually found in area which has more slit and clay but the percentage of sand not less than 90% (Purchon, 1968).

Due to razor clam habitat preference that it prefers sandy area, razor clam has succeeded to distributing over the major parts in the world (Figure 2.3). Following Von Cosel, 1990, razor clams are predominately tropical and subtropical with the distribution in the Indo Pacific such as Madagascar, New Guinea, Taiwan, Philippine, Thailand Indonesia and few species in temperate zone. In addition, razor clam can live in cold – warm temperature water thus; it can be found in most regions of the world such as Northwest Europe, Eastern Atlantic, and West Africa.

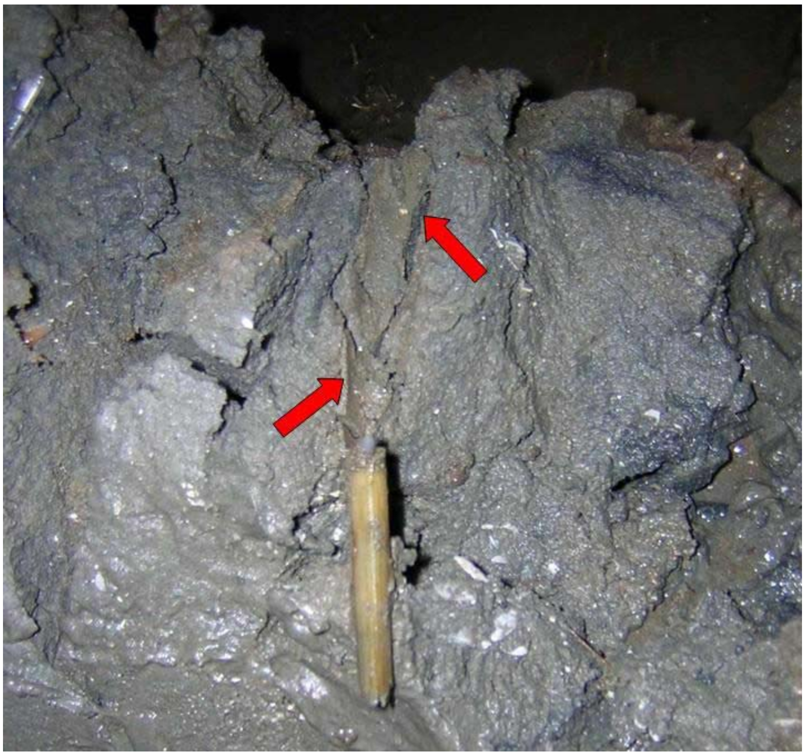


Figure 2.1 Razor clam (*Solen* sp.) living in its hole (red arrows).

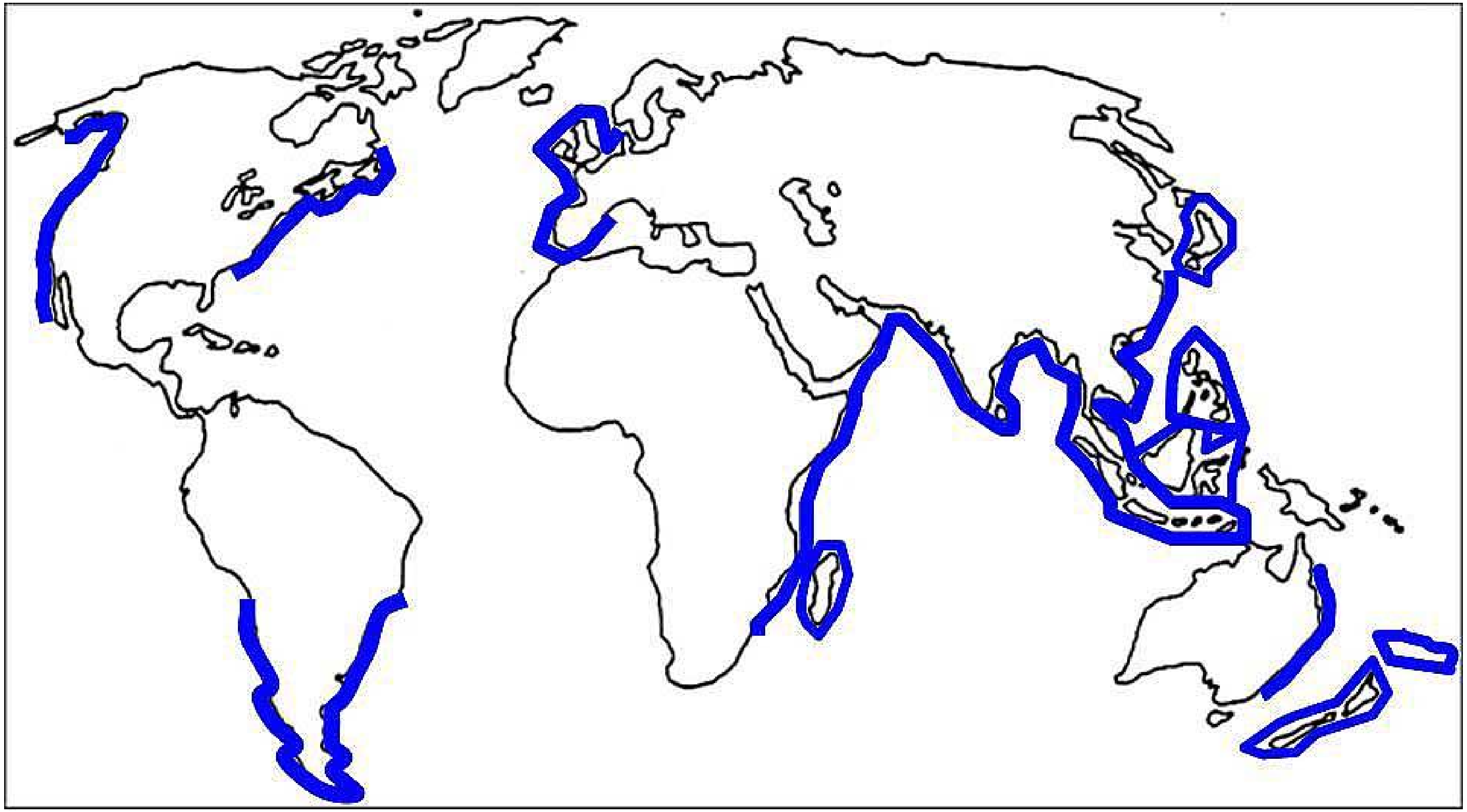


Figure 2.2 Distribution of razor clam in the world

2.1.1.5 Food

Razor clam is a suspension feeder. During high tide, razor clam moves up to surface and protrude siphon into water for pumping water and filtering food from water column (figure 2.3). Its foods contain detritus, planktons, algae, bacteria, organic matter, silt-clay size sediment (Fegley, MacDonald and Jacobsen, 1992) . Furthermore, in some species of razor clam detritus particles are majority of total gut contents.

Studied of gut content in razor clam (*Siliqua patula*) show that plankton *Chaetoceros armatum* are the principal food which compose more than 80% of the razor clam dietary (Lewin, Chen and Hruby, 1979a). Bautong (1997) found that phytoplankton in Phylum Bacillariophyta were found in gut content of *Solen regularis* and *S. strictus* in Thailand every month along 1 year of study. However, planktons are not the only one source of razor clam food, gut content of razor clam (*Tagelus slebeius*) in South Carolina, USA contains over 50% of detritus particle (Holland and Dean, 1977).

Figure 2.3 Razor clam feeding: (Left) Position in substrate, and (Right) Top view of 2 siphons of razor clam *Solen* sp. functioning in feeding mechanism.

Source for (Left fig.) : http://www.town.barnstable.ma.us

2.1.2 Razor clam and some environmental factors

Optimal environmental is required by all organisms to maintain its life. Due to razor clam is a suspension feeder it can filtrate around 3-4% of total tidal water per tide. However, basic environmental factor such as water pH and salinity are important to its feeding mechanism (De Villiers and Allanson, 1988). Phuwapanit, Limthummahisorn and Thongduang (2003) reported that if water pH at razor clam site dropped to 6.5 it effected to filtration rate and razor clam will has slow growth rate. In addition, if water pH reached to 9.1 it can kill razor clam suddenly. Moreover, razor clam feeding can significantly regenerate ammonium which is important resource for phytoplankton in surf zone in Washintan, USA (Lewin, Eckman and Ware, 1979b). Razor clam reproduction is also required suitable environmental factors as described above in section 2.1.1.3 (reproduction).

Following distribution of razor clam that usually found it in open sandy beach and sandy flat near river mouth, properties of sediment and grain-size where razor clam lived in seem to be one of environmental factor that may effect to razor clam living. Suspension feeder such as razor clam usually found in coarse sediment while deposit feeder usually found in fine sediment (Benton and Werner, 1974). Grain-size in razor clam habitat may be a limiting factor to control distribution of razor clam because grain-size can effect to aggregate property or water and air circulation in sediment (Pradatsundarasar, 1982;Purchon, 1968). In addition, small grain-size can affect directly to razor clam by reducing filtration property (Ruppert and Barnes, 1994) or congesting in respiratory organ that may caused of suffocation in early life stage of razor clam (Nickerson, 1975). Eltringham (1971) found that dissolve oxygen (DO) in water which penetrate between small particle sediment lower than penetrated water from large particle like sand and he also explained that sandy sediment has more circulation and small particle sediment. Pradatsundarasar (1982) reported that razor clam (*Solen regularis*) will live in the sediment where the proportion of sand much more than silt and clay.

Grain-size of sediment related with organic matter in sediment. Small grain-size such as silt (diameter 0.05-0.002 mm) can hold organic matter 2 times more than sand (diameter 0.05-2.0 mm) and clay (diameter $<$ 0.002 mm) can hold 4 times more than sand (Bordovsky, 1965;Tumnoi, 1996) . Thus, organic matter might be one of environmental factor which important to razor clam.

2.1.3 Razor clam harvesting

Razor clam harvesting are talking place over the world. The purpose of the harvesting can be commercial and recreation. In America, razor clam harvesting talking place from Alaska to Southern Argentina and Chile (Barón et al., 2004;Bishop, 2003;Lassuy and Simons, 1989). In Europe, razor clam harvesting talking place in Northwest and West of continent (Costa and Martínez-Patiño, 2009;Hauton, Howell, Atkinson et al., 2007). In Asia, razor clam harvesting is one of fishery activities in many countries such as Malaysia, Thailand, China, Taiwan (Kanakaraju, Ibrahim and Berseli, 2008;Pradatsundarasar, 1982;Zhang, Ye, Feng et al., 2007).

Commercial razor clam harvesting have been occurred almost 100 years as a record in Nelson (1994) that the commercial harvesting in Alaska was started since 1916 and the production reaching approximately 280 ton/year. Meanwhile, razor clam canning also operate to distribute razor clam to wildly market after commercial razor clam harvesting were wildly in pacific coast (Schink, McGraw and Chew, 1983; sited in Lassuy and Simons, 1989). Even through razor clam production were not reported in world fisheries statistic of FAO (Food and Agriculture Organization), razor clam still one of important species in fisheries activity for example production of *Ensis machan* in Chile was reached 6,000 tons in 1999 (Barón et al., 2004), razor clam production *Solen regularis* in Thailand was reached almost 1,300 tons in 1983 (Department of Fishery, 1995). Nowadays, razor clam can or processed razor clam in pack which ready to cook still wildly distribute in market even in online order (figure 2.4).

Figure 2.4 Processed razor clam which ready to cook from USA (A) and Australia (B)

Source: (A) www.pikeplace.com ; (B) www.oliverai.com/au

2.2 Razor clam in Thailand and Don Hoi Lord

2.2.1 Razor clam in Thailand and razor clam biological researches in Thailand

Razor clam in Thailand has distributed along the coastal line both of Gulf of Thailand and Andaman Sea. Such as Phuket province, Songkhla province, Prachuapkhirikhan province, Phetchaburi province, Samut Sarkorn province, Samut Songkhram provimce, Samut Prakarn province and Chantaburi province (Bautong, 1997;Suvatti, 1950;Tuaycharoen, 1999;Tuaycharoen, Suntrorn and Yodsurang, 2006). Especially in Samut Songkhram province; at Don Hoi Lord which is the largest area of razor clam habitat in Thailand (Paphavasit, Gajaseni, Khonsae et al., 2004).

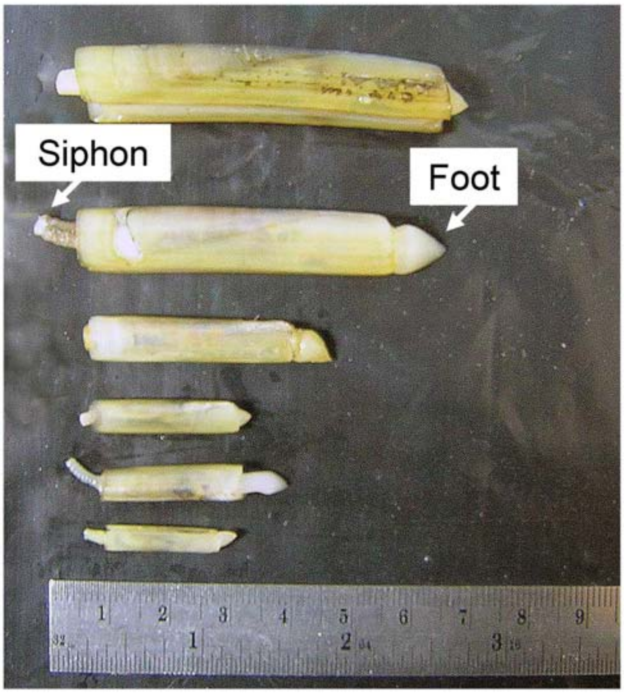


Figure 2.5 Razor clams (*Solen regularis*) from Don Hoi Lord in various sizes

The taxonomic hierarchy of razor clam or Hoi Lord (in Thai) at Don Hoi Lord is following:

Phylum: Mollusca

Class: Bivalvia

Order: Veneroida

Family: Solenidae

Genus: *Solen*

Species: *Solen* spp.

The taxonomic hierarchy of razor clam at Don Hoi Lord still non final justified due to more than 20 years of study in identification of razor clam and scientific name of Don Hoi Lord has changing over time are follow:

Pradatsundarasar (1982), identified as 2 species named *Solen regularis* Dunker 1862 and *S. vitreus*

Tuycharoean and Worra-in (1991), indentified as one species named *Solen strictus* Gould 1861.

Tuaycharoen (2006) (Tuaycharoen et al., 2006) , re-indentified again and defined as four species are *Solen corneus* Lamarck 1818, *S. strictus* Gould 1861, *S. regularis* Dunker 1862 and *S. thailandicus* Cosel, 2002.

However, the pilot study found 2 species of razor clam which were *Solen regularis* Dunker 1862 and *S. vitreus* as describe in Pradatsundarasar (1982). The target species of fisherman at Don Hoi Lord is *S. regularis* and they do not harvest on *S. vitreus* due to its price is not high and some fisherman said its taste is not good as *S. regularis*. In addition, this study will emphasize on *S. regularis* the target species of fisherman. The differences between 2 species *S. regularis* and *S. vitreus* are a character of siphon and shell (figure 2.6). Siphon of *S. regularis* consist of stratified group of tissue while *S. vitreus* has only one piece of tissue. Nevertheless, razor clam usually nips off its siphon out if they harvested thus, most of razor clam from data collection and from fisherman harvesting does not have siphon. Another character which easily to indentify between 2 species is a shell, razor clam shell at foot end position; *S. vitreus* has small edge connected from shell end while *S. regularis* does not have it.

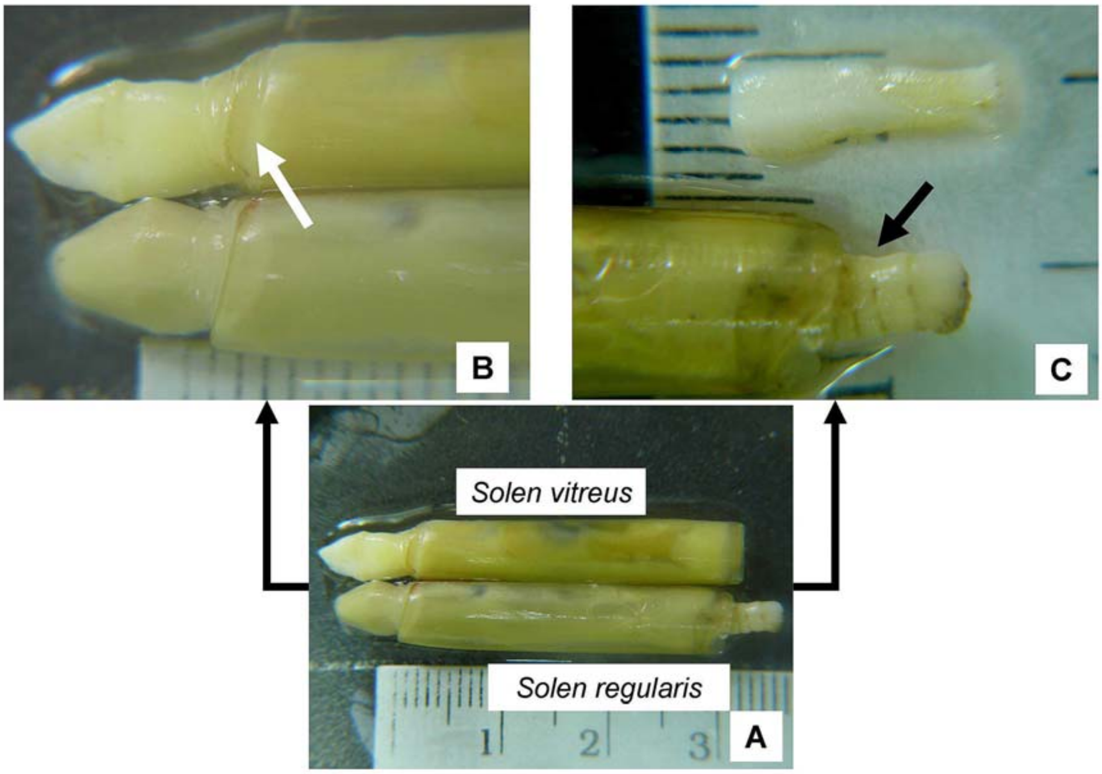


Figure 2.6 Two species of razor clam at Don Hoi Lord: (A) Comparison between *S. vitreus* ann *S. regularis*, (B) Shell edge at the end of shell (white arrow) which is a character of *S. vitreus*, (C) Stratified group of tissue contributed to siphon (black arrow) which is a character of *S. regularis*

For another area in Thailand, Department of fishery (1995) reported 3 species were found in Phuket (*Solen drlrserti*, *S. grandis* and *S. roseomaculatus*) and 1 species in Songkhla (*Solen abbreviatus*)

Pradatsundarasar (1982) studied the influence of sediment on distribution and density of razor clam (*Solen regularis* Dunker, 1862) population in Mae Klong river mouth and reported that razor clam was found in limited area where sediment size is about 0.125 mm and the dune contains almost sand with the least water and organic matter cover during low tide. Average razor clam density was reported at 10.20 clam/m^2.

Khumsupar, Audsawangkul and Tuychalearn (1991) studied distribution of bloodstock of razor clam around Mae Klong river mouth and found that density of razor clam was 26.88 clam/m^2. Moreover, razor clam has a distribution from the east coast of river mouth to Bang Bor canal mouth.

Tuaycharoean and Voraingtara (1991) studied breeding biology and environment of razor clam in Bang Bor village, Samut Songkhram province and reported that razor clam is breeding twice a year, during November to April and June to October. The sex ratio was 1:1. Besides, the suitable conditions for razor clam breeding were soil temperature between 21-38 °C, salinity between 22-31 ppt , 25% organic matter composition in soil, pH around 7.85 and Dissolve Oxygen around 5.36 mg/l. Finally, they found that razor clam can breed at size of 42.4 mm.

Jinphuhuad (1994) studied the influence of the pH of the seawater on razor clams and reported that the suitable range of pH of the seawater for razor clams was 6.9-8.5. In addition, he reported that when the pH of the seawater is lower than 6.5 or higher than 9.1, razor clams can simply not survive.

Tumnoi (1996) studied characteristic of soil from razor clam habitat in Samut Songkhram at Don Hoi Lord and Samut Prakarn at Bang Poo and reported that organic matter (OM) from both habitat sites were not difference (0.24-0.74%), whereas most of soil composition in both area were sand. In addition, the proportion of silt and clay from Don Hoi Lord were significantly difference ($p<0.05$) among collecting sites.

Boutong (1997) studied the relationship between plankton population and breeding season of razor shell genus *Solen* at Don Hoi Lord, Samut Songkhram province and reported that most food in razor clam stomach content was phytoplankton. In addition, densities of phytoplankton and zooplankton were not related to density and breeding season of razor clam population.

Ruffolo et al. (1999) studied the population dynamics of razor clam at Don Hoi Lord and reported that razor clam has a growth rate at 1 cm/month, furthermore population of razor clam was decreased from 49.5 clam/m^2 in 1994 to 4.1 clam/m^2 in 1997. In addition, most collected clam in the study has size between 2 to 4 cm. In 1998, they could not catch razor clam size bigger than 7 cm. Finally, they concluded that the decrease of razor clam population might be caused by inappropriate harvesting method.

Sriprathumwong, Sornkaew and Phuwapanish (2002) cultured razor clam from fertilization egg 860,000 eggs from 3 kg. of broodstock in man made nursery. The survival rate was 0.70 % when razor clam developed in juvenile stage of 520x1,040 micron and 0.03% when razor clam reached adult stage (1.5-3 cm.).

Worrapimphong, 2005 studied the population dynamics of razor clam at Don Hoi Lord and reported that the density of razor clam in 2004-2005 was 5.71 clam/m^2. In addition, this study was exploring more on razor clam management with stakeholders in

Don Hoi Lord by use of companion modelling. The modelling process came out with accepted management scheme.

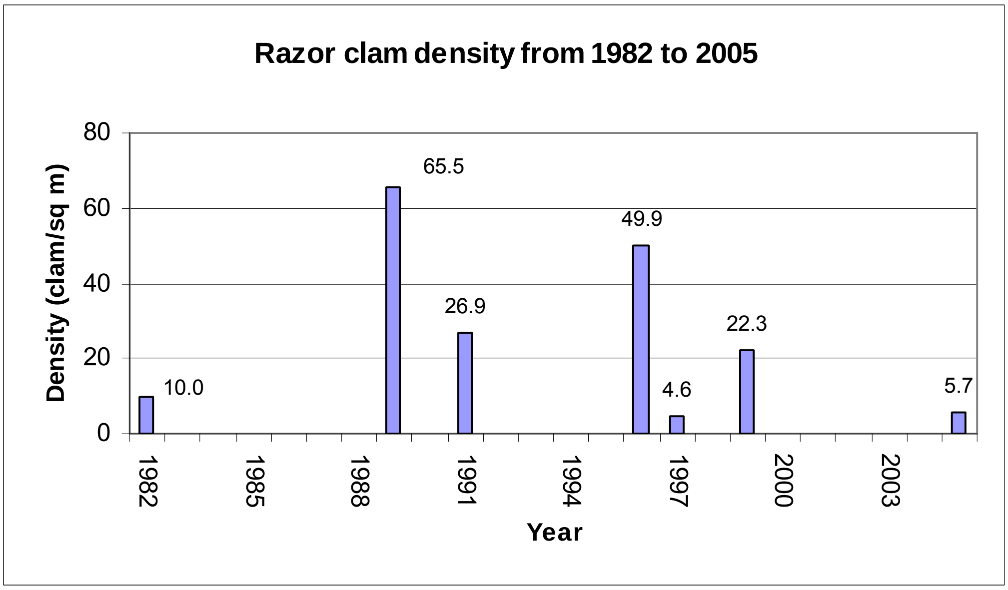


Figure 2.7 Razor clam density from 1982 until 2005

(Source: Pradatsundarasar, (1982), Pradatsundarasar et al. (1989), Khumsupar et. al. (1991), Sriburi and Gajaseni (1996), Buatong (1997), Tuaycharuan (2003), and Worrapimphong (2005))

Figure 2.7 showed razor clam density evolution at Don Hoi Lord sine there was a scientific record in 1982. The density shows fluctuation through the time. However, before 1982 Pradatsundarasar, 1982 reported that there was mass waste water around Mae Klong river mouth in 1979 (Phiyakarn et. al., 1979 sited in Pradatsundarasar, 1982) that might affect the population in his study. Razor clam density in 1989 was highest in the records. Then, 1996 until 2005 the densities seem to be sharply decreased. Nevertheless, all of study above did not talking place on the same position as a systematic collection due to technology limitation such as GPS device, only all of studies were took place in Don Hoi Lord area.

2.2.2 Samut Songkhram province and Don Hoi Lord

2.2.2.1 Samut Songkhram province

Samut Songkhram province is located in central part of Thailand between latitude 13-14^{o} N and longitude 99-103^{o} E and far from Bangkok in west direction around 74 kilometers (figure 2.8).

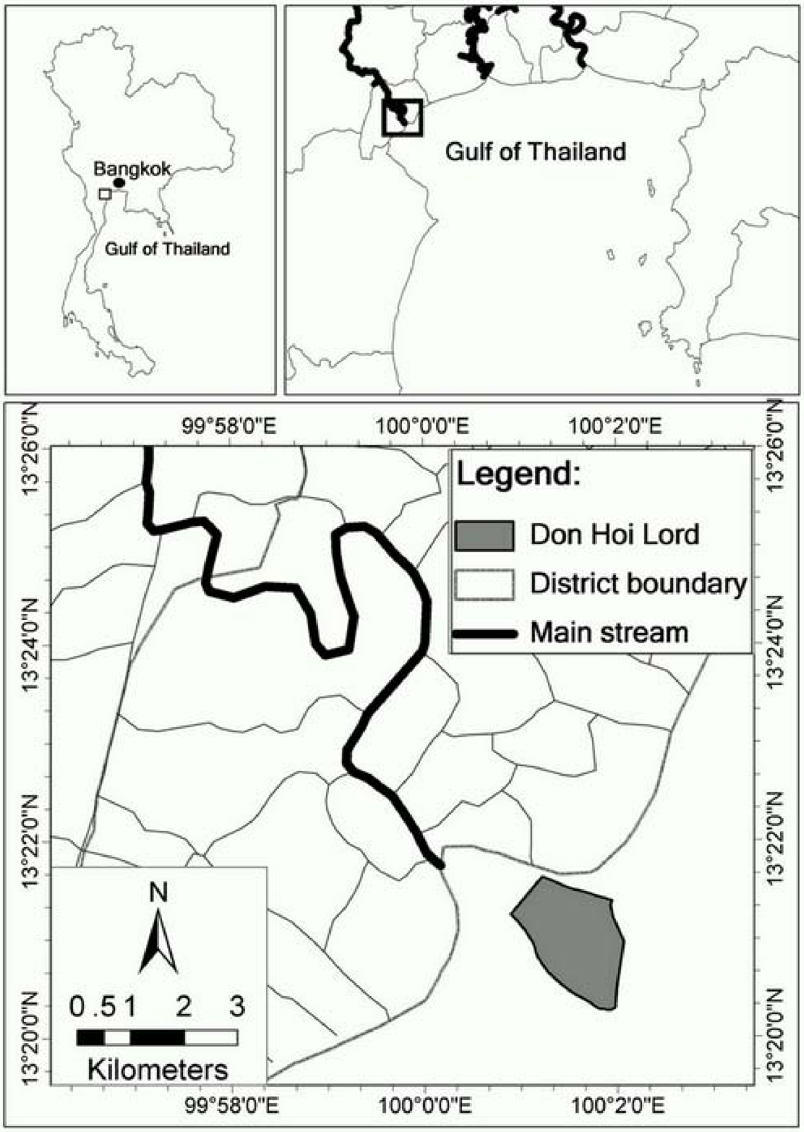


Figure 2.8 Samut Songkhram province, west of Bangkok and Don Hoi Lord area.

General geographical characteristics of Samut Songkhram is flat plain, no mountain and there is one river as main stream named Mae Klong River across province area (north-south direction) through 3 amphurs with around 300 natural and man made canals connected with the main river, Yee Sarn canal, Klong Cone canal, Bangjakreng canal, Bang Klaew canal, Chanuan channel and Maenn Harn canal are the important in this province. In addition, Mae Klong River mouth is located at amphor Muang Samut Songkhram (Sriburi and Gajaseni, 1996). In 2006, the gross provincial product (GPP) was 13,113.3 million baht. The GPP per capita was 72,620 baht (Moinistry of Industry, 2007). The main careers of people (≈80%) are agriculture, fishery and labor in industry.

Coastal area of Samut Songkhram consists of shore line length of 23.2 km. Almost coastal area in the province is characterized as muddy and sandy sediment all of area, it has slope less than 1 % in direction to coastal line. During the low tide, the mudflat will emerge approximating 4 km from shore line to the sea.

The administration of Samut Songkhram province consists of 3 amphurs, 36 districts, 5 municipality and 283 villages. Total population in 2008 was 194,054 people (51,077 households) contributed from male 93,331 people and female 100,723 people (Ministry of Interior, 2010). The majority of Samut Songkhram people have been living in Muang amphur especially Muang Samut Song Khram municipality it closed with Mae Klong river mouth area.

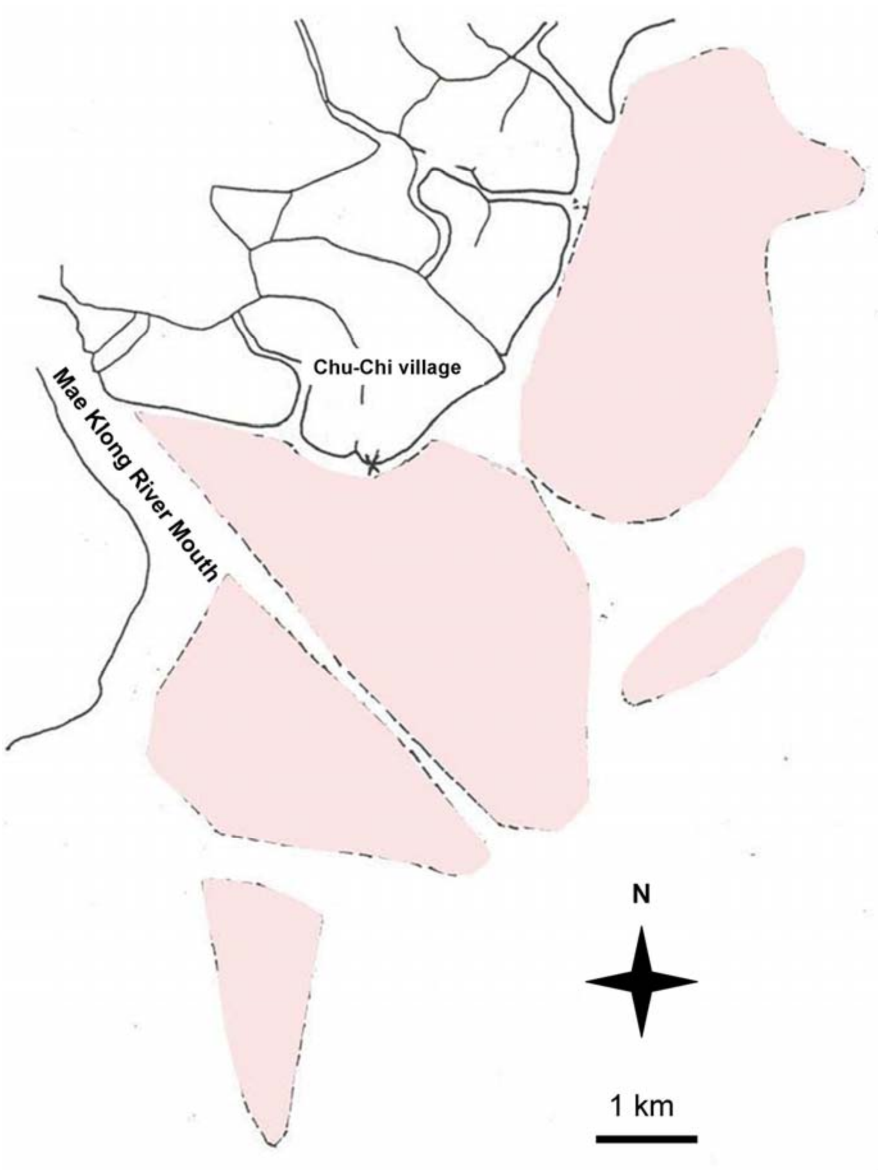
Natural resources in Samut Songkhram were various land use types including orchard (lichee, coconut, pomelo etc.), salt farm and paddy rice and aquaculture farming. The fishery activities in Samut Songkhram province include fresh water, brackish and marine fishery especially brackish area, there are many type of aquaculture such as shrimp, mud crab, cockle, green mussel and snapper fish. In the past, the mangrove area was destroying for aquaculture particularly shrimp aquaculture caused mangrove area conversion and discharged wastewater to Mae Klong estuary. Now a day, many area of shrimp aquaculture are abandon because the shrimp farmer could not get enough economic benefic (Worrapimphong, 2005).

Samut Songkhram province is divided into 2 parts by Mae Klong River. The Mae Klong estuary runs from the east of river mouth to Samut Sakhon province in distance of 12 km. and the west of river mouth run westward to Phetchaburi province in distance of 11.2 km. In addition, Samut Songkhram coastal line has been changing because of the sedimentation pattern from Mea Klong river. It makes land extending in to the sea in west of Mae Klong river mouth while there are coastal erosion in some area of east of the river mouth (Department of marine and coastal resources, 2009).

The tidal system in Samut Songkhram province is semi – diurnal tide. It consists of high tide and low tide twice times a day. Mean of high tide is +1.23 m. from mean sea level (MSL), mean of low tide is -0.15 m. from mean sea level (MSL) and mean of interval between low and high tide is 1.38 m., however the tidal system has variously effecting from the moon, sea breeze, an air pressure and water current so tidal level must be different in each month (Worrapimphong, 2005).

2.2.2.2 Don Hoi Lord

Don Hoi Lord located at the east of Mae Klong river mouth. “Don Hoi Lord” comprises 2 Thai words “Don” which means high land and “Hoi Lord” which means razor clam. The characteristics of Don Hoi Lord are sandbar which made by natural sedimentation. There are 5 sandbars (Department of Fishery, 1995) aggregated as Don Hoi Lord (figure 2.9). The compositions of a popular tourist destination in the vicinity of Bangkok as plenty of Thai tourists are going there to enjoy eating the clams and to visit the natural site.



Adapted from Department of Fishery (1995) and Suwanna (2003)

Figure 2.9 Rough map of sandbars location (Pink area) in Don Hoi Lord area.

Following Don Hoi Lord is promoted as tourist destination, nowadays, Don Hoi Lord is very well knows among Thai tourist due to the development of transportation to this area. Suwanna (2003) reported that the development of infrastructure in Don Hoi Lord were:

Around 1970: the first road was build from state highways to Mae Klong river mouth but it wasn’t reach Don Hoi Lord area.

1972: The governor realized that Don Hoi Lord had ability to be a touristic destination of province thus; a new gravel road was constructed to Chu Chi village. However, the road was not reach the sandbar people had to walk about 1 km to visit sandbar. It was the beginning of tourist activity at Don Hoi Lord. Most of tourists at the beginning were people in Samut Songkhram province.

1982: Electricity was introduced into Chu Chi village with consumerism. Fisherman started to consider electric appliances such as TV, refrigerator.

1987: Due to central government policy to promote tourism in Thailand, Tourism Authority of Thailand (TAT) cooperates with provincial government to promoted Don Hoi Lord as tourist attraction in country level. Infrastructure was developed by transform gravel road to asphalt road and prolonged it to the sandbar in Chu Chi village area. In addition, mangrove nearby the sandbar in Don Hoi Lord area was destroyed and replaced with restaurant and seafood grocery to support tourist activities.

2001: Don Hoi Lord was registered as 1099th Ramsar Site (Ramsar, 2008). Following Ramsar convention aims to protect wetland which has importance in international level. During 1990s, after Don Hoi Lord well knows in Thailand it brought a lot of tourists visit this area. Rapid development and rich harvesting fishery resource was took place consistency with tourist activity. Human activities had degraded biodiversity and ecosystem services at Don Hoi Lord and central government recognized the degradation. Hence, central government drove Don Hoi Lord area to be a Ramsar site to stimulate awareness and prevent lost of this important wetland.

2002: A new Prince Chumphon Khet Udomsak shrine was opened (Chiravej, 2002). The memorial is located nearest a pier which tourist and fisherman take a boat to go to sandbar. In addition, this memorial is also one of tourist attraction in Don Hoi Lord area.

In addition, Suwanna (2003) summarized community characteristics, way of life and resource management in Don Hoi Lord as follow:

Table 2.2 Community characteristics, way of life and resource management in area of Don Hoi Lord in different period

Period	**Community characteristics**	**Way of life**	**Resource management**
Before 1957	Richness of natural resources	Committing with natural	For household consumption and selling in small part
		Closing with their relative	
		Harvesting was an aditional occupation	
1957-1982	Development of public utility such as electricity, road	Committing with market system	For selling to market
	Encroachment of mangrove for shrimp aquaculture	Harvest for selling and catch razor clam for addititional occupation	Development of coastal aquaculture
1983-1999	Development of area for tourist	More choices for occupation in tourist activities	Forbidden some method to harvest razor clam
	Intensive shrimp aquaculture	More natural resource utilazation	Officer did not enforcment on the regulation
	Arriving of number of tourists	Loosing with their relative	
	Encroachment of mangrove for building and restaurant	More urban life style	
	Declining of local resources such as mangrove and razor clam	harvesting razor clam become major occupation due to its price	
2000-2003	Decreasing of razor clam	Trouble from declining of natural resources	Grouping of villager to solve resource problem
	Development in the area affected way of life	Reducing of income and getting in debt	Helping each other to takecare natural resource
		Migrate to another area or change occupation	

Source: Suwanna (2003)

2.2.2.3 Fisherman community at Don Hoi Lord

Don Hoi Lord located in Mae Klong river mouth surrounding with a fisherman village. Area of Don Hoi Lord connecting with 4 villages from 2 districts which are; Ban Park Marp and Ban Bang Bor belong to Bang Kaew district, Ban Chu Chi and Ban Ramun belong to Bang Ja Kreng district. According administrative system, most of the area is belong to Ban Chu Chi village Bang Ja Kreng district. In addition, touristic area of Don Hoi Lord is also located in this village it brings a lot of tourists visit the sand bar via this village.

All of villages surround Don Hoi Lord are artisan fishery village. Most of people are fisherman who fish vary of aquatic animal in coastal water such as various species of fish, blue swimming crab, prawn, various species of clams, horseshoe crab and jelly fish. Minority career in these villages are workman or merchant related with fishery activity. Razor clam harvesting is one of important fishery activity in this area, Suwanna, 2003 reported that there were around 2,000 fishermen in this area both professional and unprofessional are harvesting on razor clam at Don Hoi Lord.

2.2.3 Razor clam harvesting at Don Hoi Lord

Following the distribution of razor clam in Thailand, razor clam harvesting is one of fishery activities in several provinces along coastal line for example Phuket province (MCOT, 2010), Chumporn province (Department of Fishery, 2009), Samut Prakarn province (Tumnoi, 1996) and especially Samut Songkhram province (Pradatsundarasar, 1982) which is the largest habitat for razor clam and also the most famous in Thailand (Paphavasit et al., 2004).

Harvesting of razor clam has been practiced by local fishermen more than 80 year. The beginning of harvesting had an objectives to consume in household and/or to used as dried razor clam to exchange for rice, sugar, etc. until around 1986 intensive shrimp aquaculture was introduced to Samut Songkhram area (Suwannathad, 2002). Beside, Don Hoi Lord started well knows as touristic area among tourist. Thus, the production from razor clam harvesting were used for feeding shrimp in farm and also distributing to the market as delicacy food.

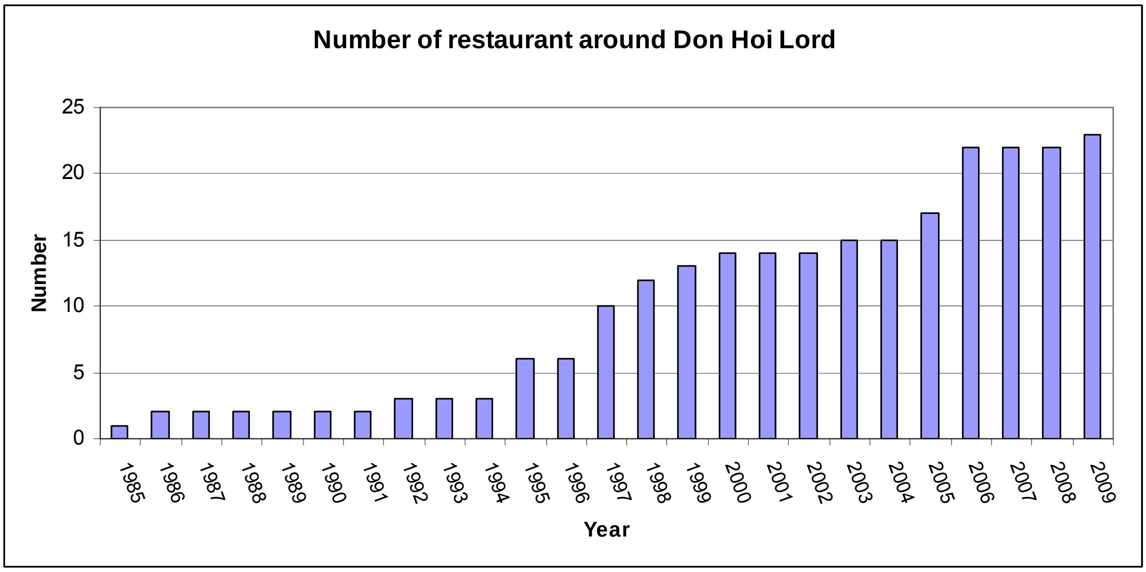


Figure 2.10 Evolution of number of restaurant around Don Hoi Lord area since 1985 (Source: Bang Ja Kreng Tumbon Administrative Organization (TAO), 2009)

Sine razor clam well knows as delicacy food and Don Hoi Lord has been promoted as tourist destination of Samut Songkhram province these bring a great demand of razor clam from the market. Figure 2.10 showed the increasing of restaurant around Don Hoi Lord sine 1985 in Ban Ja Kreng Distric area. It is clearly that the number of restaurant has been increasing through the time that reflecting a great demand of razor clam. Not only restaurant around Don Hoi Lord but a trader who direct buy razor clam from fishermen also distributes processed razor clam to Bangkok and another provinces nearby Samut Songkhram province(Worrapimphong, 2005).

Traditionally, there are 5 methods developed by local fishermen knowledge to catch razor clam during low-tide when the sandbar exposed. There are as follows:

Method I Dipping lime; this method is the original and traditional method. Local fishermen search for razor clam hole by using fingers to knock on sand dune surface. If a razor clam is near by, it will eject water from siphon thorough the hole then local fishermen has known its location. Consequently, a small bamboo stick dipped in lime is use to poke into the razor clam hole. The razor clam will react and jump up from its hole, and therefore it is caught by fishermen (figure 2.11).

Method II Applying lime; local fishermen apply lime on the wet ground where razor clams live around 1 m^2 Every razor clam in that area will react and jump up from their holes.

Method III Applying lime solution; local fishermen dissolves 1-2 kg of lime in water and apply the solution on the ground more than 2 m^2. Every razor clam in that area will react and jump up from their holes. This method is similar to method II but it can cover much more area and effectiveness.

Method IV Applying acetylene solution; local fishermen apply acetylene solution on the ground then every razor clam will react and jump up from their holes. This method is similar to method II and Method III but is much more effective. However, acetylene solution has more impact to other species than lime methods.

Method V Digging; this method is the best method for collecting razor clam because no chemicals are involved. However, digging method is unfavorable because it uses more labor and the production is not as high as the other methods.

Source: Worrapimphong, 2005

Figure 2.11 Fisherman harvesting razor clam by using Method I, which now accepted and wildly used

Nowadays, only method I and V are accepted by local government meanwhile other methods are prohibited because damage of those methods to small razor clam and other aquatic animal on the sandbar. Only method I is favored among fisherman because it save time and labor, and also worthy in current economic situation. However, due to development of harvesting method I by fisherman, they put some caustic soda in lime to make it stronger than normal lime when dip into razor clam hole.

Following razor clam harvesting by lime, there are a research emphasized on lime effect to razor clam as follow:

Srithongsuk et. al.(1990) studied the effect of lime on razor clams death rate and reported that lime 0.2 g per 1 razor clam hole could kill the clam in 72 hrs, while lime 31.2 g per 1 razor clam hole could kill the clam in 48 hrs In addition, the middle razor clam size (3.1-4.4) had maximum tolerance to lime when compared with other size.

Kanthom et. al. (1991) studied the effect of lime on razor clam death rate and found that small razor clam (1.5-2.9 cm.) has 48 hr.LC_{50} = 376.21 mg/l, large razor clam (4.5-7.0 cm.) has 72 hr.LC_{50} = 234.39 mg/l. In addition, the razor clams were exposed to lime would die faster than the clams that were new exposed.

Presently, almost harvested razor clam from fisherman were sold to trader, then trader will process razor clam before distribute to market. Razor clam processing by trader is the method to remove clam shell by soaking living razor clam in water for several hours to let clam releases sand or other materials in its digestive tract by itself. After soaking process, razor clam was boiled until it well done before separate clam from its shell. Clam without shell is the final product which ready to distribute. However, trader can keeps excess fresh razor clam into freezer if market demand is not high. Somehow, several fishermen process and distribute razor clam by themselves at the pier.

Figure 2.12 Tourist activities at Don Hoi Lord; (A) Seafood grocery and processed razor clam ready to cook, (B) Restaurant which used to be mangrove area beside the sea, and (C) Tourists going to visit sandbar at the pier near Prince Chumphon Khet Udomsak shrine.

2.2.4 Razor clam management at Don Hoi Lord

More than 3 generations, Fishermen around Don Hoi Lord have harvested razor clam for long time without any regulations. During 1980s, lime solution method (Method III) became very famous method because the need of market following the popularity of Don Hoi Lord and razor clam dish as a delicacy food (Suwanna, 2003). Thus, fisherman needs an effective harvesting method that why lime solution method was favored among fishermen. Nevertheless, lime solution method is not an appropriate harvesting method because after apply lime solution on the ground fisherman collect a big size razor clam and leave small razor clam size and another animals. Until1987 It became prohibited this harvesting method. Regarding this destructive method, it caused all sizes of razor clam to be harvested. While the traditional harvesting method (Method I) or the selective harvesting method ensures a small size razor clam to be able to survive as a natural stock. Furthermore, in 1998 the provincial government declared a reserve area for razor clam breeding site (Suwanna, 2003). Practically, only the regulation about the harvesting method has been considered, with still some arguments among fishermen about it.

Sriburi and Gajaseni, 1996 studied natural resource conservation plan in Don Hoi Lord. It had description that:

Don Hoi Lord is a beautiful wetland and important to Samut Songkhram tourism. Nowadays, Don Hoi Lord has some problems from too much tourists (figure 2.12), without waste management, appropriate understanding in relation to aquatic animal habitat or breeding ground and razor and other aquatic animal conservation.

The researches proposed conservation plan for Don Hoi Lord by divide the area into 3 sub-areas, as follows:

1. Preserved area: this area is natural area where high biological value and sensitive to environment change so any human activities are prohibited in this area.

2. Conserved area: this area is peripheral natural area with direct and indirect relationships with natural area. Some human activities are allowed in this area but it will not came environmental change.

3. Developed area: this area allows any human activities but it controlled by government under National Environment Act 1992.

Moreover, low tide in the daytime (April to August) the number of fisherman is more than 260 persons/day. On the other hand, low tide during in the nighttime start from October to January some fishermen illegally use applying lime solution method to catch razor clam. It is more damage to razor clam population than allowed method and cause population decreasing.

Oiamsomboon, 2000 studied the people opinion on Don Hoi Lord conservation at amphur Muang, Samut Songkhram province and reported that most people agreed with Don Hoi Lord conservation, because they realized that Don Hoi Lord is an important place to Samut Songkhram province in terms of the legend and tourism. Moreover, they were glad to cooperate with the government in Don Hoi Lord conservation activities.

Jarinrattanakorn, 2001 studied the media exposure, awareness and participation in razor clam conservation among people in amphur Muang, Samut Songkhram province and reported that high level of media exposure in razor clam conservation and awareness in razor clam conservation. On the other hand, the participation of people in razor clam conservation is in the medium level.

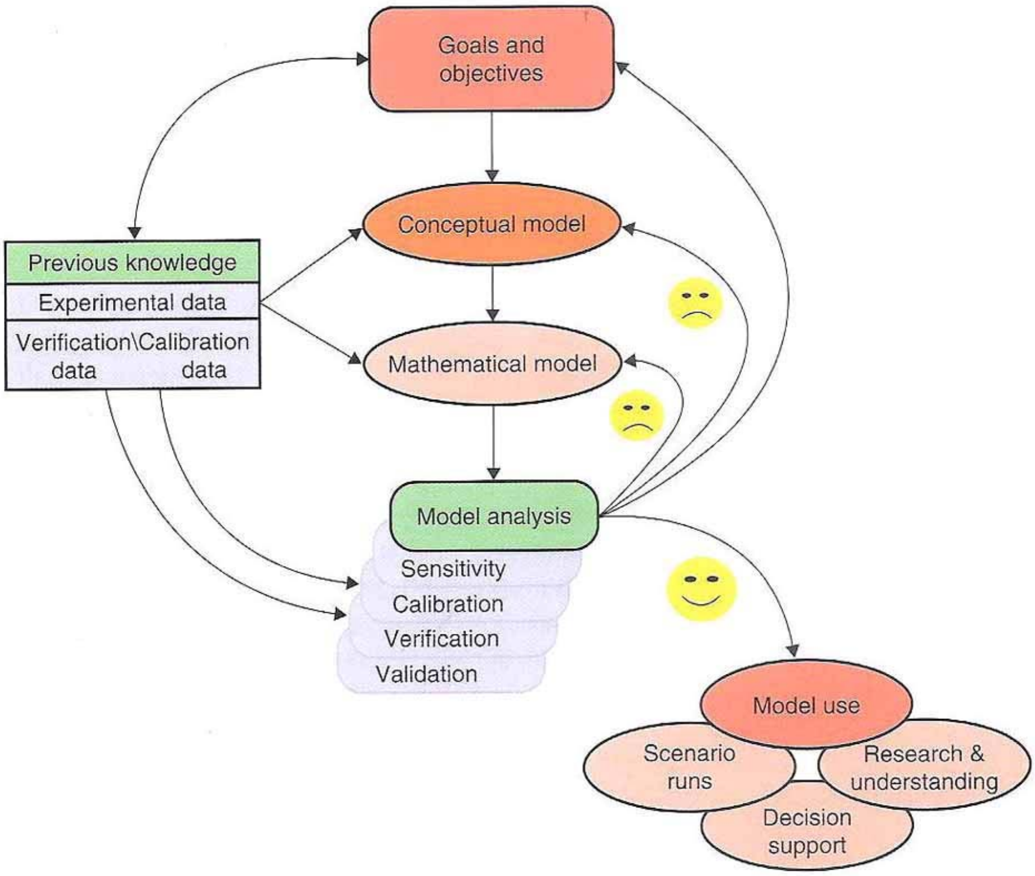
2.3 Modelling for natural resource management

Few decade ago, there is a science has been developing from many disciplinary such as Ecology, Mathematic, Computer science, etc. that integrated in terms of subsystem into main system. It calls “Modelling approach” which has main objectives are:

- To know and understand system dynamics
- To know system mechanisms
- To know situation or trend of system in the future

(Worrapimphong, 2005)

As natural resource professionals, term “model” can be found in many scientific literatures or planning document. Models are frequently developed to guide management decisions, natural resource professional must understands what models are and learn their strength and weakness (Shenk and Franklin, 2001). Combination between ecological knowledge and modelling approach can create ecological modelling which is an effective tool to study either ecosystem and/or ecosystem management. Models provide an opportunity to explore ideas regarding ecological system that it may not be possible to field-test for logistical, political and/or financial reasons (Jackson et al., 2000).



Source; Voinov, 2008

Figure 2.13 Basic modelling process

Voinov, 2008 illustrated basic process of modelling as show in figure 2.13, the modelling process start by setting the goal and objective then the conceptual model is created regarding available knowledge or sometime experiments may needed to fulfill the conceptual model. It is important to create a conceptual which reflects the system study because the good conceptual model can save time in modelling process. In the conceptual model, there will be some relationship among elements in the conceptual model and mathematical model can employ in the task to represent relationship among elements. Then, model analysis is important step to test your model including sensitivity, calibration, verification and validation. However, in this step researcher can move back to any step if some problems or mistakes are found in modelling process. Finally, when the model passed analysis step it can be used or applied in the system study. The model can employed in many purposes; to research itself, to understanding system, to test with various scenario, to be assisted in decision making, etc..

Modelling approach usually is computer-based tool, especially with simulation runs to explore scenarios on computer program, Nowadays, the computer hardware and software make modelling approach faster and applicable to many field of study such as economic, marketing, engineering and science (Worrapimphong, 2005). Following environmental problems that have been occurring over the world, modelling approach is an effective tool to understand and to fine a fit solution for the problems and may also prevent some problems which could be happened in the future for instance, the work of world modelling from Club of Rome to anticipated world resources direction in a serial book namely, The limits to growth in 1972 and Beyond the limits in 1992 (Meadows, Meadows and Randers, 1992;Meadows, Meadows, Randers et al., 1972).

2.3.1 Why modelling for natural resource management?

"*Sustainable Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*"

(World Commission on Environment and Development, 1987)

According definition of sustainable development above, sustainability is often touted as a goal for environment, resource or ecological management for instance; sustainable forest practices maintain forest structure, diversity, and production without long-term decline or loss over a region. Sustainable water use provides for the water needs of human without reducing water quality or quantity to level that might compromise ecological processes. Modelling offers a chance to explore both components and relationship to let researcher understands structure and function including spatiotemporal of the system. Consequently, management practice can be tested in the model instead of the real world then, model can guide or advise on how to appropriately manage natural resources (Dale, 2003a).

Generally, people may know an advantage of modelling is prediction the direction of the system. Of course, prediction might be a goal of the model construction but not only prediction is a goal for model. Sometime prediction may not exactly ultimate goal of modelling. However, model results always contain uncertainties and ability of anticipate might limited because models are based on; (1) current knowledge and understanding of interaction among elements in the system, (2) field or laboratory studies, therefore from prediction may change to projection of the system (Costanza and Ruth, 1998;Dale, 2003b).

Natural resource management does not require only prediction or projection. Manager has to understand both of the complexities and the uniqueness of a given situation and its response to management or change. Models allow managers to conclude information, justify where the gap and estimate across the gap, and simulate various scenarios to evaluate outcome of the model which is a consequence of management decision. In addition, Epstein (2008) described 16 reasons other than prediction to build models. The sixteen reasons are follow;

1) Explain
2) Guide data collocation
3) Illuminate core dynamics
4) Suggest dynamical analogies
5) Discover new questions
6) Promote a scientific habit of mind
7) Bound outcomes to plausible ranges
8) Illuminate core uncertainties
9) Offer crisis options in near-real time
10) Demonstrate tradeoffs/suggest efficiencies
11) Challenge the robustness of prevailing theory through perturbation
12) Expose prevailing wisdom as incompatible with available data
13) Train practitioners
14) Discipline the policy dialogue
15) Educate the general public
16) Reveal the apparently simple to be complex (or vice versa)

Following the reasons above, it can conclude that modeling offers a plenty way to help natural resource management in many dimensions such as:

2.3.1.1 To monitor (support decision making)

Following Epstein (2008) model can help by: 1) explain the context of the system to stakeholder (people in the system, resource manager and researcher) who involve in modelling process and let them make a decision based on the understanding of the system; 3) Illuminate core dynamic in the system to stakeholder can also help them realize which are important elements in the system before make a decision; 8) Illuminate core uncertainties with 9) offer crisis options in near real time, in these points uncertainty is very important in the real world because nobody know what will happen in the near future, modelling can help stakeholder aware on the uncertainty by the model itself; and 10) Demonstrate tradeoffs/suggest efficiencies in this point model can guide manager or stakeholder to select an efficiency scenario to manage their natural resources.

2.3.1.2 To share knowledge (support communication)

Again with the reasons from Epstein (2008), 13) Train practitioners and 15) Educate the general public. From both reasons the modelling process can help stakeholder gain more knowledge by involving in model building. Exchanging and discussion on different understanding from various stakeholders will be held during modelling process which may be an arena for let stakeholder share their knowledge to each other and they may also change their understanding or update their knowledge in the same time. Due to educate the general public, modelling process distributes knowledge to general public by stakeholder who involving in the process and they may distribute knowledge to other by themselves. However, sometime by the publication the model distributes its knowledge by public to a scientific journal.

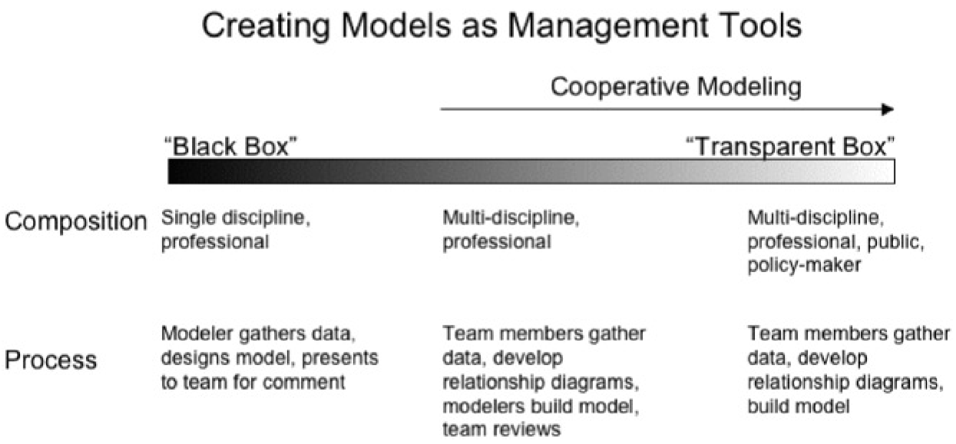
2.3.2 Participatory modelling

As diverse environmental problems or concern continue to demand our attention to tackle with those problems. Researchers try to seek for tools or method that can help us to reach the solution or understand environmental issue. One tool which significantly attended among researcher is participatory modelling, all referred to as cooperative, collaborative, mediated, or group modelling (Cockerill, Tidwell, Passell et al., 2007).

Following a key principle of participatory management is to shift authority from an autocratic position to one of share power among diverse stakeholder groups. Participatory modelling is a modelling method that utilizes principle of participatory modelling, including attempts to link relationship between environment and social to improve our understanding of complex systems (Cockerill et al., 2007). Nowadays, participatory modelling have been used to help stakeholders improve their thinking at social level and let them able to visualize the wider social and biophysical processes that they can not see without modelling process (Dung, 2008).

The traditionally, model construction to explore system study usually performed by one group of researcher and neglect participation of stakeholder who belong in the real system. From figure 2.14, Cockerill et al. (2007) presented figure which reveals difference between traditional model construction and cooperative modelling. Cooperative modelling has metaphor as “Transparent Box” which has more participation not only in stakeholder level but including discipline and professional. Beside, traditional model construction metaphorically as “Black box” which has limitation in construction process that may not understood by other stakeholders but research who constructed it.

Following the purpose of participatory modelling for increasing transparent of modelling process to stakeholders, to increase participatory modelling effectiveness, it is important to know exactly why stakeholders are being included and also legitimacy to participate in the process that can increase the democratic legitimization of management decision (Hare, Letcher and Jakeman, 2003). In addition, participatory modelling can be address in specific purpose as Renger, Kolfschoten and de Vreede (2008) defined collaborative modelling as “The joint creation of a share graphical representation of a system”. A representation or understanding of the system form each individual can be opposed but the common one for everyone in the system can achieve from collaborative or participatory modelling process.



Source: Cockerill et al. (2007)

Figure 2.14 Cooperative modelling as a transparent box which reveals the process and gains more participation in model construction.

2.3.3 Companion modelling

Models have been known to represent the system structure and dynamics in a simplified form to enhance the understanding of complex systems. The sharing of knowledge to guide or support management decision and modelling process should be performed together to make maximum use in modelling approach (Worrapimphong, 2005).

Companion modelling (ComMod) approach is one of many modelling processes. The ComMod approach is based on participatory approach applied to Renewable Resource Management (RRM). The history of ComMod was started in 1993 at CIRAD or Centre de coopération internationale en recherche agronomique pour le développement, France; a group of researchers in Management of renewable resources and environment (GREEN) research unit tried to improve methodology to manage renewable resources collectively. The improvement was to design a trans-disciplinary research approach to explore linkage between ecological and social dynamics by regarding their interaction and integration of point of view in each stakeholders in a given RRM problem (Trébuil, 2008).

2.3.3.1 The charter and theories

There is no preside definition of ComMod rather than scientific posture of the team. The posture of ComMod team represented in the charter from 13 researchers as in 2003 (Barreteau et al., 2003b) in the first official publication namely, “Our Companion Modelling Approach” in Journal of Artificial Societies and Social Simulation (http://jasss.soc.surrey.ac.uk/JASSS.html). Nowadays, 48 researchers sign in the charter (http://www.commod.org/).

ComMod approach is a interdisciplinary action-oriented research it aims to strengthen adaptive management capacity in local scale (Bousquet and Trébuil, 2005). As Barreteau et al. (2003b) the ComMod approach can be used in two following specific objectives which are:

- To understand complex environments
- To support collective decision-making processes in complex situation.

To achieve the specific objectives, ComMod is dealing with a combination of pragmatic and theoretical question regarding the management of renewable resources and the environment, and also confront with uncertainty, complex and dynamics of research objects. Then, different view point deserve to be take in to account in the process to better understanding and analysis interaction. Therefore, ComMod approach has common meaning that:

a. The fate of all the assumptions backing modelling work is to be discarded after each interaction with the field, that is to say to be voluntarily and directly subjected to refutation,

b. Having no a priori implicit experimental hypothesis is an objective implying the adoption of procedures to unveil such implicit hypotheses,

c. The impact in the field has to be taken into consideration as soon as the first steps of the approach, in terms of research objectives, quality of the approach, quantified monitoring and evaluation indicators.

d. Particular attention should be given to the process of validation of such a research approach, knowing that a general theory of model validation does not exist, and that procedures differing from those used in the case of physical, biological, and mathematical models need to be considered.

(Barreteau et al., 2003b)

In addition, Trébuil (2008) describe main theoretical references of ComMod approach. ComMod emerged from common problems that researchers face in empirical research on their complex objects of study. The theoretical consist of;

(1) The science of complexity: to analyze emergence at the whole system level properties.

(2) Resilience and adaptive management: to understand the system function which improve adaptive capacity of the stakeholders, and also its self-regulation and self-organize properties.

(3) Collective management of multi-actor processes: to understand linkage and creation of institution for RRM by resources users themselves.

(4) Constructivist epistemology: to explicit the different point of view and representation of the system from different stakeholders who have different experience.

(5) Post-normal science: to improve collective decision-making process. Post-normal science considered by the researcher that soft social-ecosystem are based on assumption from stakeholders involving in social learning processes.

(6) Patrimonial mediation: to practice and understand co-management. A patrimonial represents an area or set of resources through the generations of manages with their obligation, while mediation is a negotiation approach which tries to neutral or facilitate agreement among conflict in different parties.

2.3.3.2 Tools in ComMod

The tool selection to using in ComMod approach is depending on the situation in various systems. However, there are privilege tools to be used in the approach (Barreteau et al., 2003b). Multi-Agent System (MAS) and Role-Playing Game (RPG) are the privilege tool in ComMod. However, another tool such as Geographical Information System (GIS), Economic theory, etc can be accompanied with MAS and RPG to enhance the collective decision-making and make stakeholders understand rhe system better. Thus, in a given system the production of knowledge or a share representation of point of view from the tools in ComMod approach could lead to:

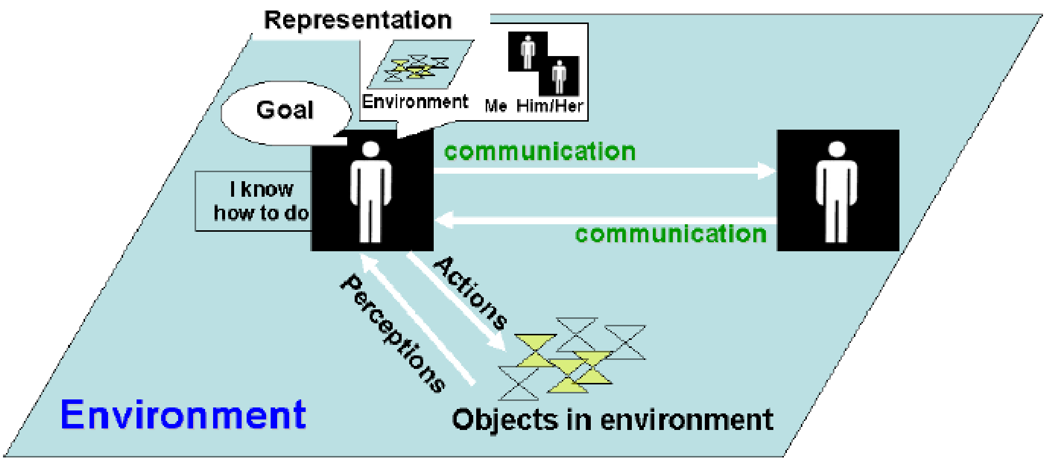
- improve knowledge of actor and/or decision-maker
- facilitate dialogue among stakeholders (include expert)
- providing a framework for discussion and sharing of information
- exchange of view point, knowledge and beliefs among stakeholders

- negotiate support system aim at reducing the gap between view point and conflict in system study

Adapted from: Worrapimphong (2005)

Recent decade, several researchers have started to use multi-agent system, also called Agent-Based Modelling (ABM) in different fields. Especially, ecologist and economist use this tool for ecosystem management (Bousquet and Le Page, 2004). Originally, MAS came from to field of Artificial Intelligent (AI). MAS at the beginning was called Distributed Artificial Intelligent (DAI) because of the heterogeneous agent in AI can reproduce knowledge and reasoning itself.

MAS are an assembly of agents with specific goals, The agents have capability to perceiving, communicating, interacting and acting in the environment that they belong with other agent (Ferber, 1999). Meanwhile, Le Page, Bousquet, Bakam et al. (2000) proposed that MAS are made of a collection of agents, each agent being a computerize autonomy entity and able to act locally in response to stimulus from environment. In addition, Janssen (2002) describes MAS consists in a number of interacting autonomous agent, an agent can be human, animal, plant or organization. The agent can be reactive or proactive; may respond to its environment; communicate with other agents; learn, remember, move and have emotions. Figure 2.15 shows the principal and organization of MAS which has agents, environment as an object and interaction among those objects.



(Adapted from Ferber, 1999)

Figure 2.15 MAS representation, general organization and principal

Agents have:

· - internal data representations (memory or state),

- means for modifying their internal data representations (perceptions),

- means for modifying their environment (behaviors)

The key-concept of MAS concerns the interactions between agents. These interactions may occur through the environment, either by being at the same place at the same time or less directly (for instance by ownership, resource depletion, pheromone depletion), or may occur explicitly, either via direct communication (exchanges of messages) or via transactions (e.g.,financial) (Le Page et al., 2000).

Cormas (**Co**mmon-pool **R**esource and **M**ulti-**A**gent **S**ystems) is a one of available simulation platforms for MAS. As a synonym of MAS is ABM (Bousquet, Bakam, Proton et al., 1998), a simulation model which is produced by the platforms usually called ABM. Cormas has been developed since 1995. It provide capacities to build ABMs which represent ecosystem where various human activities compete for natural resources (Le Page and Bommel, 2005). Smalltalk language is a computer language for Cormas, the platform is running under the software namely VisualWorks. Cormas and VissualWorks are both freely distribution; VisualWorks is freely for education and research purpose only, while Cormas is absolutely free for download at http://cormas.cirad.fr/indexeng.htm . Following construction of ABM, the goal of Cormas is not to making the accurate model for prediction about system behavior but to providing framework to help people develop new ways of thinking (Gurung, 2004). The construction of AMB in any platform, Unified Modelling Language (UML) has been used to create conceptual model of the system study. UML is the first modelling language to describe the system based on simple graphic representation. In addition, UML is a formal and normalized language and was accepted by the Object Management Group (OMG) (Le Page and Bommel, 2005). With UML diagram, an ABM should be understandable even by non-computer scientist.

RPG is a type of game in which the participants assume the role of characters and collaborate in a given story (Dung, 2008). There are 3 objectives for using the RPG as follows; training, observation and negotiation support. RPGs has been used with MAS in the field of natural resources management since 1996 (D'Aquino, Barreteau, Etienne et al., 2002). MAS and RPG can be developed separately; however, both MAS and RPG can be used together. The joint of used between MAS and RPG can enhance the approach more effectively (Barreteau, Bousquet and Attonaty, 2001). The RPG can be used to validate the ABM as well as simulation outcomes and let participants give feedback or critic on RPG and/or ABM to researcher. Then, researchers can improve AMB, RPG as well as their understanding of the system.

Recently, another joint use of AMB and RPG was purpose, it called “Participatory Simulation” (Droguoal, Venbergue and Meurisse, 2002;Guyot and Honiden, 2006). It combined both AMB and RPG into the same event; by integrating computer simulations into RPG and allowing stakeholders and expert (researcher) to interactively define these behaviors, through RPG or by being as human agent in the running simulation. (Guyot and Honiden (2006) gave us some reason why we need participatory simulation as follows:

- Simulation can involve stakeholders who are geographically distance
- Recording of interactions in computer can help stakeholders better understand the dynamic of the game
- Merging of game and agent-based simulation decrease the gap between ABM and behavior of participants
- Participant can be replaced by artificial agents in ABM

Following ComMod, the privilege tools which are MAS and RPG, these have some similarities in both tools and its unique application fit in various contexts in different situation as listed in table 2.3.

Table 2.3 Similarities between MAS and RPG

Multi-agent systems	Role-playing game
- Agents	- Players
- Rules	- Roles
- Interface	- Game set
- Simulation	- Game session
- Time step	- Turn

Adapted from Gurung (2004)

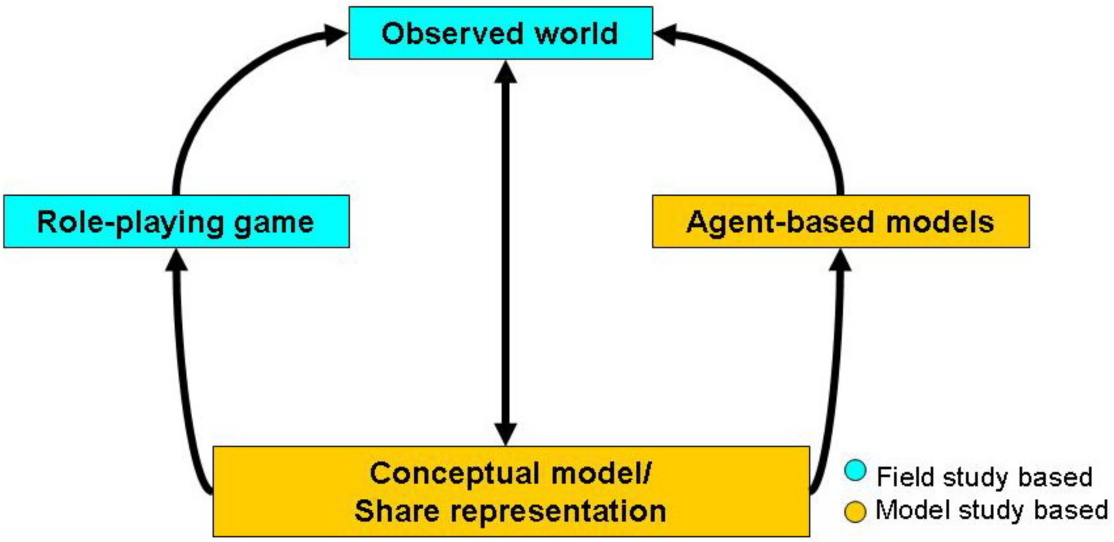
There are few experiences with the coupled use of models and role games for ecosystem management. For example: Fish banks game it was developed in 1993. It is a famous role game which is used for educational purpose. Human players play the role of fish companies that share a common resource. A simulation model simulates the dynamics of fish resource that the human plays as harvester. The objective of the Fish

Banks game is to illustrate and teach the tragedy of the commons principle: free access to resources leads to biological depletion and consequently to economic overexploitation (Bousquet, Barreteau, d'Aquino et al., 2002).

2.3.3.3 ComMod process

ComMod approach requires a permanent and iterative confrontation between theories and field work. Therefore, ComMod is based on repetitive back and forth step between the model and the field situation (Barreteau et al., 2003b). In addition, this approach is opened to: i) consider as legitimate and take into account point of view which could be contradictory, ii) organizes the compulsory questioning of any new element introduced in the approach, iii) confront a new element which could be emerged from internal and external system.

Linkage between privilege tool in ComMod approach (Barreteau, 2003a)can be illustrate in figure 2.16, It is an iterative step between field study and theoretical of tool. Researchers have a choice to select tool to implement the approach in the system after they created a conceptual model of the system. However, validation or comparison with observed world is necessary in order to improve the model.



Adapted from Trébuil, Ekasingh, Bousquet et al.(2002)

Figure 2.16 Iterative used of ComMod approach between RPG and ABM

Following the iterative process, Trébuil (2008) summarized 5 main phases of ComMod methodology as follows:

(1) Initialization of a ComMod process

(2) The co-construction & conceptualization of models with stakeholders

(3) Implementation and validation of ComMod models

(4) Scenario identification, exploration and assessment

(5) Monitoring & evaluation of ComMod effects and impact

2.3.3.4 ComMod in Natural resources management

Since ComMod approach was created and has been distributing from its origin to many parts of the world such as Europe, Africa. Until 2002, ComMod was introduced in Southeast Asia (http://www.commod.org and http://www.ecole-commod.sc.chula.ac.th). There have been many case studies carried out in renewable resources management in Europe, Africa, and Asia by using separately application either MAS (ABM), RPG or complete ComMod approach in the study. For example;

Bousquet, Cambier and Morand (1994) were build fishery model case of the central delta of the Niger river and tired to contribute the multidisciplinary knowledge from the model. This case was using DAI method which is ABM in currently.

Barreteau and Bousquet (2000) studied the viability of irrigated systems in Senegal River Valley. RPG and MAS as ComMod approach were conducted to explore viability of irrigated system in social network, it well knows in SHADOC model.

Bousquet, Le Page, Bakam et al. (2001) studied simulation for hunting wild meat in a village in eastern Cameroon by using Cormas and reported that a hunting behavior can affected population and age structure of blue duiker, it is a meat for local villager.

Trébuil et al. (2002) conducted ComMod approach for watershed management in northern part of Thailand, focusing on steep-land management by limiting land degradation in rapidly diversifying and market-integrated farming system of Akha village. The results showed that ComMod helped to identify acceptable rules for an improve regulation of collective uses of land resource.

Mathevet, Bousquet, Le Page et al. (2003) studied interactions between duck population and farming decision for agriculture or leasing of hunting rights in the Camargue (Southern France) by using Cormas. There were 3 scenarios in this study: Scenario A: “high rice-crop profitability”, Scenario B: ”critical period for the agricultural market” and “Scenario alternation”. The results from each scenario showed that in Scenario A population of duck will be increased to more than 120,000 individuals this number more than duck population in scenario B about 2 folds and in term of land use agricultural land quickly increased to cover nearly 80% of the region but in Scenario B the natural land has developed to cover 55% of the region because of the increased of hunting marshes. For “Scenario alternation” whatever in order ABABAB or BABABA the results was not differ from the beginning of simulation.

Suphanchaimart, Wongsanum and Panthong (2005) used ComMod approach studied farmer decision making in enlarge area for growing sugar cane in North of Northeastern in Thailand. The results contributed to more understanding how farmers make a decision to use their land to grow a type of agricultural product

Gurung, Bousquet and Trébuil (2006) used ComMod approach to study irrigation system in cased of water sharing in Lingmuteychu watershed, Bhutan and reported that those tools in the study can improve stakeholders in watershed shared their perception and helped collective decision to managing their water resource.

Dung (2008) used ComMod approach to study impact of environmental regarding saline water and socio-economic on rice-shrimp farming in Meakong Delta, Vietnam. The result showed that ComMod approach fitted with the situation where the conflict of water using is occurring. The approach can help stakeholders exchange point of view and cooperate in saline and fresh water using in sustainable way.

From the example of case studies, ComMod approach seem to be an effectively tool for renewable resources management. It can apply in various situations and type of resources. Nevertheless, when comparison with other approach; there are still some weakness and strength of ComMod approach as shown in Table 2.4 which discussed by Robinson, Brown, Parker et al. (2007).

Table 2.4 Strengths and weakness of Companion modelling

Strength	**Weaknesses**
* Role-playing games can be used to confirm known decision functions, both individually and collectively	* Modeller can play many roles, including being part of the system being modellered.
* Testing of decision-making strategies occurs within the context of the situation being modelled.	* Independent tests of the model and game are difficult to design, given involvement of subjects throughout.
* Facilitate awareness in subjects of the modelling goals and approach	* Very costly and time-consuming to devise role-playing situations.
* Provides a structured opportunity to observe agent-agent interactions.	* Limitation in the number of players in any game. * Limits to generalizability of the findings.

Source: (Robinson et al., 2007)

CHAPTER III

RAZOR CLAM POPULATION AND SOME ECOLOGICAL FACTORS

3.1 Introduction

Don Hoi Lord is a coastal wetland ecosystem located in the province of Samut Songkhram about 100 km west of Bangkok. This wetland ecosystem has been registered as an international wetland called the 1099th Ramsar Site since 2001. It covers the area of 87,500 ha of a sandbar formed by the accumulation of sediment at the Mae Klong river mouth. In Thai, "Don" means the sandbar area at the river mouth and "Hoi Lord" is thai name for the razor clam *Solen spp. (Tuaycharoen, 1999)*. The razor clam is a bivalve that is a very popular delicacy food in Thailand. The sandbar is a large habitat of razor clams that traditionally are harvested by local fishermen. Apparently, Don Hoi Lord is nowadays a popular destination for Thai tourist in the vicinity of Bangkok where they can appreciate natural atmosphere and enjoy eating the clams as delicacy food.

The razor clam resource at Don Hoi Lord is a common asset that local fishermen have been freely harvesting the clams for more than 80 years without any regulation. In 1987, the provincial government implemented a regulation about the harvesting method (Suwanna, 2003). It prohibited the harvesting method that spread the lime solution directly over the sand substrate. The lime solution is more effective that caused some reactions to the clams getting out of their holes but it caused more destructive to population stock due to all size be caught. Therefore, the traditional and sustainable harvesting has now reintroduced by using a bamboo stick dipping with lime and put into the razor clam holes. .Practically, only the regulation about the harvesting method has been considered but it still has some arguments among fishermen about it. Furthermore, in 1998 the provincial government also declared a reserved area for razor clam breeding site. However, according to the fishermen and previous studies, the density of razor clam population has been decreasing gradually as well as the average size of razor clam population also decreased. In connection with the promotion of tourism at Don Hoi Lord, it has caused the increasing of demand of razor clams production that obviously put more pressure on razor clam harvesting to this area, It clearly threats this wetland ecosystem become more fragile ecosystem and particularly razor clam population is also exploited and degraded. Razor clam population at Don Hoi Lord has been studied since 1981 (Pradatsundarasar, 1982). Reportedly, many researchers from various institutions conducted studies on many aspects of razor clam biology such as breeding biology (Sriprathumwong, Sornkaew and Phuwapanit, 2002; Tuaycharoen and Worra-in, 1991), feeding biology (Bautong, 1997), etc.

This chapter describes the study on ecological aspects in relation to razor clam population. It includes the scientific method and following by the results of both field and laboratory works. Then, the relationships between razor clam population and relevant ecological factors were analysed and discussed. Finally, the discussion on razor clam population change at Don Hoi Lord by comparing with previous data since 1981 is presented.

3.2 Methodology

3.2.1 Study site

The largest sandbar at Don Hoi Lord was selected as a study area due to the previous studies reported that this sandbar has been a major site for razor clam harvesting for long time. It covers an area around 321 hectares and located nearest to local community (Worrapimphong, 2005). Fishermen consider this sandbar as priority to harvest because it has large area and can easily access. Furthermore, tourists who visit Don Hoi Lord usually go to visit natural site at this sandbar. This sandbar is a triangle shape and located from the east side of Mae Klong river mouth along the coast approaching into sea (Figure 3.1)

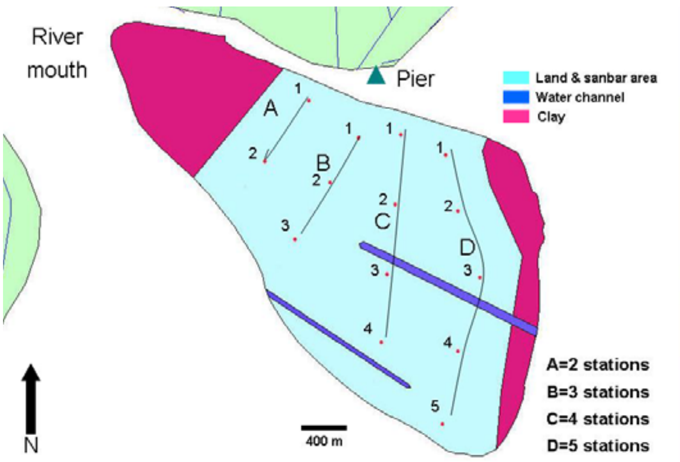


Figure 3.1 The largest sandbar which is the study site and indicate the location of sampling stations

3.2.2 Field data collection

Monthly filed data collection was carried out from June 2008 to May 2009 (Table 3.2). Four transect lines were set up to covering the sandbar area. Then, sampling stations were determined in each transect line and recorded each station's position by using Geographical Positioning System (GPS) device. Total 14 stations (Table 3.1) in 4 transect lines were created for monthly data collection (June 2008).

Table 3.1 Geographical position of each station at Don Hoi Lord represented in UTM datum

Station	Zone	Easting	Northing
A1	47P	610646	1476909
A2	47P	610365	1476518
B1	47P	610967	1476667
B2	47P	610782	1476318
B3	47P	610556	1476013
C1	47P	611240	1476688
C2	47P	611201	1476238
C3	47P	611149	1475787
C4	47P	611112	1475350
D1	47P	611528	1476557
D2	47P	611605	1476196
D3	47P	611747	1475768
D4	47P	611603	1475290
D5	47P	611503	1474818

The interval distance between stations is approximately 400-500 m depending on the physical characteristics of the sandbar. In each month, razor clam population and soil sample collection were carried out during low tide while water sample and some ecological factors were collected and measured during high tide (Table 3.2). Moreover, the study was designed as shown in Figure 3.2 that indicates the overviews of monthly field data collection and detail in each activity.

Table 3.2 General information of tidal and date in each monthly data collection

Trip	Date	Tide level (m)		Tide time		Sandbar expose duration (Hr)
		Min	Max	Min	Max	
1	20 Jun 08	0.7	3.4	1:00 pm	8:00 pm	6
2	30 Jul 08	0.7	3.3	9:00 am	6:00 pm	6
3	27 Aug 08	0.8	3.3	8:00 am	5:00 pm	6
4	25 Sep 08	1.0	3.5	8:00 am	4:00 pm	4
5	30 Oct 08	1.2	3.7	12:00 am	7:00 am	3
6	18 Nov 08	1.1	3.7	3:00 am	10:00 am	4
7	13 Dec 08	1.0	3.8	12:00 am	7:00 am	4
8	25 Jan 09	1.2	3.6	12:00 am	6:00 am	4
9	25 Feb 09	1.1	3.5	12:00 am	6:00 am	4
10	29 Mar 09	1.1	3.6	2:00 pm	8:00 pm	3
11	29 Apr 09	0.8	3.6	3:00 pm	10:00 pm	5
12	28 May 09	0.5	3.6	3:00 pm	10:00 pm	6

Source: Thai Royal Navy, 2008 and 2009

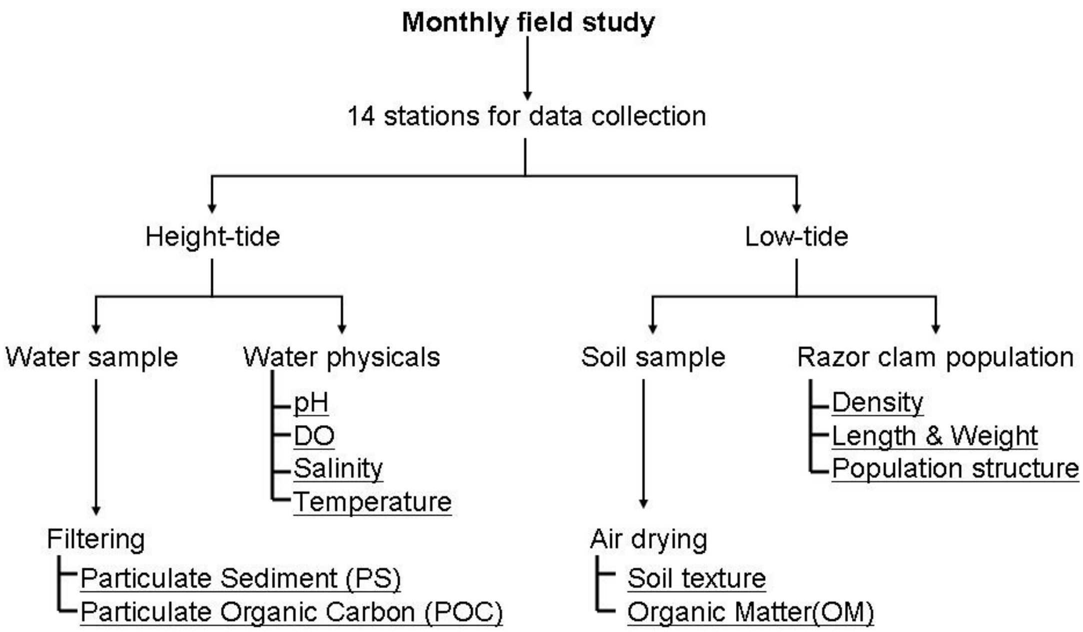


Figure 3.2 Overviews of monthly field data collection

3.2.2.1 Razor clam population

At each station, the quadrat sampling method (Krebs, 1989) was used to census razor clam population. Three replicated quadrats (1 m^2) were designed for collecting razor clam as follows:

(1) Using a bamboo stick dipped lime and dropped into the razor clam hole.

(2) Using spade to dig sand around 30 cm depth from the surface to collect all remaining razor clams in the quadrat (Figure 3.3).

Caught razor clams from each quadrat were separated into 2 groups, first from dropped lime method and second from digging method.

Figure 3.3 Digging remaining razor clam in quadrat for census razor clam population

3.2.2.2 Soil sample

A soil sample in each station was collected by using Auger soil sampler at 0-20 cm depth and took back to the university laboratory for soil analysis.

3.2.2.3 Water sample

Two liters of water were collected at each station during high tide and kept at 4 ºC until filtering.

3.2.2.4 Some ecological factors

Water pH, dissolved oxygen (DO), salinity and water temperature were measured at each station during high tide by using the following instruments:

- pH meter (YSI-PH100) for sea water pH,
- DO meter (YSI-550A) for DO and water temperature
- Refractometer for salinity.

3.2.2.5 Razor clam growth rate

During April – May 2009, the study of actual razor clam growth rate was carried out on the sandbar. Three class sizes of razor clam which are 3-4 cm, 4-5 cm and >5 cm were collected for the study of growth rate in duration of one month. The method was designed as follows:

(1) Collect razor clams and separate into 3 size classes as described above

(2) Select only active clams for 20 clams/size class and measure the length of individual clam, then make a label on each clam by using nail polish (Schweers, Wolff, Koch et al., 2006) and also do coding of each color use according to size class.

(3) Release all 20 clams of each class size in a experimental site that is covered with net over a cage. There were 3 cages for 3 size classes (Figure 3.4)

(4) Recapture razor clams in the experimental cages after one month by using the lime and digging method

(5) Measure the length of live razor clam and analyze the growth rate after one month.

Figure 3.4 Experimental cages for the study of razor clam growth rate on the sandbar

3.2.3 Laboratory analysis

Water, soil and razor clam samples from the field were taken to laboratory and prepared for analysis as follows:

3.2.3.1 Razor clam measurement

The shell length was measured by vernier caliper in centimeter (cm) and the clam weight was measured by digital balance in gram (gm).

3.2.3.2 Soil preparation

(1) The soil samples were air dried at room ambient temperature for at least 2 weeks or until the sample dried well (Jones, 2001).

(2) The dried soil samples were sieved by 2 mm soil sieve filter and stored in sealed plastic bag. Thus, soil samples were ready for laboratory analysis of soil texture and organic matter (Figure 3.5).

Figure 3.5 Soil air drying (A) and soil sieving (B)

3.2.3.3 Soil texture analysis

Soil texture analysis was carried out by method provided by American Society of Agronomy (Gee, Bauder and Klute, 1986) in Figure 3.6 (A). (Annex A)

3.2.3.4 Soil organic matter analysis

One sieved soil sample was prepared for 2 replicates and then analyzed for organic matter content by wet oxidation method (Walkley and Black, 1934) in Figure 3.6 (B). (Annex A)

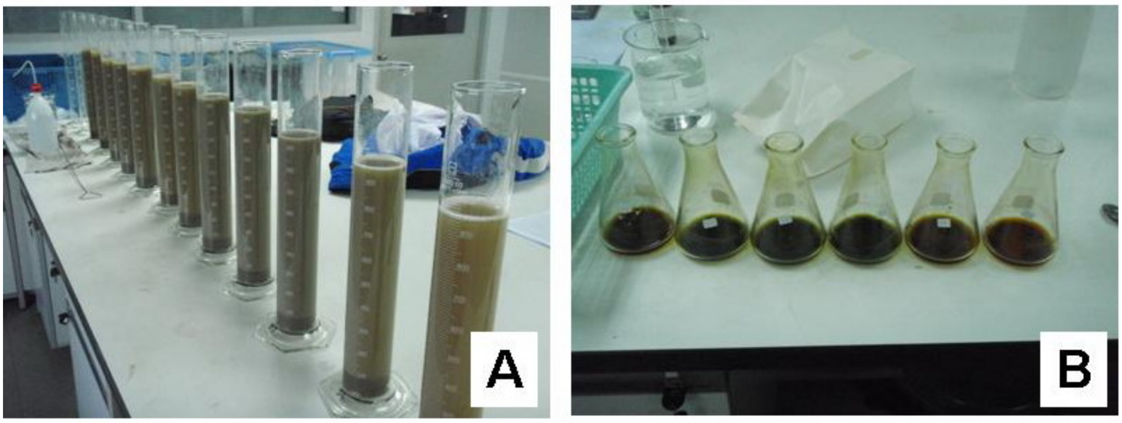


Figure 3.6 Soil texture analysis (A) and organic matter analysis (B)

3.2.3.5 Water sample preparation for Particulate Organic Carbon (POC)

(1) Water sample from the field for particulate solid purpose was filtrated by using pre-cleaned GFC filter paper accompany with standard Millipore suction device (Parsons, Maita and Lalli, 1984) in Figure 3.7 (A). There were 3 filtered samples from each station.

(2) The filtered GFC filter papers were preserved in a desiccator for the chemical analysis process.

3.2.3.6 POC analysis

Combustion method was used to determine POC as follows:

(1) Weight the each filtered paper and cut it to small pieces in Figure 3.7 (B)

(2) Combust the filtered filter paper in SHIMADA TOC Analyzer in Figure 3.7 (C)

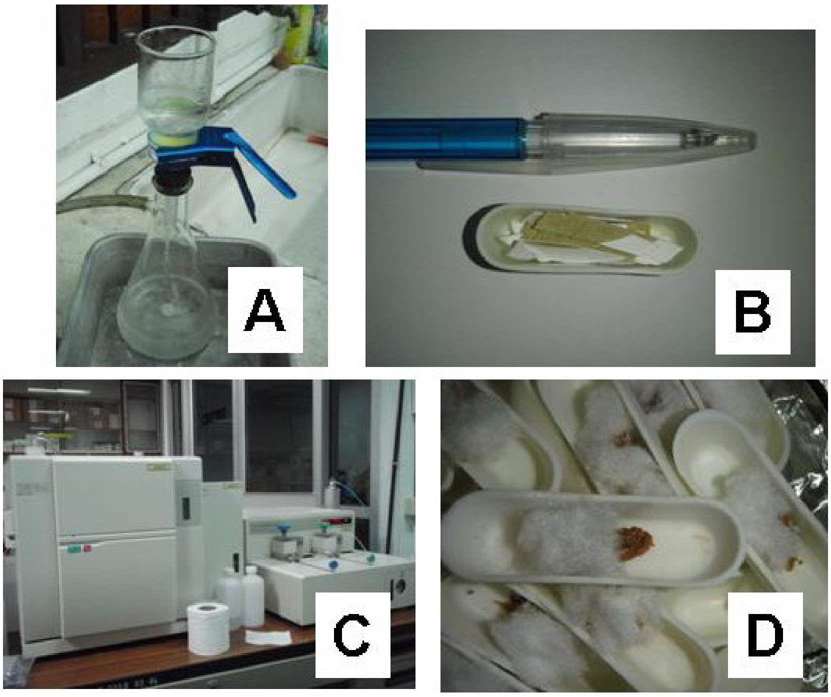


Figure 3.7 Process of POC analysis; (A) Filtering sediment, (B) Filtered filter ready to analyzed, (C) TOC analyzer and (D) Residue of filter after process

3.2.4 Statistical analysis

SPSS statistical software for Windows was used to employ statistical tasks. Particularly, Correlation Analysis and Non-parametric Analysis were used for testing the relationship among razor clam population and ecological factors.

3.3 Results and Discussion

3.3.1 Razor clam population

3.3.1.1 Razor clam population density

There were 2 dimensions of data of razor clam density which were emphasis on time (the mean of each month for 12 months of study) and space (the mean of each station through 14 stations).

The razor clam density in each month in Figure 3.8 showed the fluctuation of population density. Also in Table 3.3, the mean density was ranged 0.57-0.74 clam/m^2 in the beginning of field study from June 2008 until August 2008. Then, it decreased in September 2008 (0.57±0.99 clam/m^2) and sharply decreased in October 2008 (0.07±0.14 clam/m^2) which was a minimum density in the study. After October 2008, the density started increased a bit and fluctuated until February 2009, and then the razor clam density increased every month until May 2009 which was the last month of field data collection.

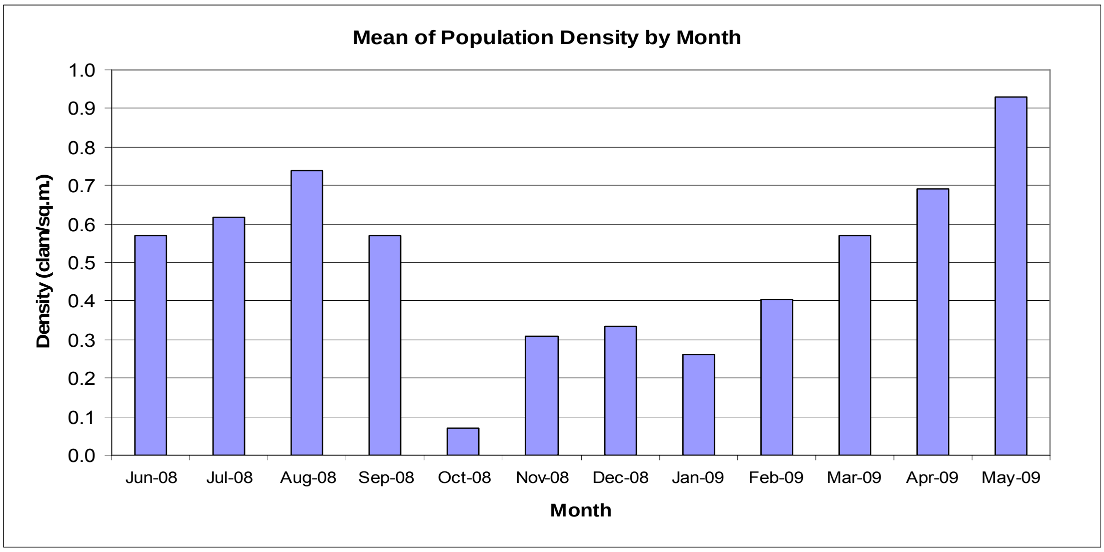


Figure 3.8 Mean of razor clam density in each month from June 2008 - May 2009

The mean of razor clam density was 0.51±0.30 clam/m^2 during the study period. The minimum population density was 0.07±0.14 clam/m^2 in October 2008 while the maximum density was 0.93±1.16 clam/m^2. From Table 3.3 also showed the mean with standard deviation (SD) value in each month; there were only 2 months in August 2008 and May 2009 that SD values did not higher than mean value. It can imply that only 2 months (August 2008 and May 2009) the density was distributed over the study site. Meanwhile, the rest 10 months had some differences among density which made the SD value higher than mean density value (Table 3.3). However, the normal distribution of population density was checked and found that the density was not distributed normally. Thus, non-parametric test was carried out and found that the median of mean density in each month was not statistically different among 12 months (Kruskal-Wallis H Test, $p < 0.05$).

Table 3.3 Mean of razor clam density in each month with standard deviation value

Month	Density
Jun-08	0.57±0.61
Jul-08	0.62±0.63
Aug-08	0.74±0.49
Sep-08	0.57±0.99
Oct-08	0.07±0.14
Nov-08	0.31±0.74
Dec-08	0.33±0.57
Jan-09	0.26±0.35
Feb-09	0.40±0.94
Mar-09	0.57±0.85
Apr-09	0.69±0.96
May-09	0.93±1.16

The mean of razor clam density by station is showed in Figure 3.9 and Table 3.4.

In Figure 3.9, there were some differences in mean density of razor clam in each station. The minimum density was 0 in station C1 while the maximum density was 1.53±0.81 clam/m^2 in station D5. In connection with the location of each station (Figure 3.1) and its density, the low density stations as A1, B1, C1 and D1 located near shoreline, meanwhile the high density stations as B2, C3, D4 and D5 located at the middle of sandbar (B2 and C3) or located far from river mouth (D4 and D5).

Again, the results indicated some differences between mean and SD value; only station C3, D4 and D5 that had mean value higher than SD value (Figure 3.9). It can imply that those stations had quite consistent density throughout a year of study. Meantime, another station had SD value which higher than mean value, it can imply that those stations had some fluctuation in density during the study.

According to the details of density both spatial and temporal scale, the maximum density was 3.67±2.06 clam/m^2 in station B2 in May 2009, while the minimum density was either 0 clam/m^2 or no razor clam in the station. There were many stations in every month did not have any razor clam. Particularly, station C1 never found any razor clam through 12 month of the study (Figure 3.11). However, there were 3 stations; station C3, D4 and D5 usually had razor clam most of the study period except only 1 month in each station, whereas another stations had scatted density.

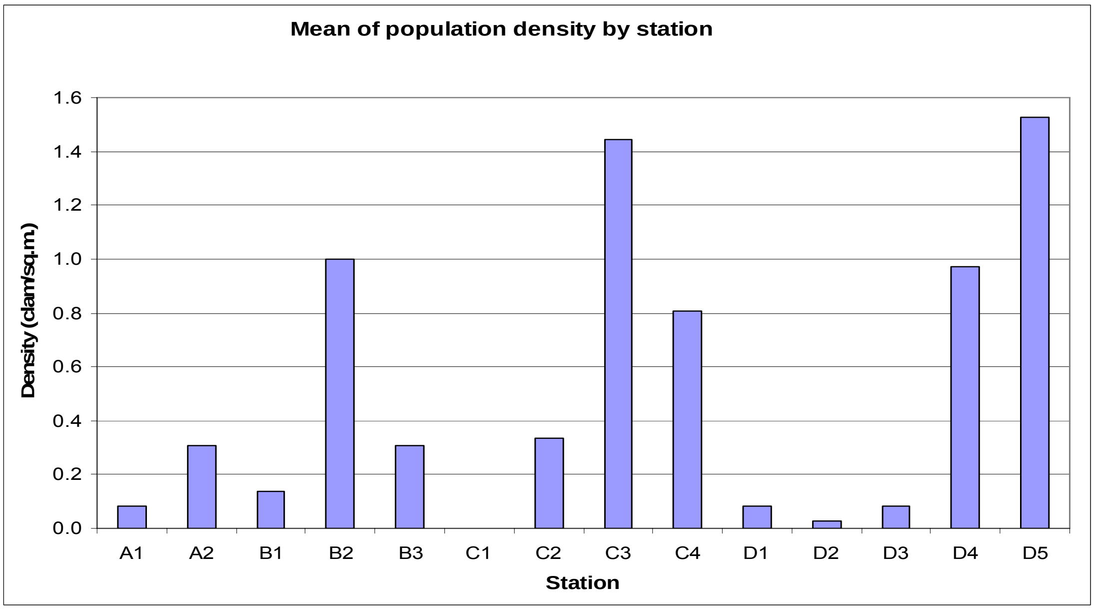


Figure 3.9 Mean of razor clam density from each station from June 2008 – May 2009

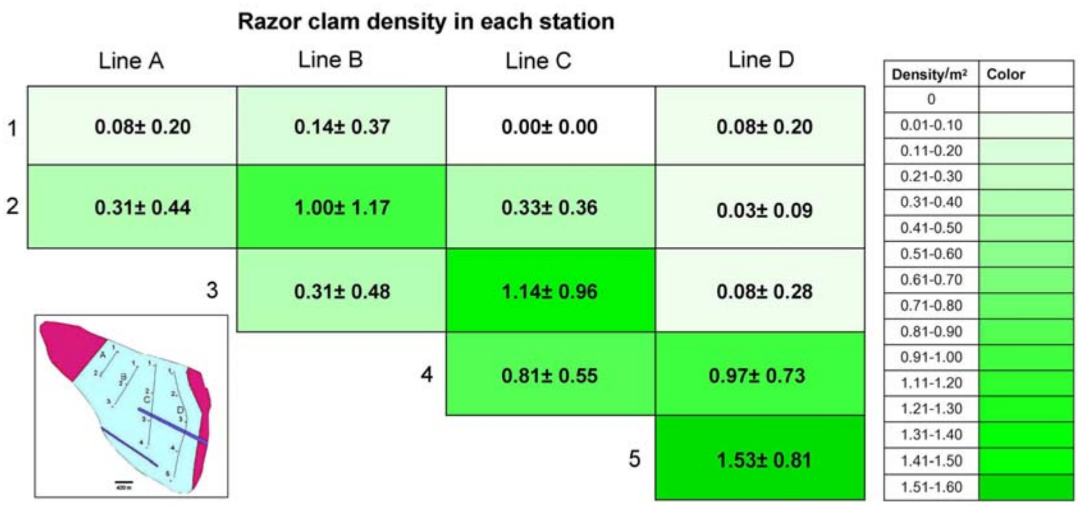


Figure 3.10 Mean density represented by color chart in each station from June 2008 – May 2009

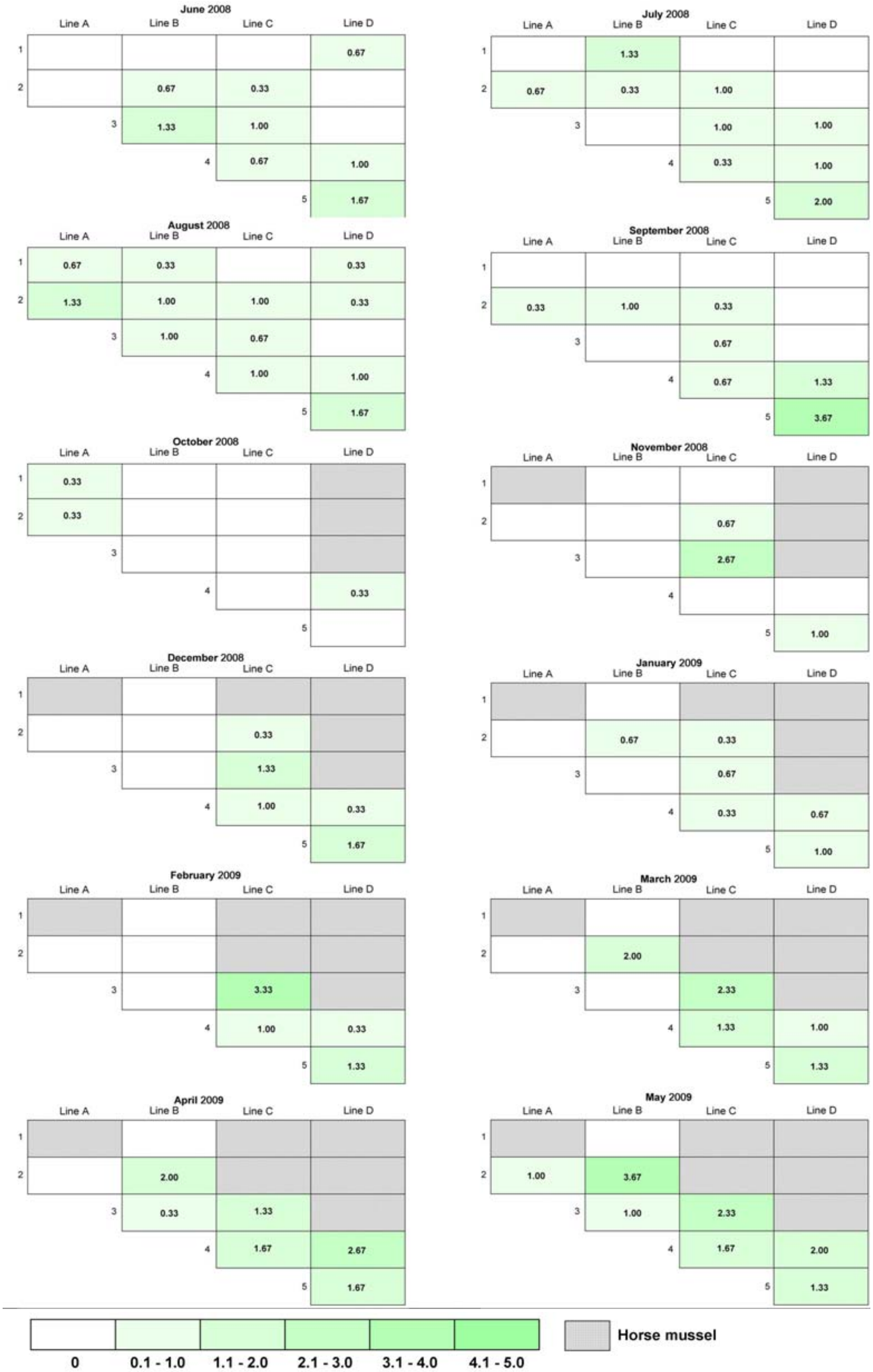


Figure 3.11 Mean density in each station represented in monthly from June 2008 – May 2009 and invasion of horse mussel (*Musculus senhousia*) during the study

Figure 3.11 shows the dynamics of razor clam density in the study with the invasion of horse mussel (*Musculus senhousia*) into razor clam habitat. At the beginning of study there was no horse mussel found, until October 2008 horse mussel started invading into 3 stations of razor clam habitat including station D1, D2, and D3. Then, the invasion successfully expanded every month, until February 2009 horse mussel invaded more area that extended from 3 stations into 6 stations covering station A1, C1, C2, D1, D2, and D3 and still remained. Furthermore, station B1 supposed to be occupied but horse mussel could not occupy because the effect of tourists disturbance by getting off the boat near station B1 and walk through the sandbar. The effect of tourist walking may affect negatively to the establishment of horse mussel's colony.

Horse mussel can occupy razor clam habitat by setting its colony on substrate that is shown in Figure 3.12. During the invasion of horse mussel, the research team could not access at the occupied stations even some stations we could access but not discovered any razor clam.

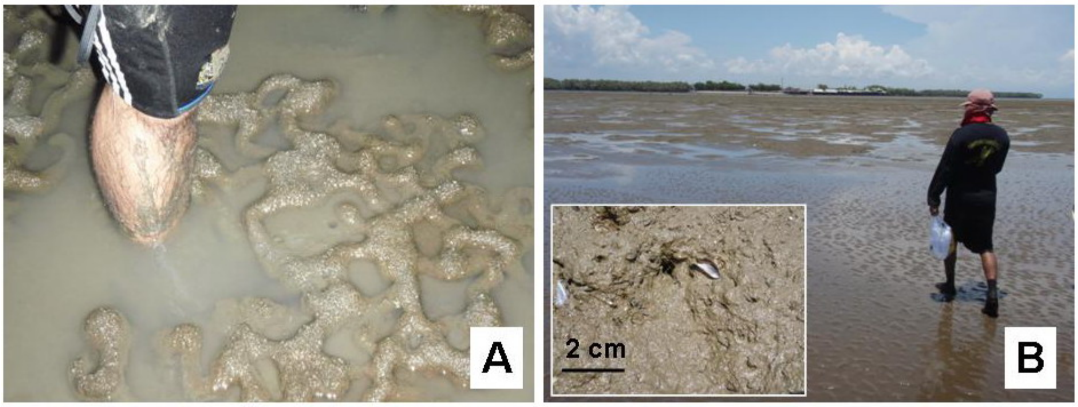


Figure 3.12 (A) The beginning of horse mussel colonization which the substrate is very muddy more than normal substrate that found razor clam and, (B) Difference between normal razor clam habitat (the big figure which can easily walk through) and horse mussel habitat (at left corner of figure which is very difficult to walk), and horse mussel colony is very dense

3.3.1.2 Razor clam length and weight

The monthly mean length of razor clam was over 4.5 cm except only 1 month in October 2008 that the density dropped to around 3 cm (Figure 3.13). It was indicated that the monthly mean length was increasing in the first 4 month of the study (June – September 2008), then sharply dropped for 1 month in October 2008. After that, the mean length increased to 5 cm./clam and it was stable through the end of the study in May 2009. The maximum monthly mean length was 5.90±0.84 cm/clam in September 2008 while the minimum mean length was 3.16±1.27 cm/clam in October 2008. The mean length of razor clam in this study was 5.34±1.21 cm/clam.

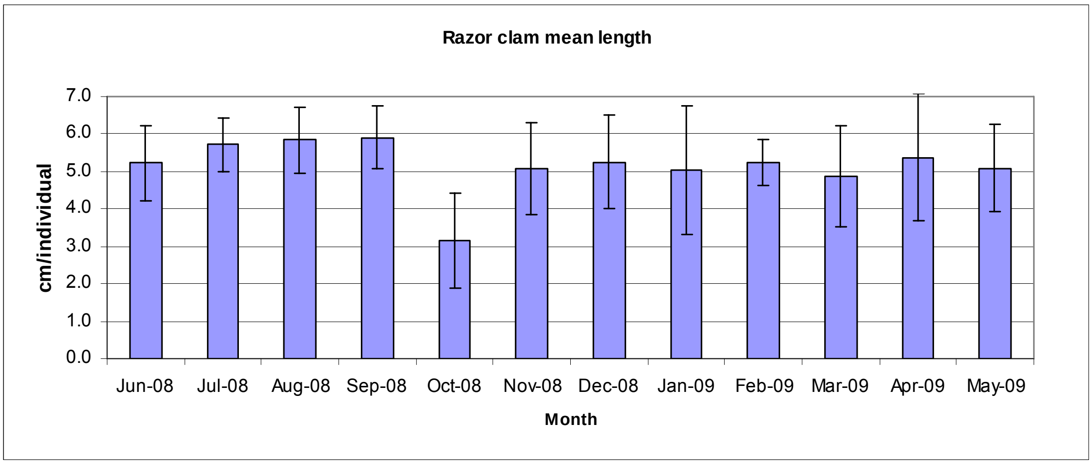


Figure 3.13 Mean length of razor clam in each month from June 2008 - May 2009

Regarding the comparison of the mean length of razor clam with the previous studies since 1997, it indicated the mean length of razor clam in this study had longest (Figure 3.15). Due to the low population density in the study site, it caused some difficulties to fisherman as low harvesting. Eventually, some of them stopped harvesting razor clam and started harvest on other aquatic species such as shrimp, tiger moon shell.

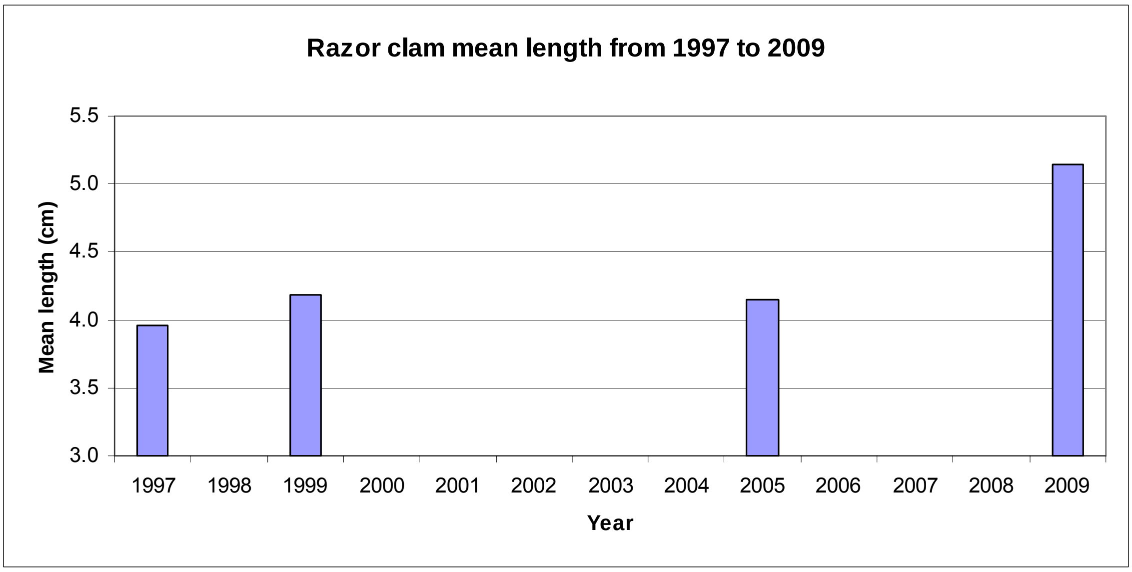


Figure 3.14 Comparison of mean length of razor clam at Don Hoi Lord from 1997 to 2009

Source: Buatong (1997), Tuaycharuan (2003), Worrapimphong (2005), and this study (2009)

In Figure 3.15, the results indicate that in the first 3 months the mean weight of razor clam increased every month, then it sharply dropped for 1 month in October 2008 and fluctuated until the end of the study. It indicated that the monthly mean weight of razor clam had a trend in corresponding with the mean length. The maximum mean weight was 5.56±1.84 g/clam in September 2008, while the minimum mean weight was 1.71±2.00 g/clam in October 2008. The mean weight of razor clam in this study was 4.21±2.30 g/clam.

Normal distribution of mean length and weight were checked and found that both length and weight were not distributed normally. Thus, non parametric test was carried out and found that the median of length and weight were statistically different among 12 months (Kruskal-Wallis H Test, $p < 0.05$).

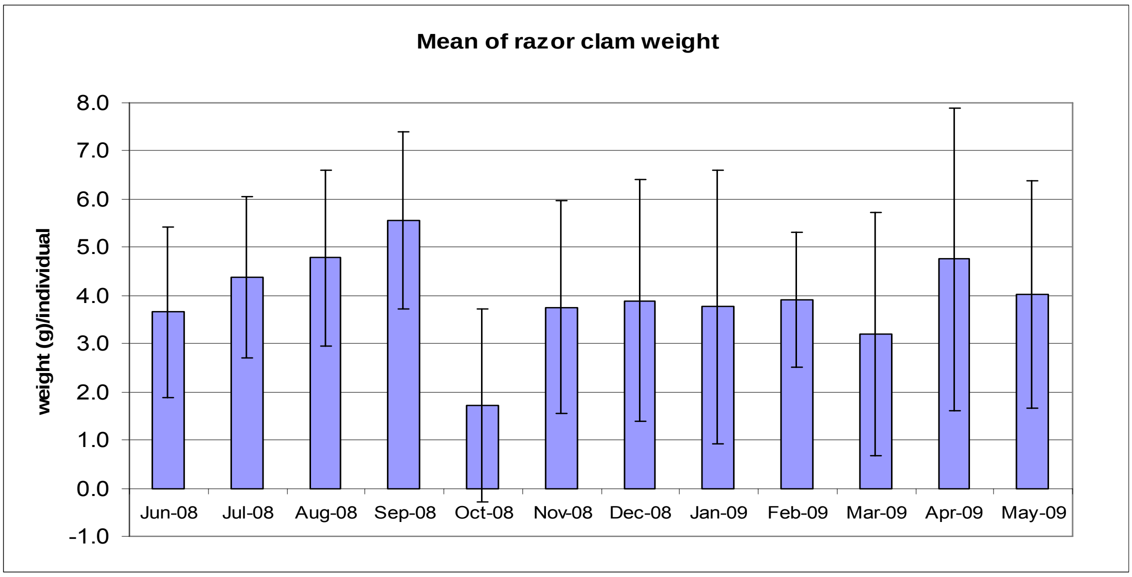


Figure 3.15 Mean weight of razor clam in each month from June 2008 - May 2009

The study of Length and Weight Relationship (LWR) of razor clam was explored in Figure 3.16.

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: (Park and Oh, 2002;and Thapanand, 2000)

Thus, power function of LWR of razor calm in this study is **$W = 0.0354L^{2.778}$**

Correlation coefficient (*r*) = 0.9534, n=254

The exponent (*b*) was 2.778, and it can imply that razor clam has allometric growth pattern because the growth is equal to 3 (Thapanand, 2000). In addition, the LWR of razor clam was estimated by a regression curve and ANOVA using SPSS for Windows to assess their relationships. The result showed that length and weight had 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 to the previous parameters (*a* and *b*).

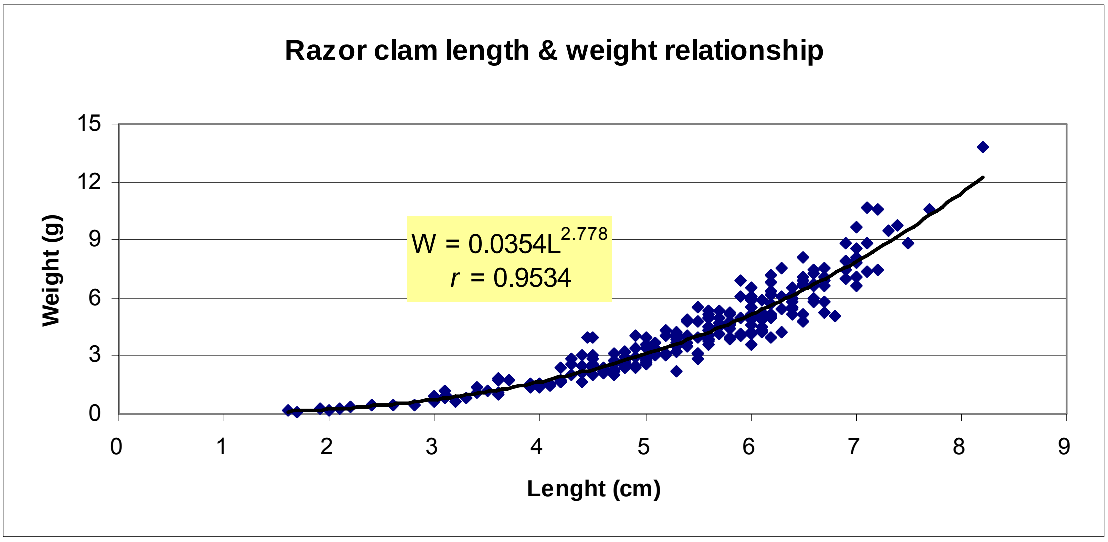


Figure 3.16 Razor clam length and weight relationship in this study

Correlation coefficient (r^2) in this study was 0.9534, it meaned that the length of razor clam could relate to the variation of razor clam weight at 95.3 % (Vanitbancha, 2003) or the correction of the power equation of razor clam LWR in this study was 95.3%.

In comparison with the previous study in 2004 (Worrapimphong, 2005), it was found that the relationship still correlated as *a* value was the same at 0.035, *b* value was 2.81, and r^2 was 0.953. There were very small difference in the power function, it may cause from the majority size class of the population (which will present in next section) but the specific gravity was the same value with previous study. In addition, 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. Apparently, these parameters correspond with this study (b = 2.778, r = 0.9534).

3.3.1.3 Population structure

Razor clam population structure was presented in monthly size class distribution which was determined by shell length. There were 6 size classes as follows: (1) ≤ 2 cm; (2) 2.1-3.0 cm; (3) 3.1-4.0 cm; (4) 4.1-5.0 cm; (5) 5.1-6.0 cm; and (6) ≥ 6.1 cm. Figure 3.17 and 3.18 represented the razor clam population structure in number of caught clam and the percentage of caught clam.

In case of razor clam harvesting, fishermen normally will harvest razor clam at size class over 4.0 cm. and the preference size class was ≥ 5 cm. Practically, they try to avoid small size class of razor clam in particular to ≤ 3.0 cm and they can notice a small size by its hole on the sandbar during harvesting.

The monthly population structure showed the variation of population structure. Majority of population was the size class (5) 5.1-6.0 cm and (6) ≥ 6.1 cm. Particularly, in June-September 2008, both size classes were found more than 60% of total population in each month, while in October 2008 the study found only 3 clams in the field study. However, this month was the first month which found small razor clam in the first size class (≤ 2.0 cm) and that was only one month we could not find size classes bigger than 5.1 cm. In the following 3 month (November 2008-January 2009), 5 size classes (2 - ≥6 cm) were found every month but in a small number of 10-15 clams/month. Then, the rest 4 months (February-May 2009) the number of caught razor clam was increasing every month and were identified in size class (5) ≥ 5.1 cm but the proportion of population was 72.7% in February, 66.7% in March, and rebound to 72.4% in April. Interestingly, the small size class (1) (≤ 2.0 cm) was found in February and March as well as all size classes also were found in April. At the end of the study in May 2009, it found that there was no small razor clam size ≤ 2.1 cm and the size class ≥ 5.1 cm was not majority size class in this month. In addition, due to number of caught razor clam, we could catch razor clam in maximum number in the last month of study.

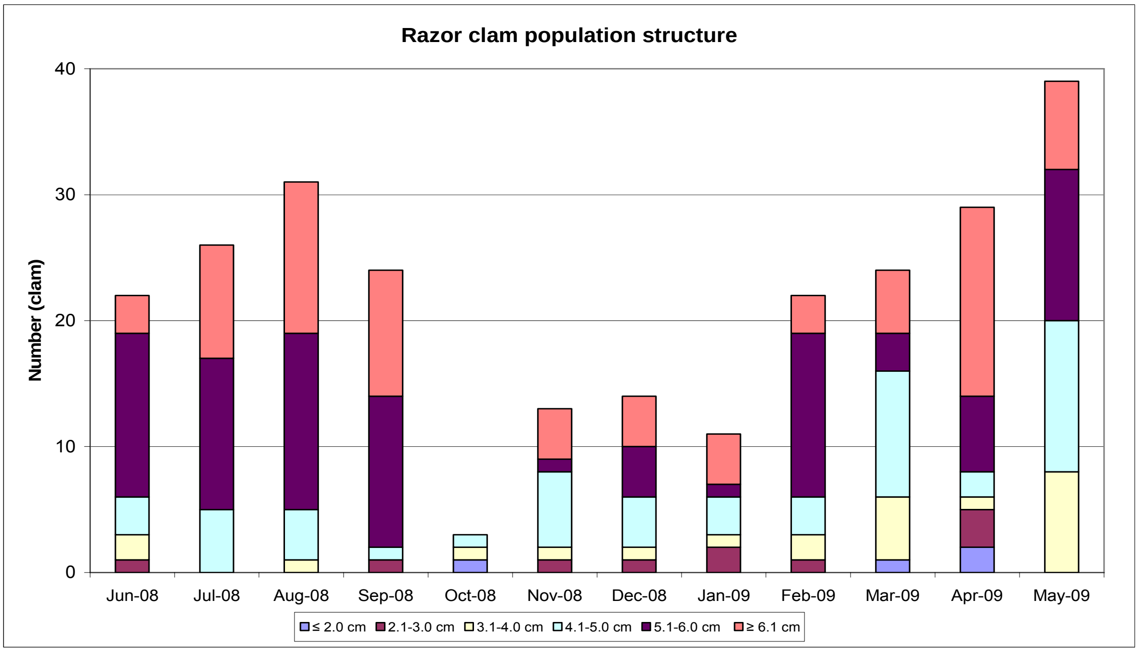


Figure 3.17 Razor clam population structures in each month from June 2008 - May 2009 in number scale

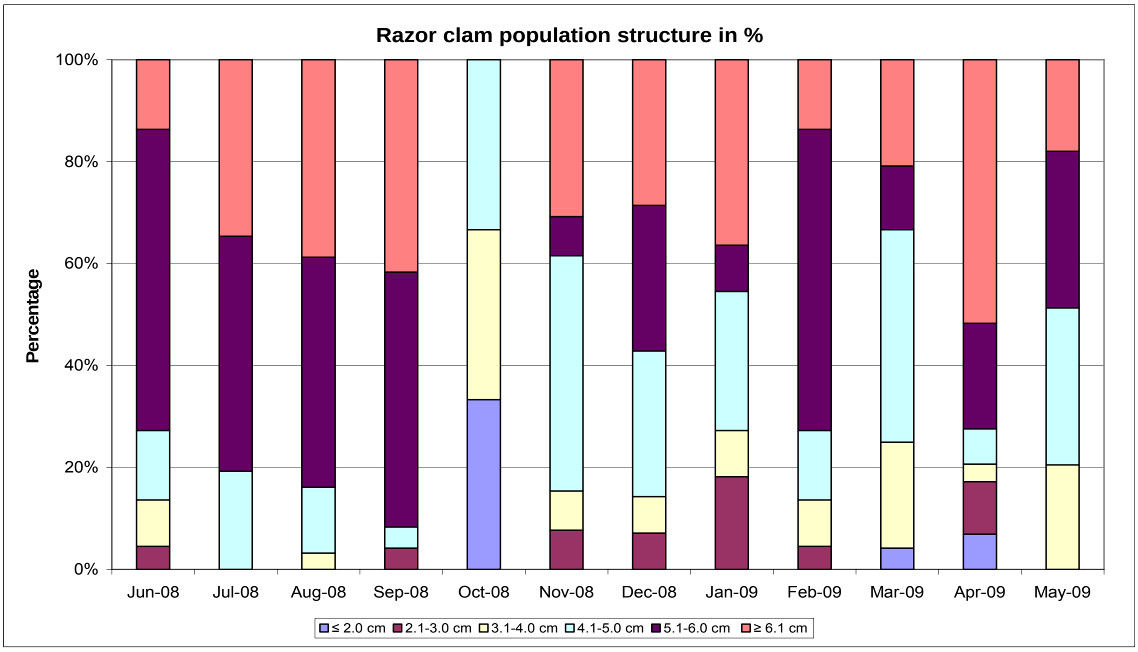


Figure 3.18 Razor clam population structures in each month from June 2008 - May 2009 in percentage scale

The conclusion of population structure from 12 months of study is showed in Figure 3.19. It was clear that the majority size class of razor clam was size class (5) 5.1-6.0 cm. at 35%, and size class (6) ≥ 6.1 cm. at 29 %. Meanwhile the small razor clams were found in very small proportion; ≤ 2.1 cm at 2 % and 2.1-3.0 cm. at 4 %. In this study it seemed to find big razor clam size, it might cause from the harvesting pressure from the fisherman. During field study, I noticed that some fishermen who harvest on razor clam had absented from the study site from September 2008 to February 2009 due to less economic return causing by the low production and night time harvesting.

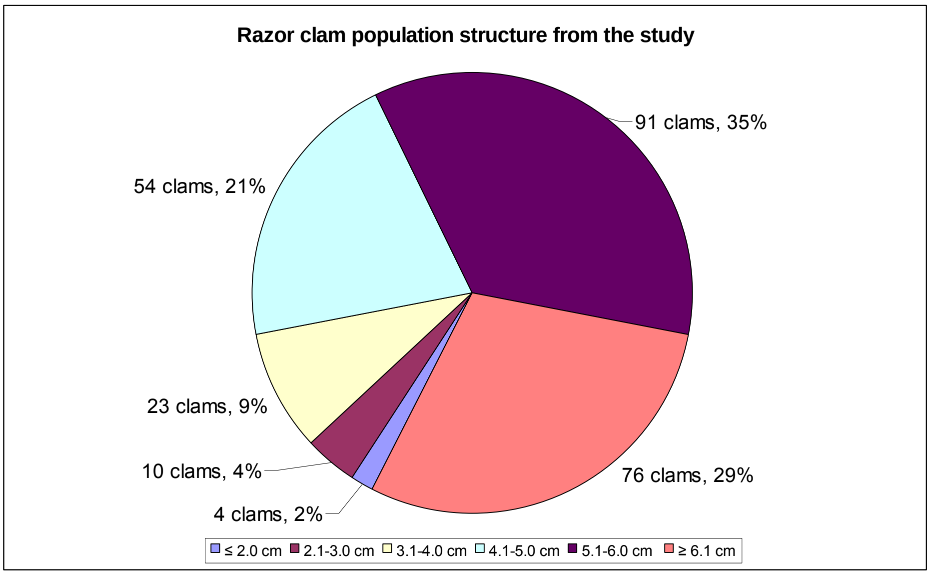


Figure 3.19 Conclusion of razor clam population structure from 12 months in number and percentage

Density of razor clam at Don Hoi Lord has been recorded in previous scientific reports since 1982 (Figure 3.20). From the beginning of the razor clam density record were not so high due to mass waste water in Mae Klong river before the first scientific study was carried out (Phiyakarn, 1979 sited in: Pradatsundarasar, 1982). Seven years later in 1989, the density was 65.5 clam/m^2, which was the highest mean density of razor clam in the records due to the bloom of shrimp aquaculture development in the surrounding area of Mae Klong estuary ecosystem and nearby area. It caused the discharge of high organic waste loading into this Mae Klong estuary ecosystem in which also induced phytoplankton bloom and supported the nutrient rich environment in particular to razor clam growth condition (Sriburi and Gajaseni, 1996). After the collapsed shrimp aquaculture activities occurred around 1993, then the razor clam density had been fluctuated in negative direction over the time. Although the studies were not organized in systematic frequency but the trend of density was decreasing sharply. Considering the study from 1989 – 1999, there were 5 studies in 10 years and the most frequently study was conducted between 1996 and 1997. The results showed that the density sharply decreased and gradually recovered in later 2 years. Density of razor clam in this study was 0.51 clam/m^2 and the lowest density in comparison with previous studies.

Regarding the decreasing of razor clam population, it might relate to continuous harvesting pressure and environmental change in which can consider as the main causes of reduction. Particularly, the harvesting pressure from local fisherman on razor clam has been practiced more than 2 generations with adaptive harvesting method to improve harvesting production.

The recent development of harvesting method was introduced around 2005 by using caustic soda (Sodium Hydroxide (NaOH)) mixing with lime powder to make it stronger and it also wildly used among fisherman. Due to the promotion of tourist activities at Don Hoi Lord, it also promotes razor clam as a delicacy food that increase harvesting pressure on razor clam demand. Moreover, the land use change around Don Hoi Lord area from the transformation of mangrove area into development area such as restaurant, seafood grocery, parking space (Figure 3.21) might be one of environmental factor change which is a cause of razor clam reduction.

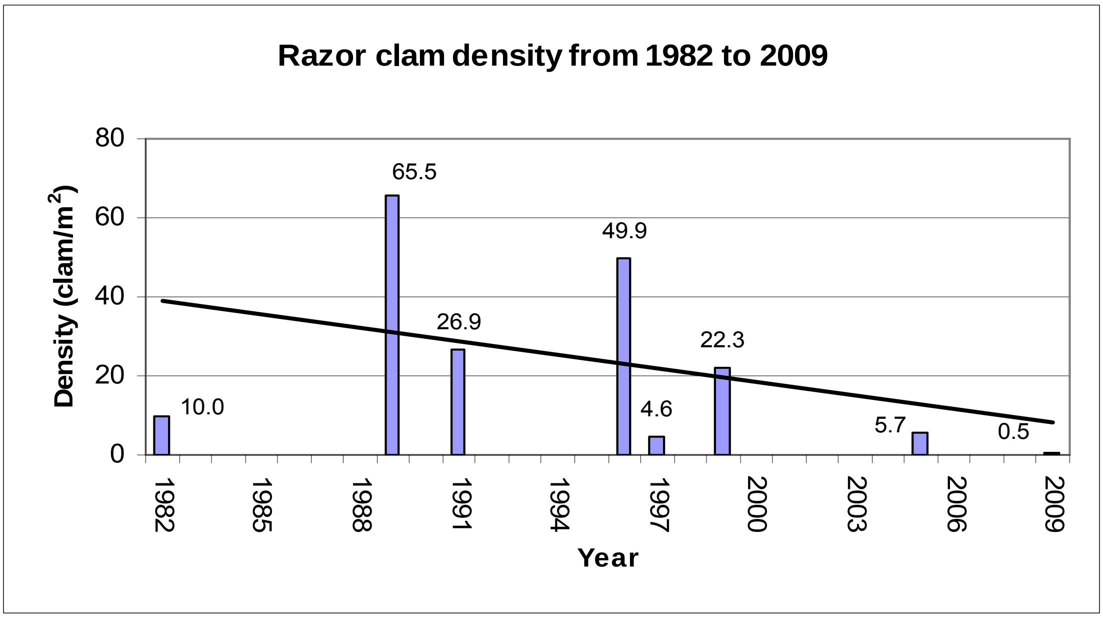


Figure 3.20 Comparison of density of razor clam at Don Hoi Lord from 1982 to 2009 (Source: Pradatsundarasar, (1982), Pradatsundarasar et al. (1989), Khumsupar et. al. (1991), Sriburi and Gajaseni (1996), Buatong (1997), Tuaycharuan (2003), Worrapimphong (2005), and this study (2009))

Figure 3.21 Restaurant (A), Seafood grocery (B), and Parking space (C) located in the area used to be mangrove forest.

Comparison this study with the last study by Worrapimphong (2005), the monthly data of station can be considered according to GPS recorded data (Figure 3.22) The density in last study between 2004 and 2005 was 5.71±2.49 clam/m^2 whereas this study was 0.51±0.24 clam/m^2. It can conclude that from 2005 to 2009 the density of razor clam at Don Hoi Lord decreased around 10 folds. In addition, during the field study in 2008 - 2009, there was less fishermen to harvest razor on the sandbar especially during nighttime at low-tide.

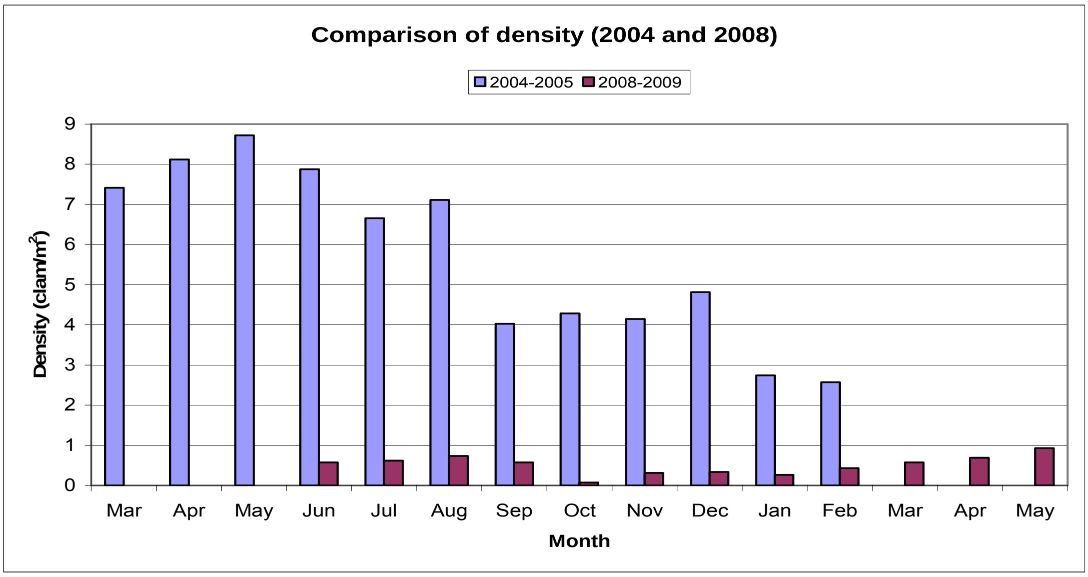


Figure 3.22 Comparison of razor clam density in 2004-2005 and 2008-2009

Due to rapid decreasing of razor clam population in 4 years, it found that the environmental change was the substrate composition in which some areas of sand bar had become muddy flat instead of fine sand composition. Therefore, the invasion of horse mussel occurred in more muddy substrate, around 50% of area of the study was invaded when the study ended (Figure 3.11). Naturally, horse mussel are usually found in muddy flat area (Suraniranat, 2009) but at the beginning of this study the study sites were predominated by fine sand and there was no horse mussel on the study site. However, the horse mussel invasion was one of indicator of huge environmental change. As described in the above, it also found that had another factor in relation to the construction of a new port was built on the east side of Mae Klong river mouth (Figure 3.23). The port cause some obstruction and change water current which normally bring sediment from Mae Klong rive to the sandbar. Unfortunately, there is no scientific study on the effect of this port to environmental condition around Don Hoi Lord such as water current, sedimentation pattern or any effects that may affect biodiversity at Don Hoi Lord.

In other part of the world, horse mussel can invaded razor clam similar to the case at Don Hoi Lord, Crooks (2001) reported that exotic horse mussel (*Musculus senhousia*) same species as species at Don Hoi Lord has been succeeded to invade native razor clam *Solen rostriformis* at Mission Bay, San Diego, California, USA. However, horse mussel can be removed by natural predator from several taxa such as bird, fish, mollusk, and human (Crooks, 2002). Generally, horse mussel mat usually found every year at Don Hoi Lord but it hasn't distributed and occupied cover a big area on sandbar. Normally, It is natural phenomena occurred around edge of the sandbar during nighttime low-tide when the sediment coming with flood. After that it was removed by natural phenomena by win and sunlight during daytime low-tide or sometime fisherman from other area use a big boat equipped with special gear to harvest it if its size reached market standard (Khongrugsar, **Interview**, 28 March 2009).

Figure 3.23 A new port for sea going vessel at Mae Klong river mouth; view from the sandbar and Google™ map view (red circle) with some study stations (red spot)

Although the density of razor clam in this study was very low when compares with the previous study but the population structure in each month form this study has showed variety of class sized (Figure 3.17 and 3.18). Small razor clam size ≤ 3.0 cm were usually found all year long except July, August 2008, and May 2009. In addition, the population structure showed razor clam can breed all year round and find the recruitment at size ≥ 4 cm. Particularly, the small razor clam size ≤ 2 cm was found in 2 periods of the year in October 2008 and March - May 2009. The finding of small razor clam in those 2 periods obviously indicated that razor clam had 2 peaks of breeding season in year round.

The finding of razor clam breeding season in this study corresponded with the previous study on razor clam breeding season at Don Hoi Lord (Pradatsundarasar et al., 1989;Sriburi and Gajaseni, 1996;Tuaycharoen and Worra-in, 1991;Worrapimphong, 2005). Based on the study of breeding of razor clam in man-made conditions by Sriprathumwong et al. (2002), they could introduce razor clam breeding from egg and sperm and successfully fertilizing upto reach young clam at size 2 cm in approximately 2 month. Thus, peak of breeding season in this study could be calculated by counting back 2 months from the month that razor clam size ≤ 2.0 cm was found. Therefore, the peak of breeding season in this study were around January – February 2009 and August 2008, it might be related to the environmental change due to temperature drop in January and February and the salinity fluctuation during the heavy freshwater runoff into the river month in August (Pradatsundarasar, Saichuae, Teerakup et al., 1989; and Sriburi and Gajaseni, 1996). It is clear that the peak of razor clam breeding season in each study from 1989-2006 varied as shown in Table 3.4.

Table 3.4 Razor clam's peak of breeding season from 1989 to 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	■	■						■				
2005						■	■				■	■
1996				■	■	■	■					
1991	■	■	■	■		■	■	■	■	■		■
1989			■	■			■	■				

■ Peak of breeding

Source: Pradatsundarasar et al., 1989; Tuycharoean and Worra-in, 1991; Sriburi and Gajaseni, 1996; Worrapimphong, 2005 and this study (2009)

The differences peak of razor clam breeding season in each study maybe caused by various environmental factors. In marine invertebrates, changing of temperature in each season and tidal cycle including lunar period are important to its breeding. These factors can help gamete fully mature at right season and right tidal cycle also for effectiveness of fertilization (Levinton, 1982). Furthermore, Wong et. al. (1986) reported that temperature was an important factor for razor clam in maturation of gamete and breeding success. At Don Hoi Lord during the daytime low-tide (usually take place from February to August), the sandbar directly exposes to sunlight and have high temperature. This environmental condition could induce razor clam's gametes to reach a mature stage and be consequently indicated as the peak of breeding season. Thus, the variation of tidal cycle which differs in each year can be a reason of the variation of breeding season.

Besides, razor clam normally has 2 peaks of breading seasons. There might be another factor is a cause of peak of breeding season apart from temperature.
From the transition of the end of daytime low-tide up to the end of nighttime low-tide usually from July to February, the temperature dropped due to raining season and winter season. However, a flooding occurs during the end of raining season, it usually brings a lot of nutrients to river month. Both nutrients and sunlight affect positively to promote the photosynthesis of phytoplankton. Bautong (1997) found that the composition of plankton in razor clam stomach content was phytoplankton only. In addition, Wong et al. (1986) reported that concentration of diatom which is phytoplankton could induce razor clam spawn in more percentage than using temperature as an induced stimulus. Furthermore, Worrapimphong (2005) reported that the role of phytoplankton as breeding stimulus was more effective and longer during nighttime low-tide than in daytime low-tide. Therefore, food source such as phytoplankton can be considered another environmental factor stimulating razor clam's peak of breeding season. Nevertheless, flooding pattern and tidal cycle are fluctuated annually, the peak of breeding season also changes in correspondant with food availability and temperature variation.

The observation in yearly revealed the dramatically decreasing of razor clam population but the monthly data in this study has showed sign of population recovering by the density was increasing month by month in the last 3 months of study. There is a question raised; Can razor clam recovery population itself or not? It is a serious question because razor clam is an important species for fisherman income and the uniqueness of the species is also important to biodiversity.

Following r/K selection theory (MacArthur and Wilson, 1967), razor clam can be categorized as *"r-selected species"* due to it has high growth rate, reproducing lots of offspring, short life span, living in fluctuation condition, etc. (Parry, 1981). From the previous studies and this study also have suggested razor clam has ability to reproduce offspring all year long and showed that razor clam population at Don Hoi Lord could recover itself from low density to high density such as from 1981 – 1989 or 1997-1999 (Figure 3.20). Even, the density of this study was lowest in the records but it has showed the majority of population structure was size ≥ 5.1 cm; this size class can breed successfully (Prasitdaycharchai, 1994;Tuaycharoen and Worra-in, 1991). Beside, harvesting pressure also defined as an influential factor on razor clam population, its density was low and rationally it was not worth to go to harvest at Don Hoi Lord (Chaloklang, : **Interview**, 28 March 2009). Finally, it seemed that was less harvesting pressure on this population due to very low population density, even the price of razor clam is still very high correspond to market demand. It is very interested in the dynamics of razor clam population after 2009 that with low harvesting pressure it may recover if the environmental factors in good qualities.

3.3.2 Razor clam growth rate

Razor clam growth rate were explored in the natural condition by using experimental cages. There were 3 size classes including 3.1-4.0 cm, 4.1-5.0 cm, and > 5.0 cm. The experimental cages were installed at coordination position of 47P 611078, 1475749 following UTM datum. Table 3.5 and Figure 3.24 show the results from 1 month of study. 20 clams/size class were measured before released into the cage. It was found that firstly, razor clam survived around 40-45% in every size classes and secondly, in each size class had various growth rate; size 3.1-4.0 had at 0.54 cm/month, 4.1-5.0 cm had at 0.44 cm/month, and size bigger than 5.0 cm had at 0.22 cm./month

Table 3.5 Results of the study of razor clam growth rate in situ in 1 month

Size	**Survival num**	**% Survival**	**Mean size at start (cm)**	**Mean size after 1 month (cm)**	**Diference in 1 month(cm)**
3.1-4.0	8	40	3.46±0.38	4.00±0.30	0.54
4.1-5.0	9	45	4.52±0.25	4.96±0.21	0.44
>5.0	9	45	6.02±0.45	6.24±0.36	0.22

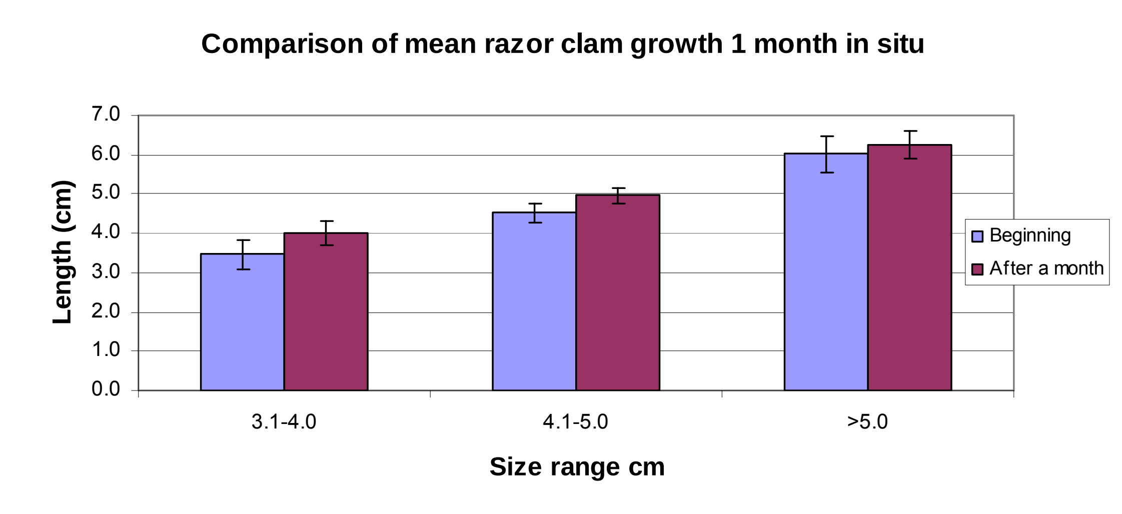


Figure 3.24 Comparison of razor clam mean length in each size class between the beginning of experiment and after one month passed.

From the study of razor clam growth rate in natural condition (Figure 3.25), the statistical analysis was carried out by using t-test in each size class. and the tests showed that mean size of razor clam in size class 3.1-4.0 cm. and 4.1-5.0 cm. during 1 month were significantly different (p < 0.01), while the size class > 5.0 cm was not significantly different (p <0.05). From Table 3.5, the mean difference in each size class was varied depending on its size as the smaller razor clam could grow faster than the bigger razor clam.

In the study of growth rate, it seems to be quite a short period because of time and budget constraints. In addition, due to the low density of razor clam during field study, it caused some difficulties to find enough number of razor clam in each size class that why only 3 size classes were designed for experimenting in the study. However, this study was the first study at Don Hoi Lord which succeeded to install semi-permanent devices on the sandbar for certain period of time without a disturbance from fisherman. Furthermore, the study had enough information to reveal the actual razor clam growth rate including natural mortality rate without harvesting pressure. Finally, we suggest to study in this topic for longer period and also duplicate experiments to produce better quality scientific information because this study spent only 1 month. Naturally, the growth rate of clam is affected by various environmental factors which has its dynamics overtime (Espinosa and Allam, 2006;Ringwood and Keppler, 2002).

Figure 3.25 (A) The cage after passed 1 month. (B) Razor clam with nail polish label found in a cage.

3.3.3 Environmental factors

<u>3.3.3.1 Basic environmental factors</u>

Basic environmental factors in this study consist of water pH, dissolve oxygen, salinity, and water temperature those are important as water physico-chemical parameters which can be directly measured in the field with scientific devices (Ringwood and Keppler, 2002). The results of environmental factors will be represented in 2 dimensions which are based on time (monthly) and space (station).

<u>3.3.3.1.1 water pH</u>

Monthly mean water pH had range from 5.92 to 7.74 (Figure 3.26). It was sharply reduced in September and October 2008 with broad SD value. Then, water pH was sharply increased in November 2008 and steadily increased for 2 month with narrow SD value. Since February 2009 until the end of study in May 2009, water pH decreased every month especially April and May 2009. Maximum monthly mean water pH was 7.74±0.06 in August 2008 and the minimum monthly mean water pH was 5.92±0.65 in October 2008. Meanwhile, the monthly mean water pH through the study was 7.18±0.61.

It was clear that in September and October 2008 the mean pH water were acidity and also below the national water quality standard of coastal water at pH 7.0-8.5 which provided by Pollution Control Department (PCD, 2010) . However, the rest of mean water pH had been in the standard range only except in May 2009 was at pH 6.96.

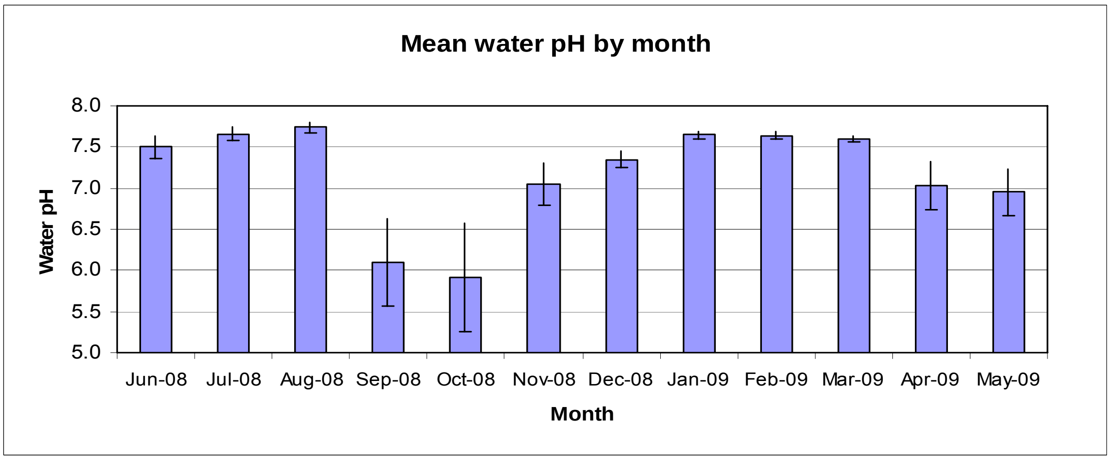


Figure 3.26 Mean water pH from June 2008 - May 2009

Figure 3.27 shows the mean water pH by station, it was found that the mean water pH of all station had reached 7.0 and met the national water quality standard value for coastal seawater (Pollution Control Department, 2010). In addition, the SD values of all stations seem to be slightly different but the statistical analysis indicated all were not significantly different (One-Way ANOVA, $p < 0.05$).

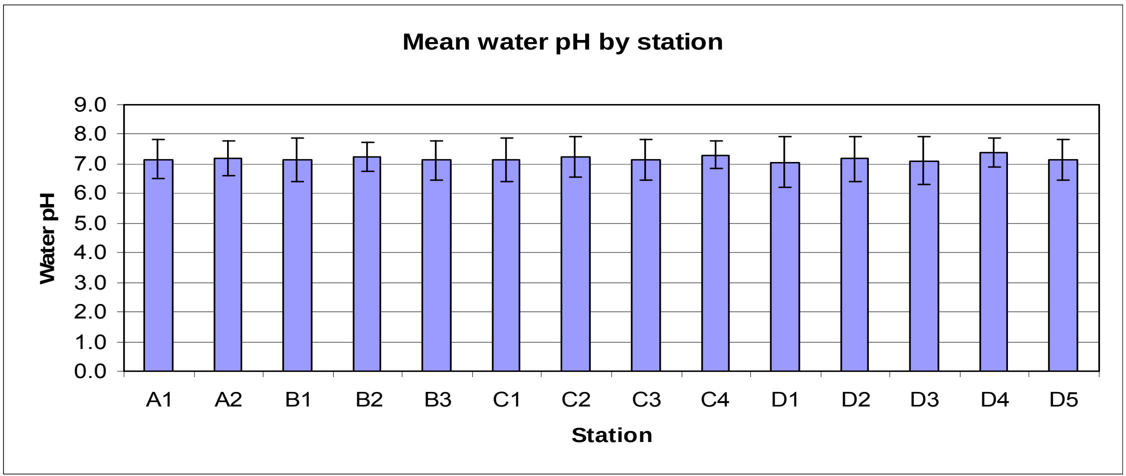


Figure 3.27 Mean water pH station from June 2008 - May 2009

3.3.3.1.2 Dissolve oxygen (DO)

The results of mean DO indicated the fluctuation all year round, which had a range of 2.55-7.59 mg/l (Figure 3.28). From June 2008 to September 2008, the mean DO had fluctuated in a range of 4-6 mg/l. Then, in October 2008 the mean DO sharply dropped to the minimum but it rapidly increased in the following month and continued increasing until January 2009. In the last 4 months of study from February to May 2009, the mean DO steadily decreased every month until the last month which the mean DO was at 3.53 mg/l. The maximum mean DO was 7.59±0.46 mg/l in January 2009, while the minimum mean DO was 2.55±0.50 mg/l in October 2008 and the mean DO was 4.74±1.29 mg/l.

By referring the national water quality standard of coastal seawater, the acceptable DO is equal or above 4.0 mg/l. Thus, in this study there were 2 months; October 2008 and May 2009 which had the mean DO values below the standard.

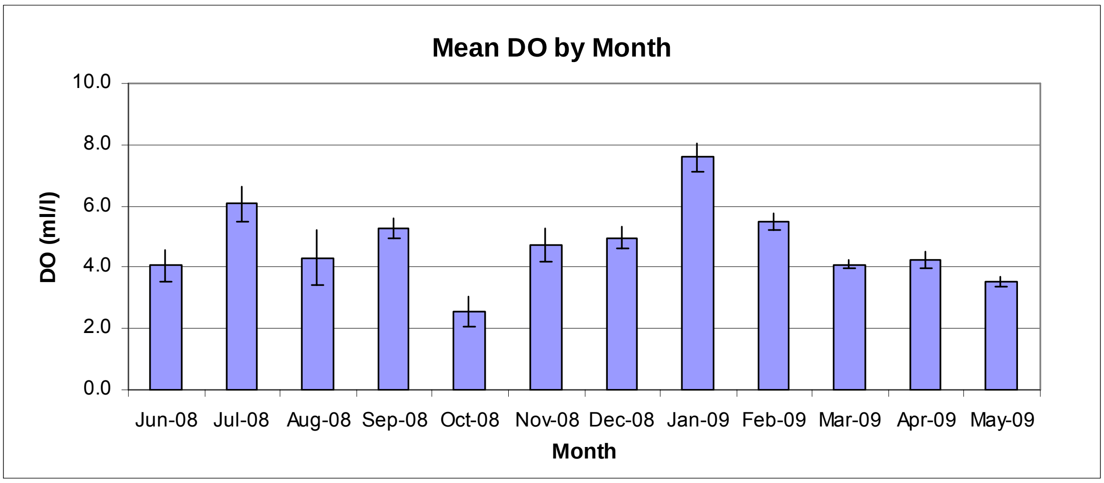


Figure 3.28 Mean dissolve oxygen (DO) from June 2008 - May 2009

Figure 3.29 shows the mean DO in each station, it was found that every station had DO at acceptable due to the national water quality standard of coastal seawater by PCD. There was very little fluctuation among the stations. In addition, the statistical analysis indicated that the mean DO of all stations was not significantly different (One-Way ANOVA, $p < 0.05$).

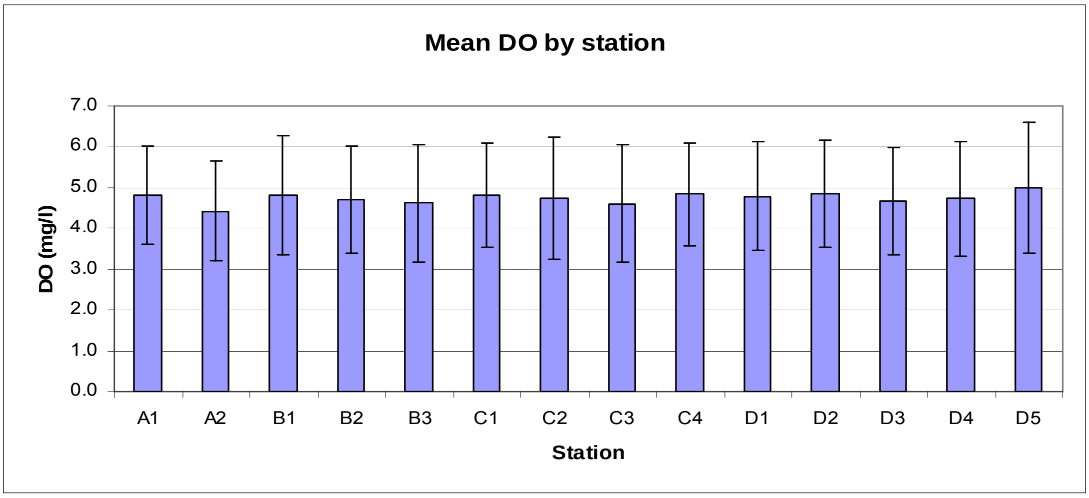


Figure 3.29 Mean dissolve oxygen by station from June 2008 - May 2009

3.3.3.1.3 Water temperature

Monthly mean water temperature had a range of 26.21-31.07ºC (Figure 3.30). Furthermore, the mean water temperature showed a pattern which corresponded with season. The study was started in raining season as reference then the water temperature started dropping when approached to winter season from October 2008 - January 2009 and increased again during summer season from March – May 2009. Because the daytime low-tide occurred in summer and raining season, it caused higher temperature than the winter season which had the low-tide during the night. The maximum mean water temperature was 31.07±0.78ºC in August 2008 and the minimum mean water temperature was 26.21±0.05ºC, while the mean water temperature in this study was 29.05±1.52ºC.

By referring to the national water quality standard of water temperature by PCD that the acceptable value is not over 33ºC (PCD, 1997 sited in Paphavasit and al., 2006). Thus, the mean water temperature in this study still was acceptable due to under the standard. In addition, the comparison of mean seawater temperature between this study and the nearest meteorological station which located in Ratchburi province, that was 27.04ºC (Thai Meteorological Department, 2009). The reference of temperature between seawater temperature and air temperature is normally related to due to heat capacity of water.

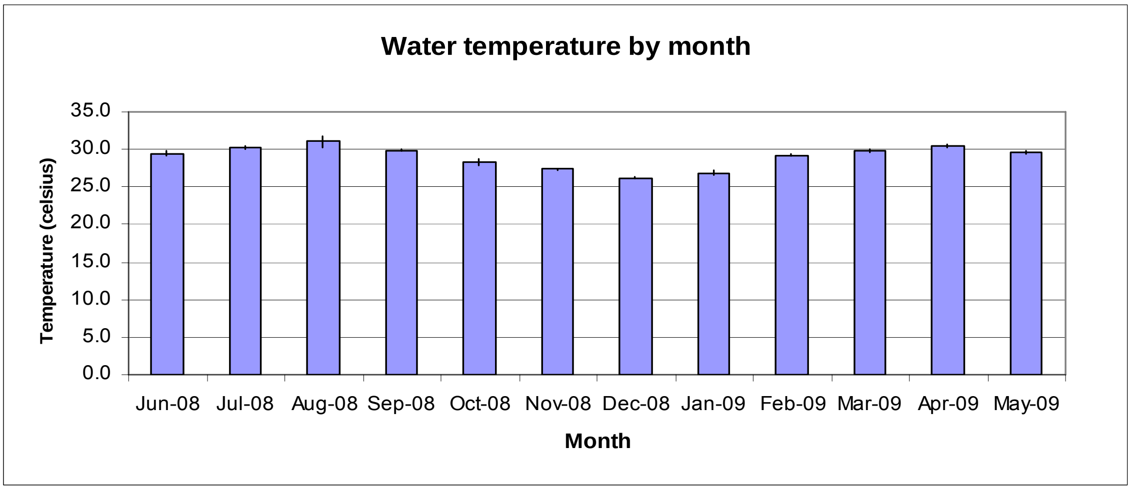


Figure 3.30 Mean water temperature from June 2008 - May 2009

Mean water temperature in each station showed that monthly mean temperature was around 29ºC (Figure 3.31). The statistical analysis indicated that the mean water temperature of all stations was not significantly different (One-Way ANOVA, p < 0.05).

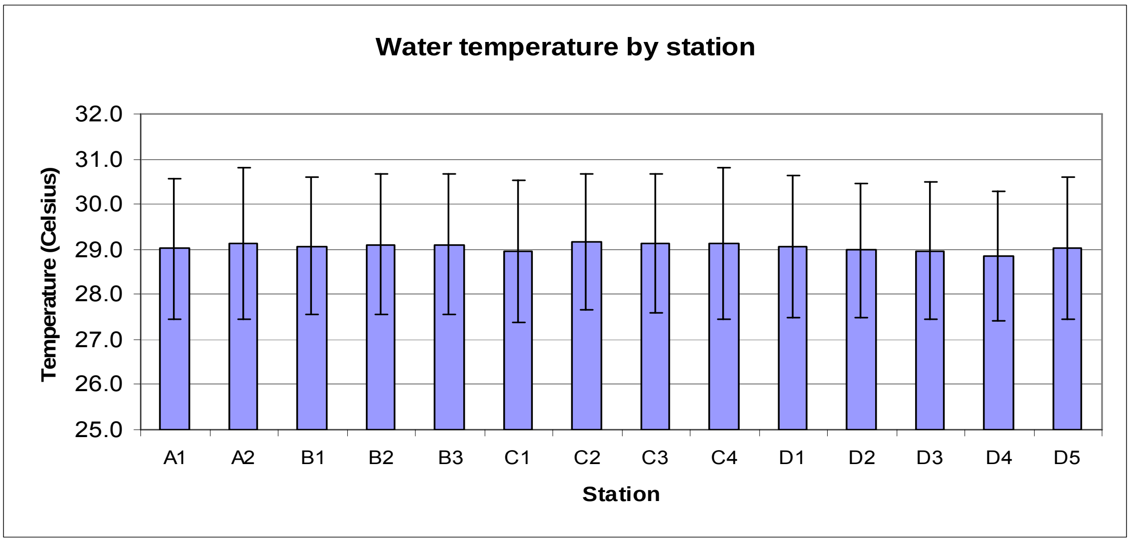


Figure 3.31 Mean water temperature by station from June 2008 - May 2009

<u>3.3.3.1.4 Salinity</u>

Monthly mean salinity showed that the variation of salinity had a range of 7.29-25.86 psu (Figure 3.32). There was no concrete pattern of fluctuation of salinity during the study. The maximum mean salinity was 25.86±1.41 psu in July 2008 and the minimum mean salinity was 7.29±3.47 psu in October 2008 due to the heavy freshwater discharge from the river upstream into the river mouth. Even there are several dams constructed along the Mae Klong river and water gates along the stream to control water, it still causes lots of freshwater discharge into the river mouth. The mean salinity was 18.37±7.03 psu.

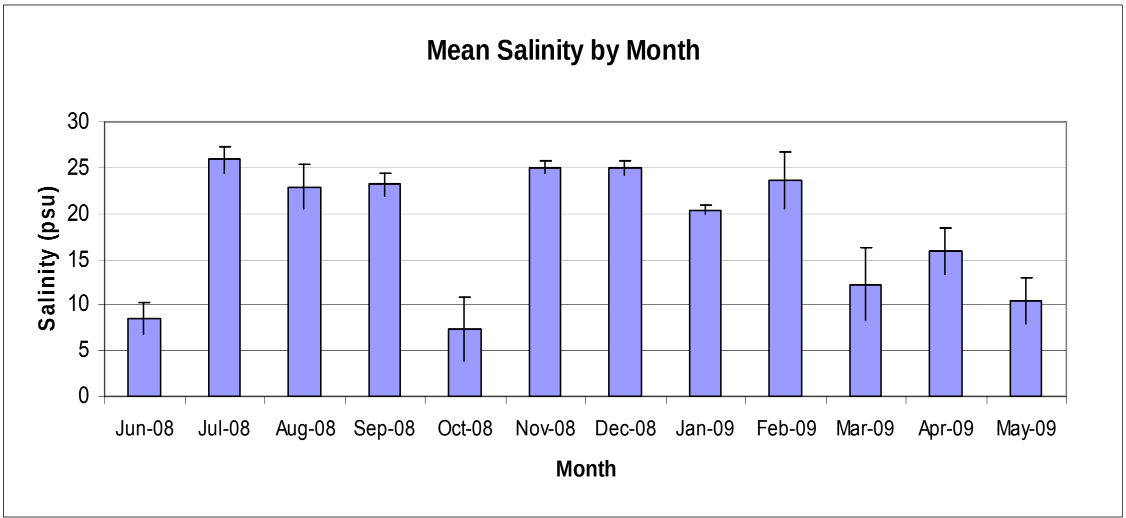


Figure 3.32 Mean salinity from June 2008 - May 2009

Due to tidal cycle pattern in the estuary ecosystem at river mouth, it can influential the fluctuation of salinity all year round. Figure 3.33 shows the water discharge at the last water gate located in Kanchanaburi province and also rainfall in Bang Khon Tee district, Samut Songkhram province. There are some relationships among water discharge, rainfall and salinity, for example it had a maximum discharge in June 2008 and maximum rainfall in October 2008; consequently the salinity was less than 10 psu in both months. In addition, from November 2008 – January 2009 there was no rain in this area and salinity was higher than 20 psu. However, razor clam can tolerate a broad range of salinity from 5-28 ppm (FAO, 1990) but the less salinity may cause the slow growth of razor clam (Costa and Martínez-Patiño, 2009).

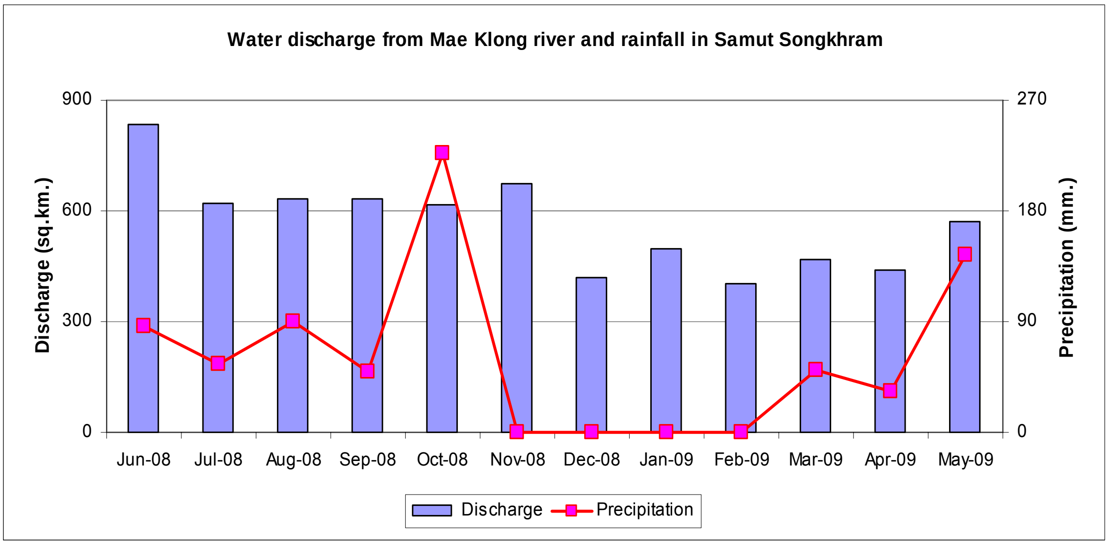


Figure 3.33 Water discharge in each month from Mae Klong river and rainfall in Samut Songkhram province from June 2008 - May 2009
(Source: Hydrology and water management center for western region (Kanchanaburi Thailand), (2009) and Thai Meteorological Department (2009))

Mean salinity by station showed that had a range of 16-18 ppm (Figure 3.34). In addition, the statistical analysis indicated that mean salinity by station were not significantly different (One-Way ANOVA, $p < 0.05$).

The important physic-chemical parameters in this study showed the fluctuation in each month through one year of study. Nevertheless, the mean value of all factors when considering by stations had no significant difference among stations. Thus, it can imply that distance from Mae Klong river mouth or distance from shoreline was not influenced those factors due to the water current in this study.

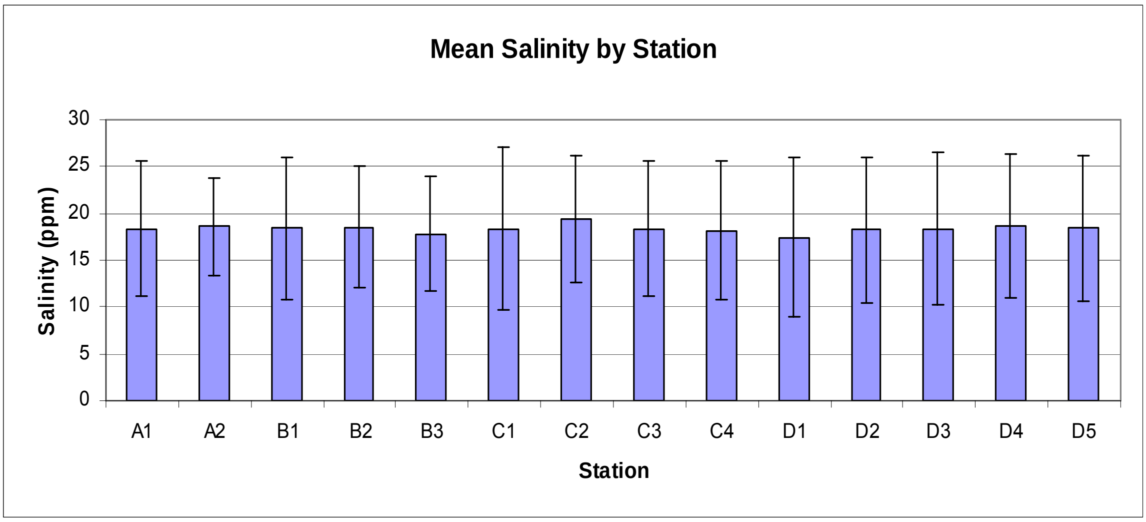


Figure 3.34 Mean salinity by station from June 2008 - May 2009

3.3.3.2 Soli texture and soil type

Soil texture was presented in percentage of soil composition in terms of sand, silt, and clay. In each month there were 14 stations to be designed for collecting soil samples by Graber during high-tide and all stations were showed in Figure 3.35. As the results, the majority of soil composition in this study comprised high percentage of sand and less percentage of silt and clay. At the beginning of the study in June 2008, the percentage of sand was over 80% except station D1, D2 and D3 where were located in the far most from the river mouth. It is seemingly that silt and clay were increased in soil composition at station D1, D2 and D3 almost the end of the study. These 3 stations were invaded by horse mussel as presented in section 3.1.1.1 in relation to the density of razor clam. However, those stations were not invaded by horse mussel, the percentage of soil composition still had more sand at least 80% through the study. In addition, the statistical analysis in each station showed that sand, silt, and clay were significantly different (One-Way ANOVA, $p < 0.05$).

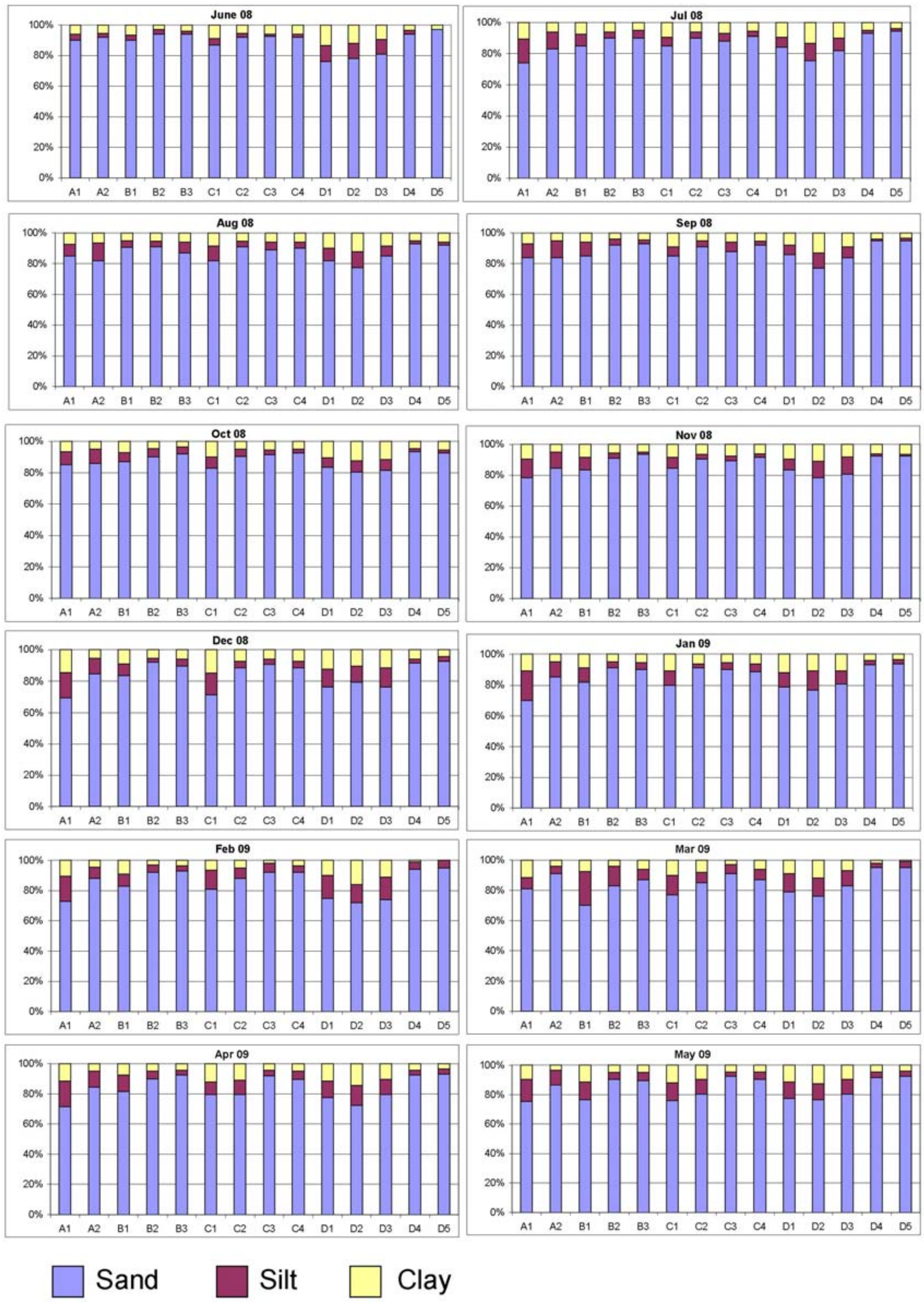


Figure 3.35 Composition of soil texture in each station from June 2008 - May 2009

In case of soil composition in each station, soil type was identified by using soil texture triangle (Figure 3.36 (A)) which uses percentage of sand, silt, and clay to identify soil type. It is clear that the razor clam habitat was identified as sandy and sandy loam.

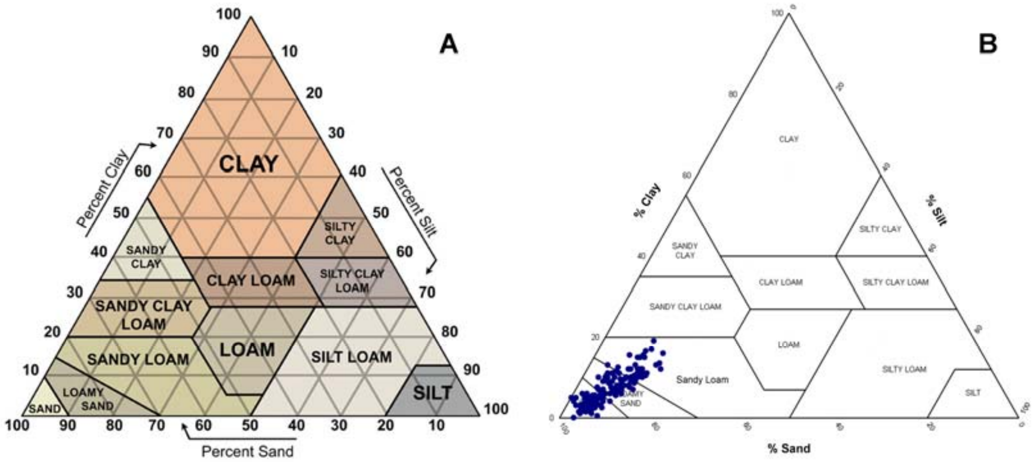


Figure 3.36 (A) Soil texture triangle (Source: www.soilsensor.com), (B) Soil type results from the study (dark blue dot)

By referring Pradatsundarasar, (1982) and Tumnoi (1996) reported that the soil composition of sandbar at Don Hoi Lord is fine sand; therefore, the results of soil type in this study will use fine sand instead of sand. There were 3 soil types in the study, the soil types consist of fine sand, loamy fine sand, and fine sandy loam (Figure 36(B)). Fine sand usually found in the station located in the middle of sandbar such as B2, C3 and station far from the shoreline such as D4, and D5. Meanwhile, loamy fine sand and fine sandy loam usually found in the stations located near river mouth and coastal line. It also indicated that the change of soil composition seemed to increase % composition of clay up to almost 20% as shown in Figure 36 (B). And those stations were obviously indicated in Figure 3.7 that also was invaded by horse mussel such as A1, C1, D1, D2, and D3.

Moreover, horse mussel can relate to the change of soil type from fine sand to loamy fine sand and fine sandy loam. However, the change can reverse from fine sandy loam which has more percentage of clay (Figure 3.36(A)) to loamy fine sand or fine sand depending on environmental factors such as water current and type of particulate sediment in the water and also human activities on river upstream and even at the sandbar. Meanwhile, in some stations soil type was fine sand particularly at sandbar and never changed over the study and those stations were B2, D4, and D5.

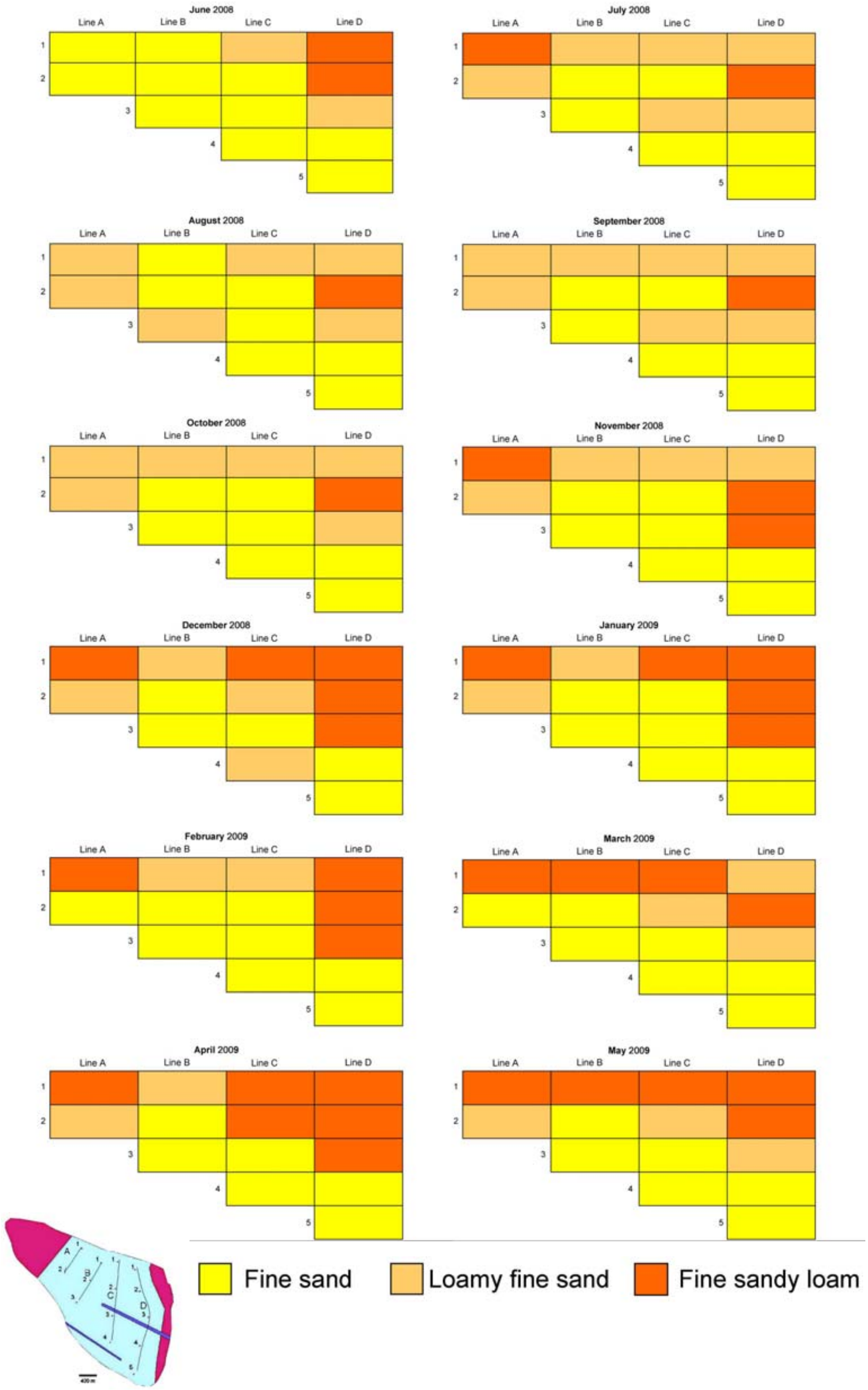


Figure 3.37 Soil type in each station represented in monthly from June 2008-May 2009

3.3.3.3 Soil organic matter

Soil organic matter (OM) represented in percentage of weight. There will be 2 dimensions of data which are time (mean in each month) and space (mean in each station) as in Figure 3.38 and 3.39.

Mean organic matter in this study had a range of 0.45-0.67% (Figure 3.38). After the beginning of the study, OM steadily decreased from June 2008 to September 2008 which was the minimum value of OM. Then, OM continually increased until reaching the maximum value in December 2008. Next, OM fluctuated in small change until the end of study in May 2009. The minimum value of OM was 0.45±0.20% in September 2008 and the maximum value was 0.67±0.26% in December 2008, while the monthly mean OM in this study was 0.54±0.06%. In addition, the statistical analysis indicated that mean OM in each month were not statistically different (One-Way ANOVA, $p < 0.05$).

Conversely, if considering mean OM in each station (Figure 3.39) there were some differences among the stations. It had a range of 0.26-0.95% in which the minimum OM was 0.26±0.06 % at station D5 and the maximum OM was 0.95±0.13% at station D2. Furthermore, the statistical analysis indicated that mean OM in each station were significantly different (One-Way ANOVA, $p < 0.05$). The station located at the center of sandbar or far away from shoreline such as B2, C3, C4, D4 and D5 usually had less OM whereas the stations closed to shoreline had more OM such as A1, B1, C1 and D1.

The details of OM at all stations in every month showed that the maximum OM 1.20% at station D2 in October 2008 and the minimum OM was 0.15% at station D5 in February 2009 (Annex B).

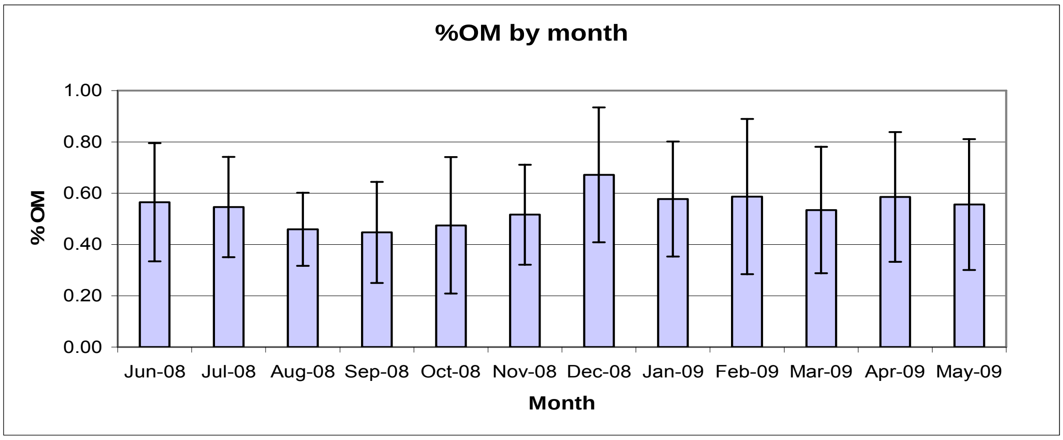


Figure 3.38 Mean percentage of organic matter in each month from June 2008 - May 2009

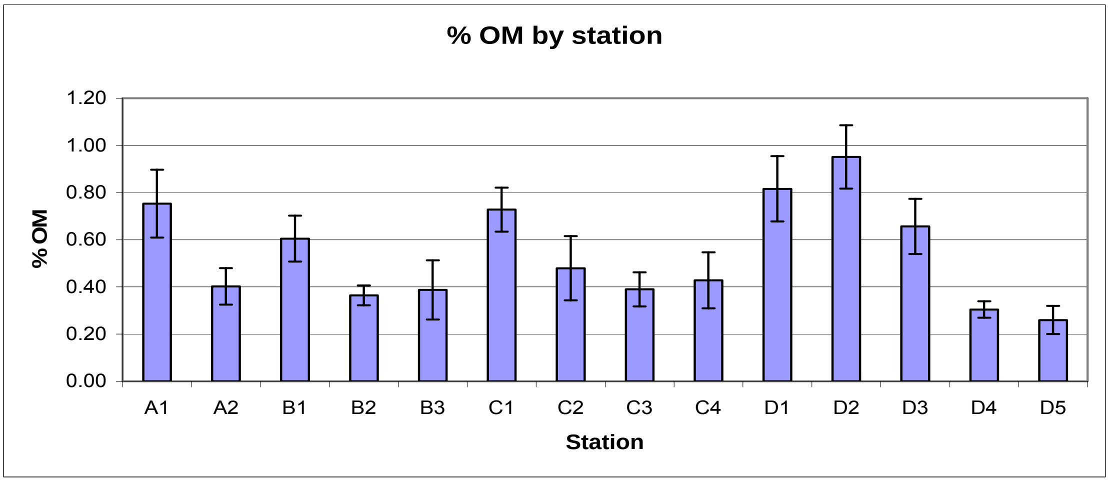


Figure 3.39 Mean percentage of organic matter in each station from June 2008 - May 2009

3.3.3.4 Particulate sediment and POC

Particulate sediment and Particulate Organic Carbon (POC) are related to each other; POC is one of components in particulate sediment. Thus, particulate sediment will be analysed first and followed by POC.

Mean particulate sediment in Figure 3.40 indicated the range of 23.74-92.90 mg/l in which the particulate sediment in each month fluctuated in a narrow range around 20-40 mg/l and increased sharply in only 2 months (October 2008 and February 2009). The minimum mean particulate sediment in each month was 23.74±1.42 mg/l in August 2008 and the maximum mean particulate sediment in each month was 92.90±35.56 mg/l, whereas mean particulate sediment from the study was 41.84±20.68 mg/l.

In Figure 3.40, the first increasing of particulate sediment occurred in October 2008 when it had highest rainfall in Samut Songkhram province and also high level of water discharge into Mae Klong river month as indicated in Figure 3.33. It clearly caused the highest particulate sediment in the study. On the other hand, the second increasing of particulate sediment was in February 2009, while there was no rain in the province and the surface water runoff was lowest and decreasing water level in the river. Possibly, it made the high concentration of particulate sediment that why the second increasing cycle occurred.

Mean particulate organic carbon (POC) in each month in Figure 3.41 showed that POC had a range of 309.55 – 2,676.25 µg/l. The beginning of the study POC had a small fluctuation at 700 µg/l for 3 months. Then, in September and October 2008 POC increased to reach a level of 1,400 µg/l. After that it decreased again in November and December 2008 below 700 µg/l. Following by January 2009 until the end of study in May 2009 the mean POC were below 700 µg/l except February 2009 POC increased suddenly over 2,500 µg/l and dropped below 700 µg/l in the following month. This result also corresponded with the condition of particulate sediment in February. The minimum mean POC in each month was 309.55±51.07 µg/l in December 2008 and the maximum mean POC was 2,676.25±577.34 in February 2009, whereas the mean POC in this study was 880.06±675.82 µg/l.

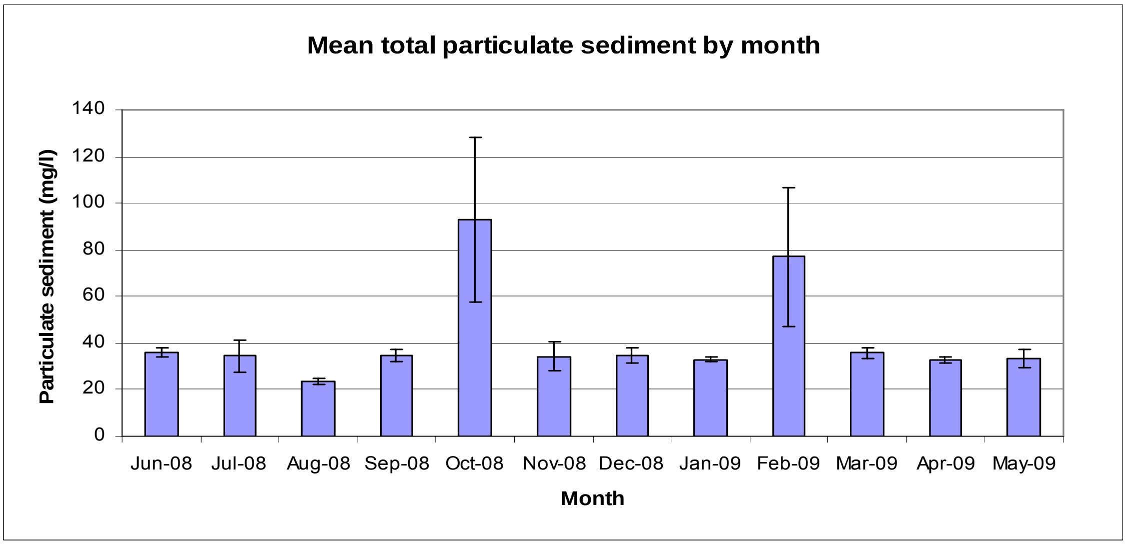


Figure 3.40 Monthly mean of total particulate sediment from June 2008 - May 2009

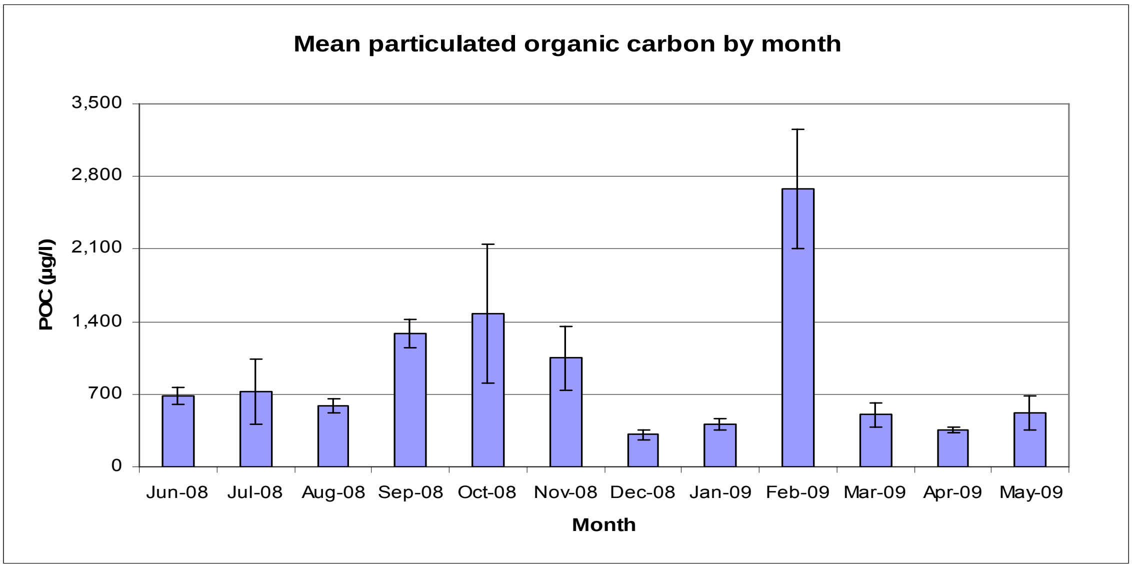


Figure 3.41 Mean of particulate organic carbon in each month from June 2008 - May 2009

In addition, the statistical analysis indicated that both mean of particulate sediment and POC in each month were significantly different (One-Way ANOVA, $p < 0.05$).

Mean total particulate sediment in each station from Figure 3.42 showed variation in each station. It had range between 34.38 – 48.98 mg/l. There was no concrete pattern of fluctuation among station but the stations which closed to Mae Klong river mouth and main gully (A1, A2, B2 and B3) seem to have broadly SD than other stations. The minimum mean particulate sediment in each station was 34.38±11.40 mg/l at station C4 and the maximum mean particulate sediment in each station was 48.98±41.05 mg/l at station B3.

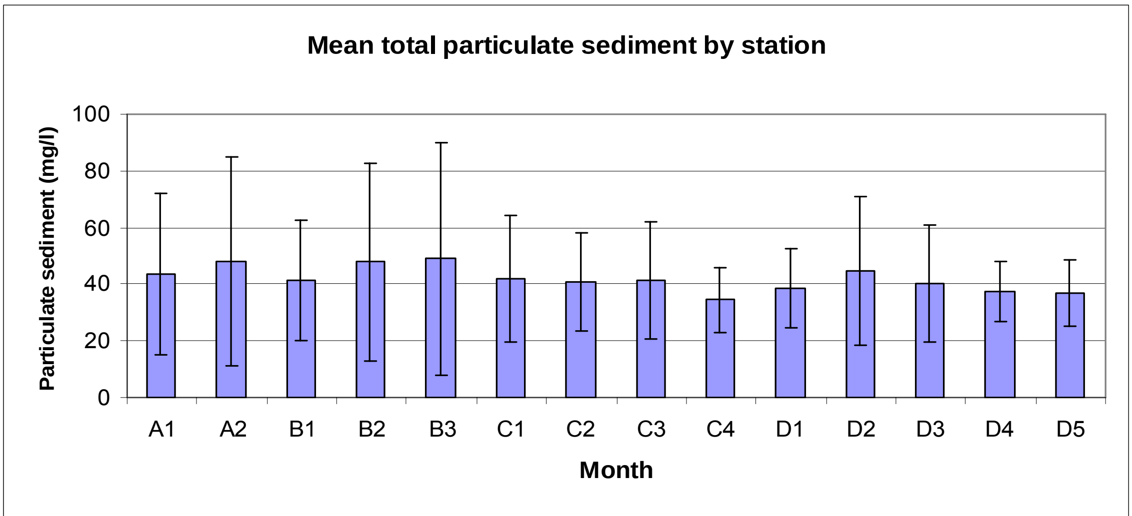


Figure 3.42 Mean of total particulate sediment in each station from June 2008 - May 2009

From the mean of particulate organic carbon in each station, mean POC in each station also showed no pattern of fluctuation among stations (Figure 3.43). In addition, most of the stations showed broadly standard deviation except station C4 and D5 which far from river mouth. Those had narrow SD when compare with other stations. The minimum mean POC in each station was 723.13±500.67 µg/l at station C4 and the maximum mean POC in each station was 1,015.79±776.43 µg/l at station A1.

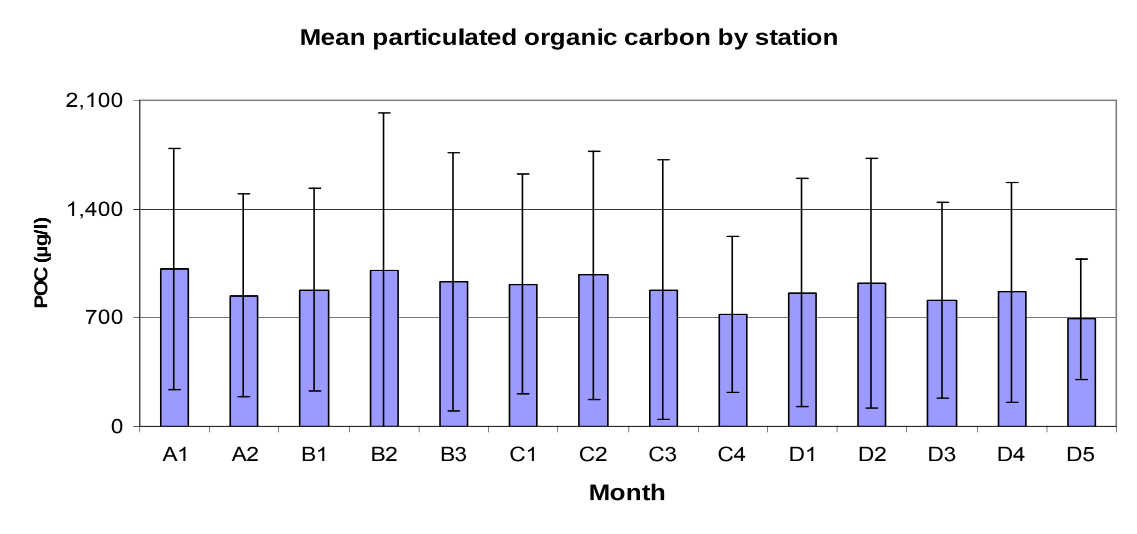


Figure 3.43 Mean of particulate organic carbon in each station from June 2008 - May 2009

Moreover, the statistical analysis also indicated that both mean particulate sediment and POC in each station were not significantly different (One-Way ANOVA, $p < 0.05$). In addition, the nonparametric statistical analysis between particulate sediment and POC was carried out to explore its correlation and found that both particulate sediment and POC correlated in a linear regression (Figure 3.44) with correlation coefficient (r) = 0.486 (Spearman correlation, $p = 0.01$). Following r value it can be interpreted that particulate sediment and POC have a positive correlation in middle level.

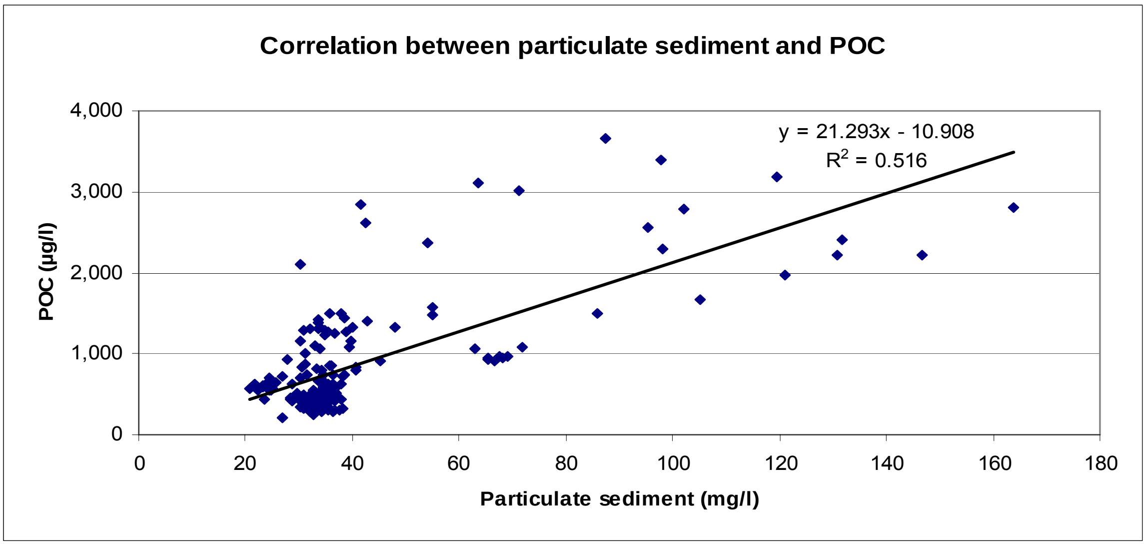


Figure 3.44 Correlation between particulate sediment and POC with linear model equation and correlation coefficient

Zhang, Liu, Xu et al. (1998) studied POC from 3 Northern China estuaries and found that r^2 between particulate sediment and POC has a range of 0.99-0.60 while this study r^2 value was 0.52. However, the study in China was conducted only 1 month in August represented flooding month in every year for 3 years whereas this study was conducted in monthly for 1 year.

Comparison between particulate sediment and POC in this study were correlated each other. Only some months had high particulate sediment but POC were not high as the particulate sediment meanwhile some months had less particulate sediment but POC were high. Furthermore, particulate sediment which contains POC in this study did not show any relationship with water discharge from Mae Klong River (Figure 3.45).

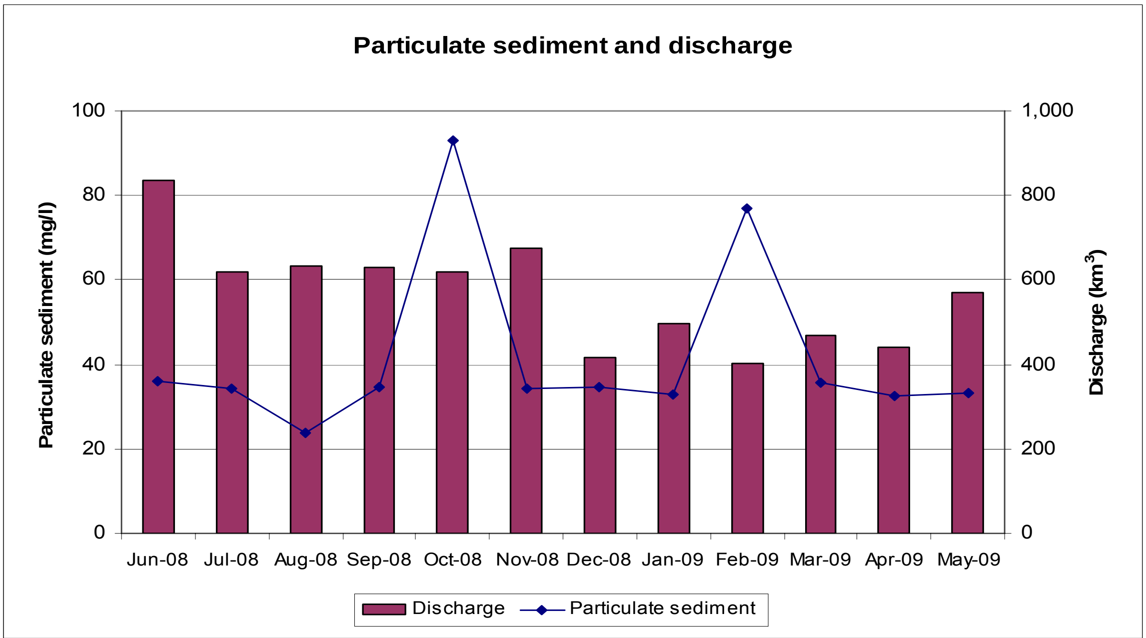


Figure 3.45 Mean particulate sediment in each month and water discharge from Mae Klong River during the study

In Table 3.6 shows the mean percentage of POC in each month, there were no sign of correlation with both water discharge and precipitation in each month, for example; in February 2009 percentage of POC was highest meanwhile water discharge was lowest. It seems to be a negative correlation but if considering the precipitation in the same month which was high level and it possibly increases discharge in Mae Klong River. Thus, the percentage of POC should not correlate with water discharge. In addition, Depetris and Gaiero (1998) suggested that the relationship between sediment loading and water discharge is complicated by frequently unpredictable patterns thus the study at Don Hoi Lord corresponds to this suggestion. Besides, the concentration of POC in particulate sediment depends on many factors, Zhang et al. (1998) hypothesized that photosynthesis can be an important contributor to POC due to increasing phytoplankton population as a reversed impacts by blocking light penetration so high turbidity reduces photosynthesis. However, not only photosynthesis is a source of POC in estuary but organic-poor debris and sediment from soil eroded loading from upstream flow downstream as a source of POC to estuary area.

Table 3.6 Mean particulate sediment (PS), POC, and % POC from particulate sediment in each month along 12 months

Month	PS (ml/l)	POC (µg/l)	%POC
Jun-08	36.02±2.24	682.61±83.08	1.90
Jul-08	34.43±6.65	721.07±316.34	2.04
Aug-08	23.74±1.42	587.66±62.97	2.48
Sep-08	34.60±2.65	1,284.76±133.06	3.72
Oct-08	92.90±35.56	1,473.68±669.34	1.55
Nov-08	34.10±6.22	1,048.01±303.82	3.06
Dec-08	34.61±3.02	309.55±51.07	0.89
Jan-09	32.98±1.23	408.14±52.84	1.24
Feb-09	77.10±29.81	2,676.25±577.34	4.00
Mar-09	35.66±2.50	500.46±113.51	1.40
Apr-09	32.65±1.18	352.37±30.06	1.08
May-09	33.31±4.00	513.67±164.45	1.53

3.3.4 Relationship between razor clam and environmental factors

The statistical analysis in this study has emphasized on razor clam population density and its environmental factors. SPSS version 16.0 package program was employed to explore correlation between razor clam density and its environmental factors which consist of water pH, DO, water temperature, salinity, soil texture, soil type, soil organic matter, particulate sediment, and POC.

Table 3.7 Spearman correlations test between razor clam density and its environmental factors

		Density of razor clam/sq. m. in each station	POC in each station (µg/l)	Particulate sediment in each station (mg/l)	%OM in each station	pH in each station	Dissolve oxygen in each station (mg/l)	Water temperature in each station	Salinity in each station	Percentage of sand in each station	Percentage of silt in each station	Percentage of clay ineachstation
Density of razor clam/sq. m. in each station	Correlation Coefficient	1.000	-.125	-.246**	-.662**	.158*	-.018	.297**	.040	.572**	-.474**	-.580**
	Sig. (2-tailed)	.	.107	.001	.000	.040	.818	.000	.608	.000	.000	.000
	N	168	168	168	168	168	168	168	168	168	168	168
POC in each station (µg/l)	Correlation Coefficient	-.125	1.000	.486**	-.032	-.127	-.017	.024	.099	.099	-.064	-.090
	Sig. (2-tailed)	.107	.	.000	.683	.100	.823	.756	.202	.200	.407	.247
	N	168	168	168	168	168	168	168	168	168	168	168
Particulate sediment in each station (mg/l)	Correlation Coefficient	-.246**	.486**	1.000	.247**	-.212**	-.176*	-.310**	-.195*	-.014	.080	-.046
	Sig. (2-tailed)	.001	.000	.	.001	.006	.023	.000	.011	.855	.304	.552
	N	168	168	168	168	168	168	168	168	168	168	168
%OM in each station	Correlation Coefficient	-.662**	-.032	.247**	1.000	-.079	-.027	-.278**	-.047	-.758**	.615**	.776**
	Sig. (2-tailed)	.000	.683	.001	.	.309	.732	.000	.542	.000	.000	.000
	N	168	168	168	168	168	168	168	168	168	168	168
pH in each station	Correlation Coefficient	.158*	-.127	-.212**	-.079	1.000	.426**	.195*	.278**	-.039	.080	.019
	Sig. (2-tailed)	.040	.100	.006	.309	.	.000	.011	.000	.612	.300	.806
	N	168	168	168	168	168	168	168	168	168	168	168
Dissolve oxygen in each station (mg/l)	Correlation Coefficient	-.018	-.017	-.176*	-.027	.426**	1.000	-.132	.661**	-.013	.006	.050
	Sig. (2-tailed)	.818	.823	.023	.732	.000	.	.089	.000	.871	.943	.518
	N	168	168	168	168	168	168	168	168	168	168	168
Water temperature in each station	Correlation Coefficient	.297**	.024	-.310**	-.278**	.195*	-.132	1.000	-.047	.026	.046	-.104
	Sig. (2-tailed)	.000	.756	.000	.000	.011	.089	.	.548	.741	.557	.178
	N	168	168	168	168	168	168	168	168	168	168	168
Salinity in each station	Correlation Coefficient	.040	.099	-.195*	-.047	.278**	.661**	-.047	1.000	-.018	.018	.058
	Sig. (2-tailed)	.608	.202	.011	.542	.000	.000	.548	.	.817	.816	.458
	N	168	168	168	168	168	168	168	168	168	168	168
Percentage of sand in each station	Correlation Coefficient	.572**	.099	-.014	-.758**	-.039	-.013	.026	-.018	1.000	-.922**	-.865**
	Sig. (2-tailed)	.000	.200	.855	.000	.612	.871	.741	.817	.	.000	.000
	N	168	168	168	168	168	168	168	168	168	168	168
Percentage of silt in each station	Correlation Coefficient	-.474**	-.064	.080	.615**	.080	.006	.046	.018	-.922**	1.000	.635**
	Sig. (2-tailed)	.000	.407	.304	.000	.300	.943	.557	.816	.000	.	.000
	N	168	168	168	168	168	168	168	168	168	168	168
Percentage of clay ineachstation	Correlation Coefficient	-.580**	-.090	-.046	.776**	.019	.050	-.104	.058	-.865**	.635**	1.000
	Sig. (2-tailed)	.000	.247	.552	.000	.806	.518	.178	.458	.000	.000	.
	N	168	168	168	168	168	168	168	168	168	168	168

* Significantly correlated at 0.001 level
** Significantly correlated at 0.005 level

Yellow highlight: Significantly correlation between razor clam density and environmental factor

Blue highlight: Significantly correlation among environmental factor

3.3.4.1 Razor clam density and basic environmental factors

Water pH, DO, water temperature and salinity were tested with razor clam density to explore its correlation. Following razor clam density was not distributed normally, nonparametric correlations were tested between razor clam density and those environmental factors. The test showed that only water pH and water temperature had positive correlation with razor clam density at correlation coefficient r = 0.158 and 0.297 respectively (Spearman correlation, p < 0.05) whereas other basic factors were not correlated with razor clam density (Table 3.7). Regarding the national water quality standard, sea water pH supposed to range 7.0 – 8.5 (Pollution Control Department, 2010), meanwhile water pH in this study was 7.18 as in acceptable level. But the correlation test indicated that the density had positive correlation with water pH. Razor clam is a marine animal it might prefer alkali rather than acidic condition in corresponding with the above standard.

Water temperature was one of basic factor which had a positive correlation with razor clam density. It indicated that during daytime low-tide the density of razor clam usually was higher than the density during nighttime low-tide. As described temperature was one factor enable to stimulate razor clam breeding, the high temperature can induce a increase of metabolic rate, while low temperature will decrease metabolic rate (Weber, Sturmer, Hoover et al., 2007). Thus, moderate high water temperature may also stimulate razor clam reproduction and increase population growth.

To investigate more on relationship between basic environmental factors which correlated with razor clam density, cluster analysis (Vanitbancha, 2005) was carried out to separate water pH and water temperature in each month into 3 groups (Annex D), and The groups can be indentified to Lo, Mid, and High level (Table 3.8-3.9). Then, cooperating the groups in each month with razor clam density and horse mussel invasion through 12 months of study (figure 3.46 – 3.47).

Table 3.8 Cluster analysis of water pH and range of water pH in each month

	Low	Mid	High	Range
Jun-08	7.28 - 7.67	7.43 - 7.55	7.58 - 7.67	0.39
Jul-08	7.49 - 7.49	7.52 - 7.58	7.76 - 7.82	0.33
Aug-08	7.60 - 7.66	7.71 - 7.75	7.76 - 7.82	0.22
Sep-08	5.29 - 5.88	5.97 - 6.65	7.52 - 7.52	2.23
Oct-08	4.92 - 5.47	5.64 - 6.42	6.80 - 7.09	2.80
Nov-08	6.46 - 6.46	6.80 - 7.07	7.15 - 7.39	0.93
Dec-08	7.17 - 7.26	7.29 - 7.40	7.45 - 7.56	0.39
Jan-09	7.55 - 7.60	7.62 - 7.67	7.68 - 7.72	0.17
Feb-09	7.57 - 7.63	7.64 - 7.68	7.76 - 7.76	0.19
Mar-09	7.51 - 7.51	7.55 - 7.57	7.60 - 7.62	0.11
Apr-09	6.67 - 6.87	6.89 - 7.01	7.26 - 7.54	0.87
May-09	6.32 - 6.32	6.67 - 7.03	7.25 - 7.37	1.05

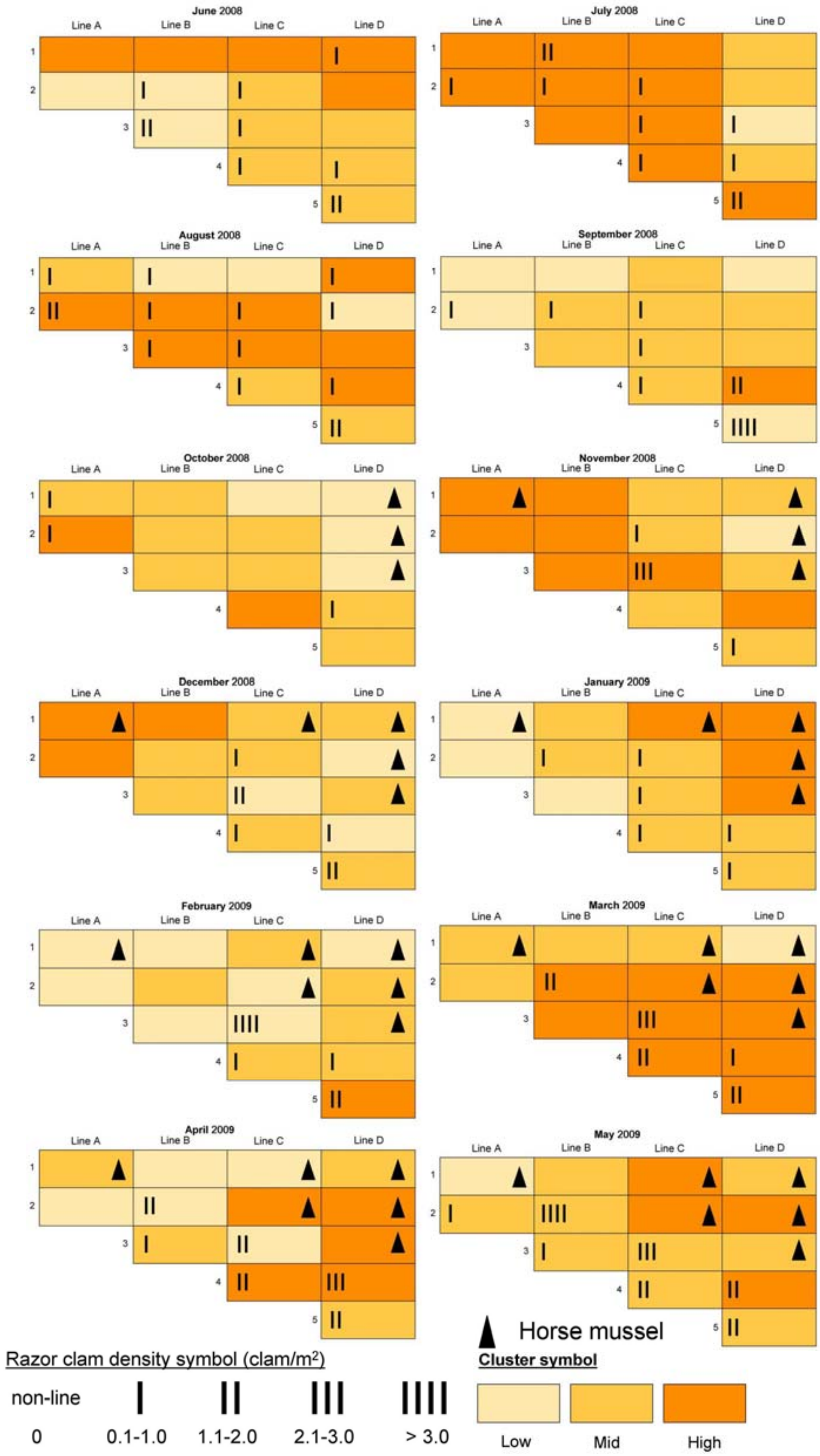


Figure 3.46 Three levels of water pH from cluster analysis including razor clam density and horse mussel

Figure 3.46 showed the heterogeneity of water pH in spatial distribution on the study area throughout 12 months of study. Differences of water pH between stations in each month has ranged from 0.11 – 2.80. Mostly, the range of water pH in each month were not differ too much except 3 months which are September 2008, October 2008 and May 2009 the differences more than 1.00 especially September and October 2008 the differences were 2.23 and 2.80 respectively (Table 3.8). Following highest difference of water pH in this study in October 2008, it was the first month that horse mussels were found on the study area.

However, there was no concrete pattern of water pH in spatial distribution (figure 3.46) for example, in June 2008 high level of water pH distributed on the station near shoreline (station A1, B1, C1 and D1) whereas next month in July 2008 high level distributed covering most of the sandbar not only the station near shore line. Beside, the levels can be mixed over the sandbar such as in December 2008 and February 2009. In addition, the proportion of each level in each month also different over the study for example, high level was found only one station in September 2008 and February 2009 while low level was also found one station in July, November 2008 and May 2009. Following razor clam density, there was no pattern on razor density and level of water pH from cluster analysis. Moreover, invasion of horse mussel had no distribution pattern with water pH level also. It can be found in every water pH level.

Table 3.9 Cluster analysis of water temperature (ºC) and range of water temperature in each month

	Low	Mid	High	Range
Jun-08	29.1 - 29.3	29.6 - 29.7	29.8 - 29.8	0.7
Jul-08	30.0 - 30.1	30.2 - 30.3	30.4 - 30.5	0.5
Aug-08	28.6 - 28.6	30.7 - 31.2	31.3 - 31.9	3.3
Sep-08	29.7 - 29.7	29.8 - 29.9	30.0 - 30.0	0.3
Oct-08	27.5 - 27.5	27.9 - 28.2	28.5 - 28.8	1.3
Nov-08	27.1 - 27.1	27.3 - 27.4	27.5 - 27.6	0.5
Dec-08	26.1 - 26.1	26.2 - 26.2	26.3 - 26.3	0.2
Jan-09	26.4 - 26.5	29.8 - 29.9	30.0 - 30.1	0.7
Feb-09	29.1 - 29.1	29.2 - 29.2	29.3 - 29.4	0.3
Mar-09	29.4 - 29.5	29.8 - 29.9	30.0 - 30.1	0.7
Apr-09	29.7 - 29.7	30.2 - 30.4	30.5 - 30.8	1.1
May-09	29.2 - 29.4	29.5 - 29.8	30.1 - 30.2	1.0

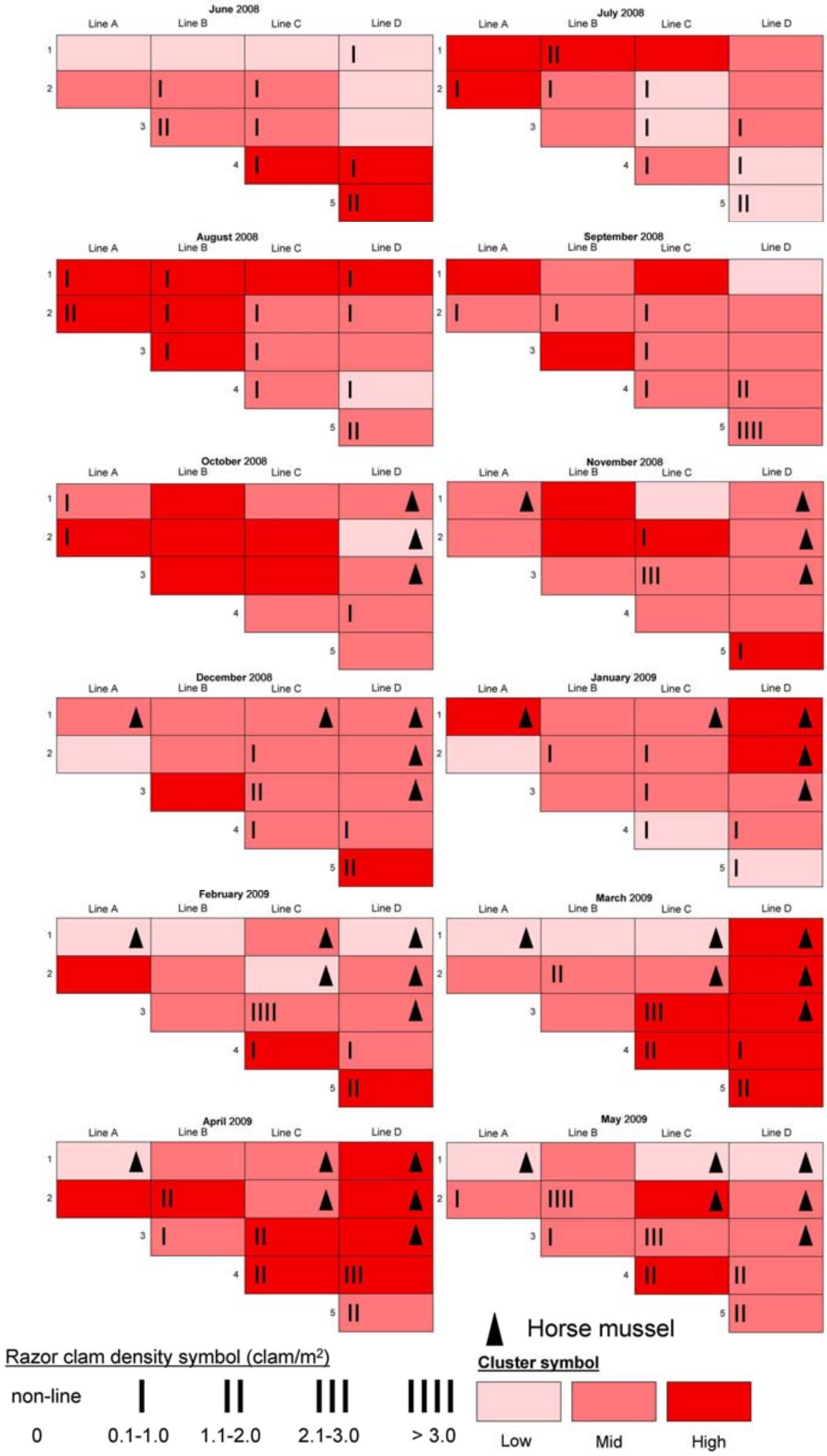


Figure 3.47 Three levels of water temperature from cluster analysis including razor clam density and horse mussel

Figure 3.47 showed the heterogeneity of water temperature in spatial distribution in each month. The differences of water temperature between stations in each month has range from 0.2 – 3.3 ºC. Broadest water temperature in this study was 3.3 ºC in August 2008 whereas in December 2008 the difference was 0.2 ºC which was minimum difference in this study. Like water pH, there was no concrete pattern of water temperature in spatial distribution. Some months the different levels distributed distinctly such as June 2008 and March 2009 whereas some months the different level mixing distributed over the sandbar such as July 2008 and February 2009.

Regarding razor clam density, spatial distribution of water temperature shown some relation with the density by most of razor clams were found in Mid and High level of water temperature in each month (figure 3.47). Beside, horse mussel was not show relation with water temperature in spatial distribution, those were found in every water temperature levels.

3.3.4.2 Razor clam density and soil organic matter

Percentage of soil organic matter (OM) and density of razor clam was tested to explore its correlation (Table 3.7). Nonparametric correlation test showed that razor clam density had negative correlation with %OM at r = -0.662 (Spearman correlation, p = 0.01).

The negative correlation between razor clam density and %OM clearly showed that high abundance of razor clam usually found in low %OM and when %OM increased razor clam density decreased. In comparison with previous study by Pradatsundarasar (1982), who study the influence of sediment on the distribution and population of razor clam at Don Hoi Lord for 6 times every 2-month interval for collection whereas, this study was took place a monthly for 1 year and confirmed his finding on negative correlation between razor clam population and %OM with the middle correlation ($r \approx 0.5$).

Regarding environmental change in this study that horse mussel has invaded into razor clam habitat successfully and occupied the area by forming its colony mat. The horse mussel's colony mat can accumulate more organic matter; therefore, it changes the condition of occupying area not suitable for razor clam (Crooks, 2001). However, OM in soil may not affected directly to razor clam, Purchon (1968) suggested that OM in soil is not affected to density of filter feeder like razor clam but other properties such as water and air circulation in soil will effected directly to it.

To investigate more on relationship between OM correlated with razor clam density, cluster analysis was carried out to separate OM in each month into 3 groups (Annex D), and The group can be indentified to Lo, Mid, and High level (Table 3.10). Then, cooperating the groups in each month with razor clam density and horse mussel invasion through 12 months of study (figure 3.48).

Table 3.10 Cluster analysis of percentage of soil organic matter and range of percentage of soil organic matter in each month

	Low	Mid	High	Range
Jun-08	0.26 - 0.44	0.57 - 0.75	0.98 - 1.00	0.74
Jul-08	0.29 - 0.46	0.52 - 0.75	0.82 - 0.89	0.60
Aug-08	0.29 - 0.48	0.55 - 0.61	0.78 - 0.78	0.49
Sep-08	0.21 - 0.45	0.56 - 0.62	0.94 - 0.94	0.73
Oct-08	0.27 - 0.50	0.53 - 0.64	0.83 - 1.20	0.93
Nov-08	0.33 - 0.50	0.57 - 0.77	0.96 - 0.96	0.63
Dec-08	0.26 - 0.49	0.56 - 0.76	0.81 - 0.99	0.73
Jan-09	0.28 - 0.48	0.51 - 0.75	0.84 - 0.89	0.61
Feb-09	0.15 - 0.42	0.62 - 0.64	0.81 - 1.14	0.99
Mar-09	0.21 - 0.49	0.54 - 0.77	0.80 - 0.99	0.78
Apr-09	0.26 - 0.44	0.60 - 0.73	0.79 - 1.04	0.78
May-09	0.27 - 0.38	0.63 - 0.73	0.80 - 0.97	0.70

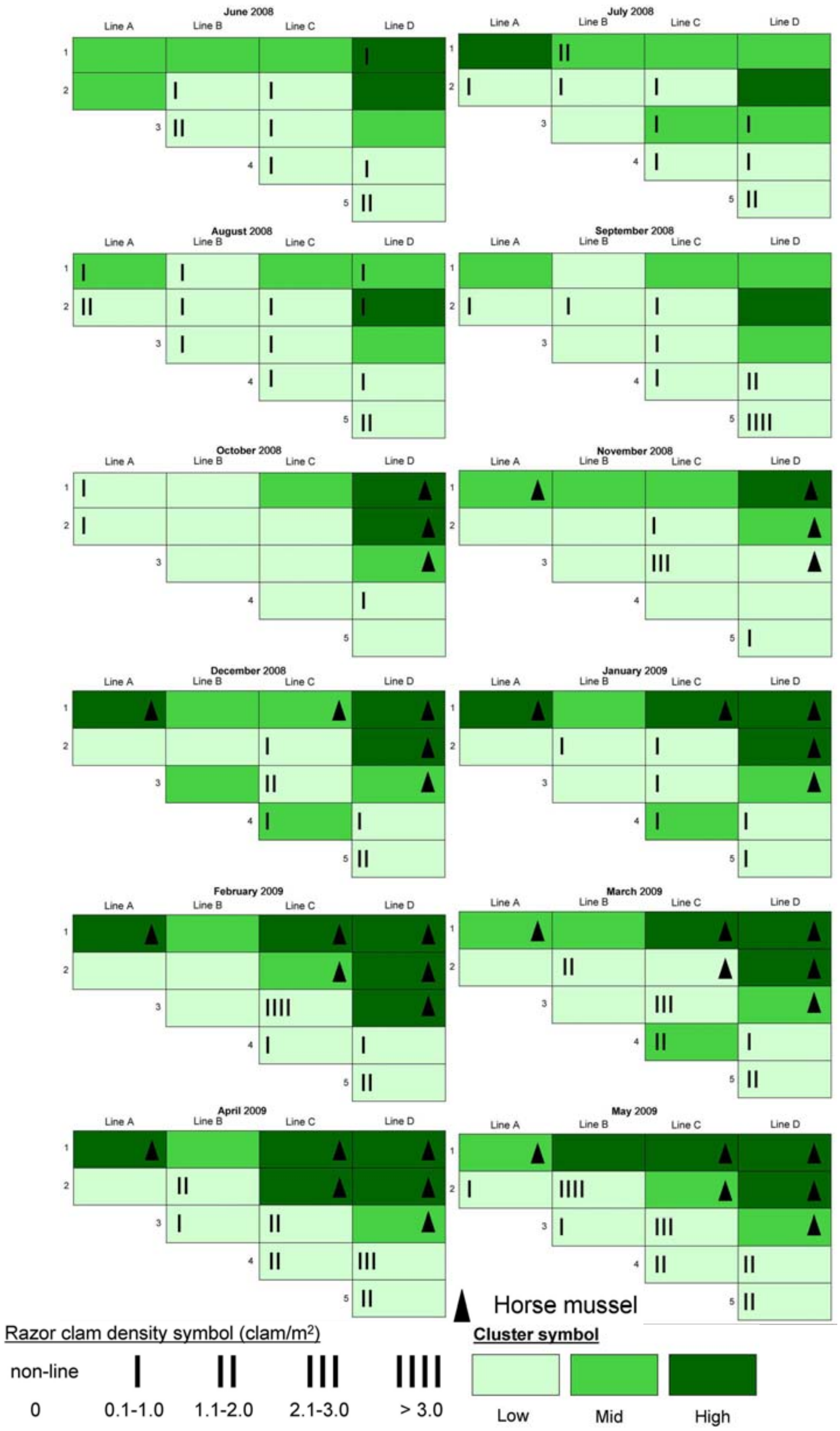


Figure 3.48 Three levels of percentage of soil organic matter from cluster analysis including razor clam density and horse mussel

Figure 3.48 showed heterogeneity of OM on the study area throughout 12 months. The differences of OM between stations in each month had ranged from 0.49 in August 2008 to 0.99 in February 2009. Following the difference in spatial distribution, OM had a pattern of distribution among the levels. The station near shoreline such as A1, B1, C1 and D1 usually classified as Mid or High level. In addition, station D1, D2 and D3, those are far from river mouth and main gully. These also usually classified as Mid and High level also. Due to OM had correlated with Particulate sediment (PS) (chapter 3.3.4.5), sedimentation rate in a station far from river mouth may promote OM. However, other stations such as C4, D4 and D5 also located far from river mouth but those were classified as Low level and very small proportion in Mid level. It may cased from station C4, D4 and D5 located near main gully which huge fishery vessels use it for navigating, the effect of vessels navigation can disturbed natural sedimentation by waves from vessel navigation.

OM in each month has showed concrete pattern of distribution among levels. The stations located near the shoreline or far from river mouth and main gully such as A1, B1, C1, D1, D2 and D3 usually classified as Mid and High level meanwhile the rests stations mostly classified as Low level and Mid level in several stations. Moreover, from figure 3.48, level of percentage of OM has showed clearly relation with razor clam population and horse mussel by it usually found razor clam in Low level of OM, several times found in Mid level and just only one time found in High level. By contrast, horse mussel usually found in High level of OM, few times found in Mid level and only one time found in Low level.

3.3.4.3 Razor clam density and soil texture, and soil type

Razor clam density was tested for correlation with soil compositions which consist of sand, silt and clay (Table 3.7). Nonparametric correlation tests showed that razor clam density had correlation with all soil compositions. It had positive correlation with %sand at r = 0.572, following by negative correlation with %silt at r = -0.474, and also negative correlation with %clay at r = -0.580 (Spearman correlation, p = 0.01).

Razor clam density had significant correlation with all soil compositions at middle level ($r \approx 0.5$). Only sand had positive correlation while silt and clay had negative correlation. Correlation coefficient between percentage of sand and clay were closely but in opposite direction, it clearly implies that razor clam prefers sand as a habitat and it avoids living in high silt and clay composition.

Hence, the statistical analysis was also carried out to explore more on the relationships between mean razor clam density and each soil type. Nonparametric test found that the median value of razor clam density in each soil type were statistically different (Kruskal Wallis Test, $p < 0.01$). Therefore, from statistical test both soil composition and soil type were concurrently that razor clam preferred more proportion of find sand than silt and clay as its habitat.

Therefore, the reasons why razor clam lives in sandy habitat due to silt and clay will reduce water and air circulation in substrate. while sand has more efficiency for air and water circulation which results in more oxygen content and less toxic chemical in soil (Eltringham, 1971). One problem of clams embeds itself in soil substrate which is composed of more silt and clay is small particle like silt or clay will congested water circulation system, it made clam difficult to feed and breath (Barnes, 1987).

Following 3 soil types found in this study and razor clam population including horse mussel invasion, figure 3.49 cooperating soil type in each station, razor clam and horse mussel throughout 12 months of study.

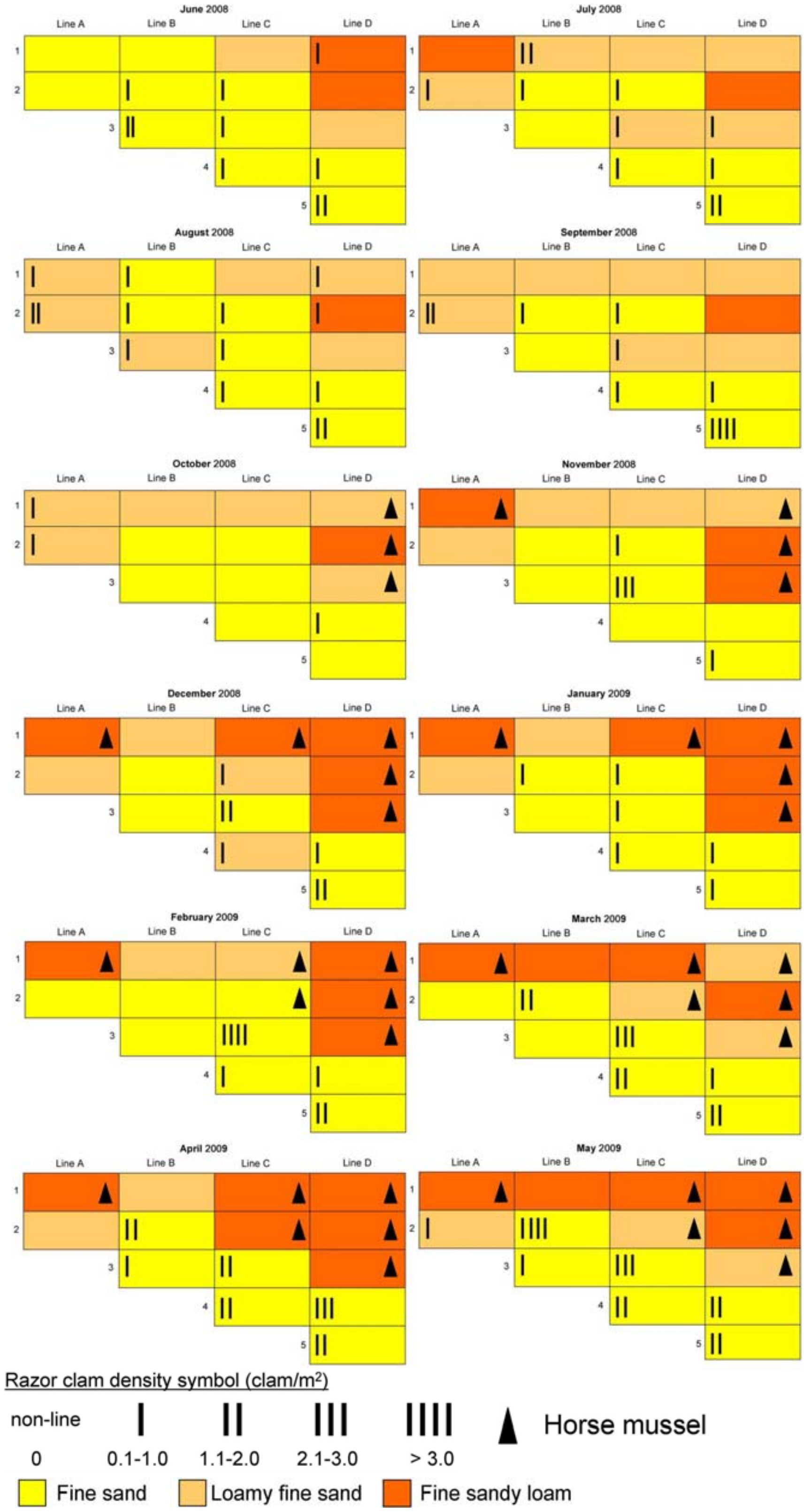


Figure 3.49 Three soil types found in this study including razor clam density and horse mussel

From figure 3.49 soil types in each station and razor clam showed some relation between razor clam and soil type by razor clam mostly found in Fine sand and several times in Loamy fine sand. Conversely, there were only 2 times to found razor clam in Fine sandy loam. Furthermore, horse mussel also has related with soil type, almost horse mussels were found in Find sandy loam, several times to found in Loamy fine sand and only one time to found in Fine sand. Regarding horse mussel and soil types, after settle of horse mussel mats in October 2008 the proportion of soil type in each month changed following succession of horse mussel mats. Find sandy loam type was found increasingly after settlement of horse mussel while number of Fine sand decreased. At the beginning of the study, Fine sand was found 10 stations from 14 stations and Fine sandy loam was found only 1 station over the study area. But in the last month of this study in May 2009, Fine sand was found only 6 stations meanwhile Fine sandy loam was found 5 stations and 4 from those 5 stations were occupying by horse mussel.

There were some similarity between soil type in each station and level of OM, 3 stations which are B2, D4 and D5 soil type never change over 12 month of the study and the level of OM from cluster analysis of those stations did not change also. It was remaining in Low level of OM throughout the study. Due to relationship between OM and soil texture (Sand, Silt, and Clay) which are the component of soil to classify soil type, Bordovsky, (1965) gave the explanation among it in chapter 3.3.4.5.

3.3.4.4 Razor clam density and particulate sediment, and POC

Particulate sediment and POC are environmental factors in water column. Both factors were tested with razor clam density to explore correlation between density and these environmental factors (Table 3.7). Nonparametric correlation test showed that razor clam density had negative correlation with particulate sediment at r = -0,246 (Spearman correlation, p = 0.01) but it was not correlated with POC.

Regarding in topic 3.3.3.7 has shown relationship between particulate sediment and POC that both factors has correlated in medium level and percentage of POC in particular to the particulate sediment depends on various factors. From this test revealed that razor clam density had less relation with particulate sediment and POC was not an important factor to determine its density. However, in another shellfish POC was an important factor as a source of food such as Ramseier, Garrity, Parsons et al. (2000)

found that POC was a source of shrimp food and the density of the shrimp positive correlated with amount of POC in Labrador Sea (Northern of Canada).

To investigate more on relationship between particulate sediment correlated with razor clam density, cluster analysis was carried out to separate particulate sediment in each month into 3 groups (Annex D), and the groups can be indentified to Lo, Mid, and High level (Table 3.11). Then, cooperating the groups in each month with razor clam density and horse mussel invasion through 12 months of study (figure 3.50).

Table 3.11 Cluster analysis of particulate sediment (mg/l) and range of particulate sediment in each month

	Low	Mid	High	Range
Jun-08	31.56 - 33.56	34.50 - 38.44	40.78 - 40.78	9.22
Jul-08	28.33 - 32.22	32.72 - 39.78	55.11 - 55.11	26.78
Aug-08	20.67 - 22.33	23.17 - 24.11	24.33 - 25.72	5.05
Sep-08	30.17 - 32.22	32.89 - 35.56	36.56 - 38.83	8.66
Oct-08	62.98 - 85.92	105.01 - 131.6	146.56 - 163.89	100.91
Nov-08	26.83 - 33.50	35.89 - 42.72	47.83 - 47.83	21.00
Dec-08	26.89 - 26.89	32.00 - 34.56	35.50 - 38.11	11.22
Jan-09	30.83 - 32.28	32.61 - 33.78	34.72 - 34.83	4.00
Feb-09	30.20 - 55.15	63.87 - 87.43	95.38 - 121.07	90.87
Mar-09	29.50 - 29.50	33.61 - 36.94	37.94 - 40.56	11.06
Apr-09	30.11 - 30.89	31.72 - 32.83	33.17 - 34.11	4.00
May-09	28.39 - 32.22	32.61 - 36.39	45.17 - 45.17	16.78

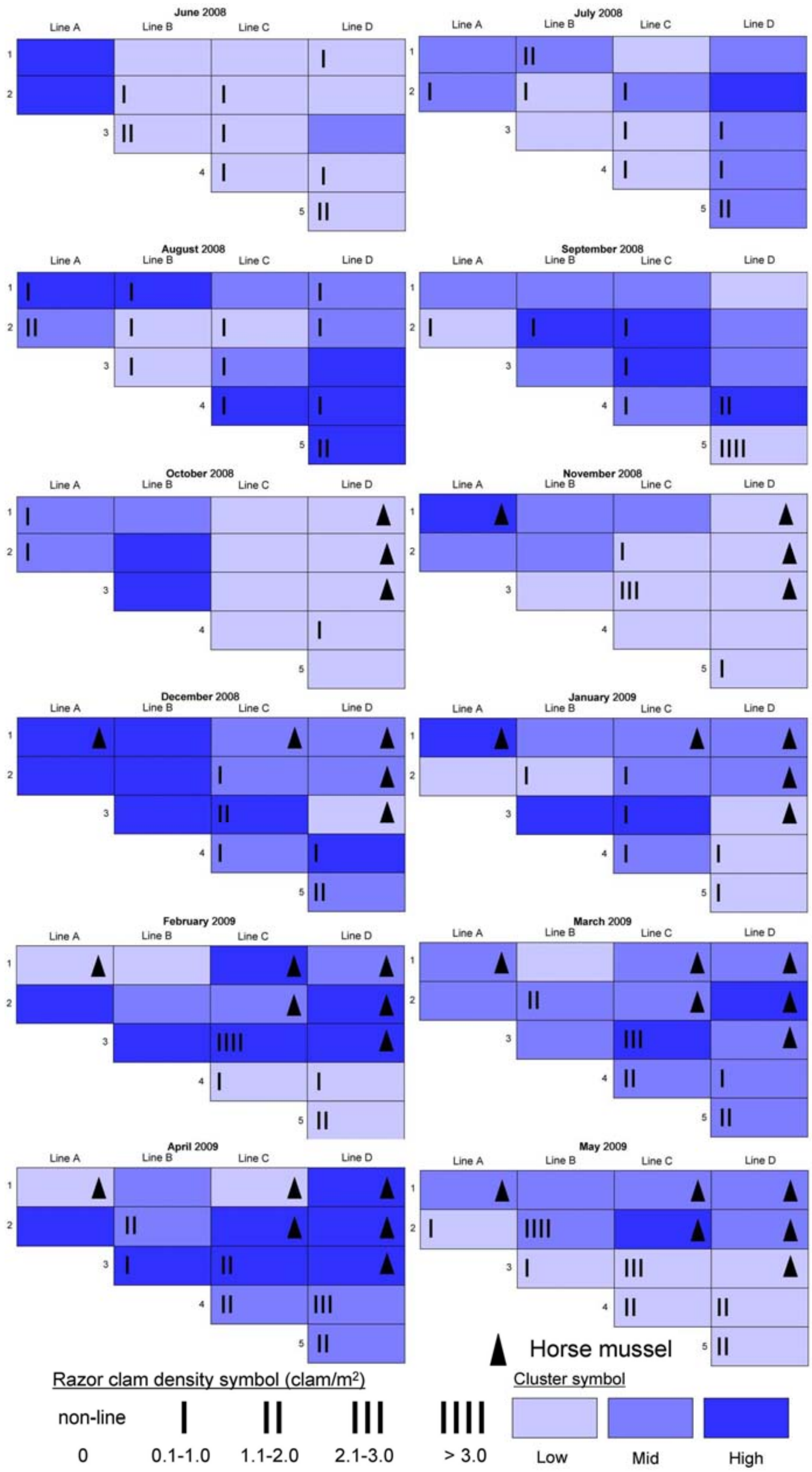


Figure 3.50 Three levels of particulate sediment from cluster analysis including razor clam density and horse mussel

Like the most of parameters correlated with razor clam density, figure 3.50 showed heterogeneity of particulate sediment in spatial distribution on the study area throughout 12 months of study. Differences of particulate sediment in each month had ranged from 0.40 mg/l in January and April 2009 to 100.91 mg/l in October 2008. The highest difference value of particulate sediment in October 2008 showed very broad range of value among levels (table 3.11) when comparing with other months. Moreover, October 2008 is the first month that horse mussel was found on the study area.

Following spatial distribution of particulate sediment in each month, there was no concrete pattern of distribution and also proportion of each level. In addition, both razor clam and horse mussel can be found in every particulate sediment level but razor clams seem to be found more in Low level station. It corresponded with correlation test that razor calm had negative correlation with particulate sediment and razor clam may prefer low particulate sediment area as its habitat.

3.3.4.5 Correlation among environmental factors

Furthermore, from the statistical analysis it also found some correlations in environmental factors itself (Table 3.7). Apparently, water pH had positive correlation with DO, water temperature and salinity at r = 0.426, 0.195 and 0.278 respectively, while DO had positive correlation with salinity at r = 0.661 (Spearman correlation, $p < 0.05$).

From Table 3.7, water pH was the only one of basic environmental factor in this study had correlation all basic factors. pH is an important factor for living organism and environment. Changing of pH in cell can harmful living cell because it may also block a function in biological processes such as photosynthesis and cell respiration (Campbell, Reece and Mitchell, 1999). In the field data collection, in October 2008 razor clam were found only 3 clams from throughout the study site meanwhile the mean water pH was acidic and the mean DO was below the standard. The study hasn't had a clear evidence to explain why water pH was below the standard. But from the fisherman interviewing in the field explained that during this period every year water quality usually has a problem and damage their mussel farm and other aquatic animals. The water quality problem in the sense of fisherman was caused by "waste water"; first from non-point source waste water from industrial areas in upstream and second from "Red tides or Eutrophication" phenomena, Due to "Red tides", it is a natural phenomena caused by blooming of phytoplankton which receives excess nutrient source from fresh water during flooding season or high waste water from community or factory which has high nutrients. The blooming of phytoplankton can be *Noctiluca* spp., *Ceratium* spp., *Chaetoceros* spp., and *Trichodesmium* spp. etc. (Aquatic Resources research Institute and Pollution Control Department, 2003). The major effects of Red tides are reducing of DO, some species have poison and release to sea water, and etc. Frequently, the poison can harm human if they eat the aquatic animals such as fish, shellfish, etc. that consumed those phytoplankton species. The second reason of waste water discharge from factory located upstream or nearby Mae Klong river mouth caused water pollution during raining season (Khongrugsar, Interview, 29 March 2009). Regarding low water pH and DO in October 2008, Figure 3.33 shows that in October 2008 had highest precipitation and water discharge from the dam was still in high level. In addition, the mean particulate sediment in this month also has highest in the study (Figure 3.40). Based on Davies and Eyre (2005) suggested that during wet season when flood, precipitation, and sediment coming together to estuary area, most of nitrogen coming to estuary are dissolving form and it available for phytoplankton or algae. Therefore, some phytoplankton may bloom following availability of nitrogen and effected to water quality. However, the study did not have clearly evidence to explain what were really happen with ecosystem at Don Hoi Lord in October 2008.

DO in this study have medium positive correlation with salinity (r = 0.66). Freshwater flooding with high sediment and organic matter can reduce DO by sediment in water column obstruct sunlight which is very important to photosynthesis and bacteria in water consume a lot of oxygen to metabolize organic matter (Paphavasit and al., 2006). The flood can also reduce salinity at estuary, while the salinity is increased by tidal cycle and bring salt water intrusion to that area. Moreover, the water current is another factor that causes a high DO level than fresh water.

Moreover, particulate sediment had negative correlation with water pH (r = -0.21), DO (r = -0.18), water temperature (r = -0.31) and salinity (r = -0.19), whereas it had positive correlation with percentage of OM (r = 0.25). Particulate sediment from river came from upstream and it directly affected to OM due to high sedimentation. By contrast, the increasing of particulate sediment loading with massive freshwater it can directly reduce salinity, water pH and water temperature by dissolved sea water which has higher pH and temperature than freshwater, and DO by reduced transparency of water resulting in reduction of photosynthesis.

In addition, percentage of OM had negative correlation with water temperature (r = -0.28) and percentage of sand (r = -0.76) while it had positive correlation with percentage of silt (r = 0.62) and clay (r = 0.78). For negative correlation with water temperature, it may obstruct the light penetration and solar energy cannot be absorbed by water body as indicated clearly during raining and winter season. Furthermore, sediment loading by freshwater flood also brings sand, silt and clay to the river mouth. Sand had negative correlation with OM while silt and clay had positive correlation. Because of the ability of sand to hold OM is less than silt and clay, which correspond to Bordovskiy (1965) also reported that silt has 2 times more OM than sand and clay has 4 times more OM than sand.

3.4 Conclusion

3.4.1 Razor clam population

From 1 year of field data collection from June 2008 – May 2009, the razor clam population at Don Hoi Lord can be summarized as follows:

- Mean density of razor clam was 0.51±0.30 clam/m^2. This density was lowest density in the records since the scientific studiess have been carried out at Don Hoi Lord.

- Mean length of razor clam in this study was 5.34±1.21 cm/individual. The mean length of razor clam in this study was higher than the previous studies since 1997.

- Majority of size class in razor clam population structure was size 5.1-6.0 cm at 35% of total sample collection through the study. In addition, the small razor clam size smaller than 3 cm was found frequently in the study, while razor clam size smaller than 2 cm was only found in 2 periods and possibly elaborated that were 2 peaks of breeding season in year round.

- In situ experiment on razor clam growth rate also indicated that the razor clam size 3.1-4 cm could have a growth rate at 0.54 cm/month and the growth rate of bigger size will decrease as follows; the size of 4.1 – 5.0 cm could have the rate of 0.44 cm/month and the size > 5.0 cm could have the rate of 0.22 cm/month.

3.4.2 Environmental factors

- In this study, the basic environmental factors consist of water pH, DO, water temperature, and salinity. Mean value of all factors were met the national water quality standard by PCD. However, not only the value of water pH in September, October 2008 and May 2009 but also DO value in October 2008 and May 2009 that were not met the national standard. Thus, both factors can affect to razor clam population especially water pH and DO are the important factors to aquatic organism.

- Majority of soil composition in the study area is fine sand and less percentage of silt can clay. From the soil composition, soil type in each station was identified and there were 3 soil types found in this study. The soil types are Fine sand, Loamy fine sand, and Fine sandy loam. Fine sand was usually found at middle of the sandbar while Loamy find sand and Fine sandy loam were found at the edge of the sandbar.

- Mean percentage of soil organic matter in this study was 0.54±0.06%. Organic matter in soil relating directly with soil composition by silt particle can hold more organic matter than sand particle (Bordovsky, 1965).

- Particulate sediment in this study had mean value at 41.84±20.68 mg/l. The highest particulate sediment was in October 2008 and it related to precipitation in Samut Songkhram province. Then, POC was determined from particulate sediment and it was found that mean value of POC in this study was 880.06±675.82 µg/l. Following particulate sediment and POC, there was positively correlated between both parameters at r = 0.486.

3.4.3 Statistical analysis between razor clam population and environment factors

Statistical analysis between razor clam density and all environmental factors in this study revealed that razor clam density had a positive correlation with water pH, water temperature, and the percentage of sand in soil composition. Besides, razor clam density also had a negative correlation with particulate sediment, percentage of soil organic matter, percentage of silt and clay in soil composition.

3.4.4 Perspective

Following razor clam density in this study was lowest in the records. It was an evidence of resource collapsing. In addition, during field data collection the researcher found the invasion of horse mussel and it has increased month by month in specific station nearby the edge of sandbar closed to the water channel. At the end of the study horse mussel was occupying almost 50% of the study area (6 stations from 14 stations). The mechanism of horse mussel settlement at Don Hoi Lord is unknown at this stage.

Therefore, the decreasing of razor clam population and horse mussel invasion to razor clam habitat are an urgent problem at Don Hoi Lord. The study of environmental factors in relation to both razor clam and horse mussel especially water current and natural sedimentation pattern should be conducted for further study in order to prove the scientific evident of those relationship which will be useful for future management. In addition, razor clam management and/or conservation action plan should be implementing urgently in order to restore razor clam population which is a source of income for the local community and also prevent biodiversity and habitat lost from the invasion from horse mussel.

CHAPTER IV

SOCIO-ECONOMIC OF RAZOR CLAM HARVESTING

4.1 Introduction

Don Hoi Lord has been well known as a famous domestic touristic place since 1980s. Razor clam or “Hoi Lord” in Thai also renowned as delicacy food from Don Hoi Lord where is the largest razor clam’s habitat in Thailand (ONEP, 2002). However, razor clam harvesting have been practiced more than 80 years by local fisherman around Don Hoi Lord. The purpose of the harvesting at the beginning around 1900s was for household consumption and for exchange with other goods such as sugar, rice, coconut etc. with farmer who live in Mea Klong River upstream in Samut Songkhram area (Suwanna, 2003). Around 1980s intensive shrimp aquaculture was promoted in Don Hoi Lord (Chiravej, 2002) and razor clams were used for shrimp feeding that made razor clam has a economic value as a additional income for fisherman. In addition, Don Hoi Lord was also initially promoted along with intensive shrimp aquaculture and razor clam was used as delicacy food for tourist. However, razor clam price was not expensive at the beginning due to the population was high density and fisherman could harvest reach 20 kg/person (ONEP, 1999). Since razor clam had its price and became a source of income for fisherman, razor clam harvesting is the one of major pressure on razor clam population. Furthermore, razor clam harvesting method has been modified by fisherman to increase the effectiveness to catch more razor clam.

Nowadays, razor clam harvesting is a major and minor career for fisherman around Don Hoi Lord area and razor clam population has decreased dramatically when compare with previous studies. Fisherman could harvest only 2-4 kg/person in average (Worrapimphong, 2005) with tend to harvest less due to the decline of population. Companion modelling (ComMod) approach has been initiated at Don Hoi Lord since 2004 (Worrapimphong, Gajaseni and Bousquet, 2007) in order to try to manage razor clam resource in sustainable way. However, the previous ComMod process was lack of the details of fisherman harvesting behavior and razor clam market mechanism which directly affected on fisherman’s harvesting decision. Thus, the study of socio-economic of razor clam harvesting is needed in order to understand better on fisherman behavior and their decision making process on harvesting including razor clam market mechanism. Those understanding will help stakeholders to identify the suitable management options in the future.

This chapter will be described the study of socio-economic of razor clam harvesting and razor clam market mechanism. Methodologies were used in this study including in-depth interview and observation of fishermen and traders. Then, a result of the study was presented with discussion regarding harvesting behavior and decision making process. Finally, the conclusion of the socio-economic of razor clam harvesting including razor clam market mechanism was presented.

4.2 Methodology

4.2.1 Study site and sample selection

Chu Chi village is a fisherman village which located nearest to Don Hoi Lord sandbar. According to this village is a special area that tourists visit to the habitat of razor clam and affected by tourism pressure. The researcher came to this village around 5 years ago by the recommendation of supervisor to contact fishery who used to assist his supervisor in a research team around 20 years ago. However, the connection between fisherman and research team were limited only a few fishermen in this village who assisted in the ecological field data collection. Therefore, this village was selected as a study site for socio-economic study as well as the research has had a long relationship with the fisherman in this village. It is very effective and possible to have cooperation from the fisherman for having the reliable information.

Before researcher started interviewing fisherman about razor clam harvesting, the researcher consulted with the former head of village, who used to work with the research team, to select the fisherman for in-depth interview. After the consultation we have a criterion for selection that they must be a fisherman who harvests razor clam regularly for long time.

4.2.2 In-depth interview on razor clam harvesting

A set of questions based on razor clam harvesting were designed to access their harvesting behavior and the effect of ComMod process. There are 21 questions which can identify into 4 groups. The first group of question is general harvesting habit of fisherman (Question 1-5). The second group is razor clam harvesting production

(Question 6-14). The third group is a connection among group of fisherman (Question 15-19). The last group of question is the effect of ComMod on fisherman opinion regarding razor clam management (Question 20 and 21). The following 21 questions are:

- First group (General harvesting habit)

Q1. When did you start harvest razor clam?

Q2: Are you going to harvest razor clam regularly since you start harvesting?

Q3: Which technique do you use to catch razor clam?

Q4: How long did you harvest razor clam?

Q5: What are your reasons to spend more or less time than average when you harvest razor clam?

- Second group (Razor clam harvesting production)

Q6: How much razor clam can you harvest in each day?

Q7: Do you keep record your harvesting?

Q8: Where did you go to harvest?

Q9: What did you do with harvested clam?

Q10: How much can you earn from razor clam in each day (average)?

Q11: In the recent, did you change the way you decide to go harvesting razor clam?

Q12: Can you specific harvesting location in each month in year round if you continue harvesting?

Q13: Regarding the way of your harvesting, how do you feel about razor clam at Don Hoi Lord since you started harvest until now?

Q14: What will you suggest to solve the razor clam reduction?

- Third group (Connection among group of fisherman)

Q15: How many fishermen who harvest razor clam do you know?

Q16: Do you usually see other fisherman when you are harvesting?

Q17: How much fisherman do they harvest razor clam in average?

Q18: How much percentage do you know them?

Q19: How do you feel about the number of fisherman who harvests razor clam?

- Forth group (The effect of ComMod on fisherman opinion regarding to razor clam management)

Q20: Have you heard about the companion modeling workshops organized 5 years ago?

Q21: In your opinion, should management rules of razor clam fishery be introduced?

Six fishermen (2 couples from 6) belong to 4 families in Chu-Chi village were selected for in depth interview in August 2009. It was composed of as follows;

- Family number 1 represents a couple and go to harvest razor clam together.
- Family number 2 is a lady who harvest razor while her husband goes to fish in the sea.
- Family number 3 is a man who changed his role from razor clam harvester only to razor clam harvester and trader.
- Family number 4 represents another couple and they also go to harvesting together like the first couple.

In addition, one trader who lives in Chu-Chi village and she have been bought razor clam from fishermen more than 10 years was interviewed to explore the information of razor clam market mechanism.

4.2.3 Harvesting record from fisherman and analysis

During in-depth interview of fisherman, there was one couple of fisherman family has been recorded their harvesting details since mid of 2003 till March 2010. The harvesting details consist of;

- Low tide period (day or night)
- Harvesting place which was recorded in local name
- Harvesting production from 2 fishermen (wife and husband)
- Razor clam price
- Daily earning
- Other additional activities if they could not harvest razor clam

In addition, this family sincerely shared their information and considerably contributed to this study. Therefore, the harvesting information was analyzed by

Microsoft Excel 2003 and SPSS statistical software for Windows to explore some relationships between harvesting behavior and economic value of razor clam.

4.2.4 Razor clam market mechanism

In-depth interview with a trader was done during field data collection. This trader has been bought razor clam from fisherman at Don Hoi Lord more than 10 years. Normally, razor clam products from fisherman are processed by boiling razor clam and done by the trader. The content of question emphasized on razor clam market and the distribution of processed razor clam.

In addition, one of fisherman who was interviewed has changed his role from razor clam harvester to razor clam harvester and small trader at the same time. The information from this fisherman also provided a better understanding in razor clam market mechanism in a small scale trading.

4.2.5 Harvesting behavior

To understand a better fisherman harvesting behavior, 3 fishermen were selected for in-depth interview in order to observe their harvesting in details. The researcher also followed this group of fisherman while they went to harvest razor clam and at the same also used GPS device for recording the location of harvesting track and details.

Figure 4.1 Fisherman get ready to start harvest razor clam with a bucket for storing razor clam from harvesting.

4.3 Results and discussion

4.3.1 Results from interview

More than 95% of family in this village is a fisherman family or working in fishery business. Regarding razor clam harvesting, the middle-aged generation in the village can harvest razor clam due to their family practices related to fishery in the past while a new generation (age under 20) can harvest razor clam in a small percentage due to the change of their life towards more time in school for better career (e.g. go to school all daylong). Nowadays, most of razor clam harvesters are middle-age fisherman in the village.

Table 4.1 Details of each fisherman family in interview

Family number	Name	Age
1 (F1)	Mr. Chalor Thanomchart Mrs. Nongyao Thanomchart	46 43
2 (F2)	Mrs Rungruang Arthaya	38
3 (F3)	Mr. Wirot Chaloklang	37
4 (F4)	Mr. Saryun Aim-Augsorn Mrs. Sutin Aim-Augsorn	39 37

In Table 4.1, the first family as a couple of fisherman who go to harvest razor clam together. The second family is a female fisherman who is a friend of former village headman. She has known our research team from Chulalongkorn University quite well since she was a child. The third family that has one fisherman also a temporally trader researcher knew from the interview but they still go to harvest razor clam. The fourth family is also a couple but they go harvest together not often comparing with the first family. They are younger than the first couple. A wife is a native people in this village but husband came from another village. They go to harvest razor clam together regularly.

The results from interview were separated into 4 groups following the objective of the question. The questions in 1st group were intended to explore general harvesting habit of fisherman and the results from each question presented in table 4.2. (The details of full interview in Annex E)

Table 4.2 Summary results of the 1st group of question (General harvesting habit)

	Q1	Q2	Q3	Q4	Q5
F1	Husband: 16 years old Wife: 14 years old	Harvest regularly	Lime (with caustic soda)	4 hrs/day 20 days/month 10 months/year	- Weather - Raining
F2	17 years old	Harvest regularly	Lime (little caustic soda)	4-5 hrs/day 20 days/month 10-11 months/year	- Weather - Low tide period
F3	12 years old	Harvest regularly	Lime (with caustic soda)	3 hrs/day 10-15 days/month 10 months/year	- Weather - Low tide period
F4	Husband: 17 years old Wife: 13 years old	Harvest regularly	Lime (with caustic soda)	4 hrs/day 20-25 days/month 10-11 months/year	- Weather - Low tide period -clam density and price

Remark: Q1. When did you start harvest razor clam?

Q2: Are you going to harvest razor clam regularly since you start harvesting?

Q3: Which technique do you use to catch razor clam?

Q4: How long did you harvest razor clam?

Q5: What are your reasons to spend more or less time than average when you harvest razor clam?

In Table 4.2, all of fishermen have started harvest razor clam since they were a teenager. They have been continued harvesting razor clam as a career since they started. Regarding the current razor clam harvesting method, all of them are using lime mixing with caustic soda to improve effectiveness of lime.

Due to time their spend in harvesting, they usually spend around 3-5 hrs/day, 12-25 days/month to harvest razor clam depending on tidal cycle and weather such as rain, temperature, etc.. In addition, they usually go to harvest razor clam 10-11 months/years. From the interview, it was found that during winter season the night-timt low tide (usually late at night) some fishermen consider to stop harvesting because of the natural constraints such as cool weather, difficulty to find razor clam hole during the night, low abundance of razor clam, etc. Moreover, it is blue swimming crab season at Don Hoi Lord during winter season, fisherman can switch their job to be a labor in crab fisheries (such as fixing gear, remove crab from the net, and separating crab meat from boiled crab) which they can work during day-time instead of harvest razor clam in nighttime.

However, major factors affected the decision of fisherman to go to harvest razor clam in the winter season are abundance of razor clam and its price. If high razor clam abundance and/or razor clam price is high, fisherman will consider to harvesting razor clam in this season in particular to earning more money than working as a labor in crab fisheries.

The answers of 2nd group which concerning razor clam harvesting production were summarized in Table 4.3 and 4.4.

Table 4.3 Summary results of the 2nd group of question (Razor clam harvesting production)

	Q6	Q7	Q8	Q9	Q10	Q11
F1	3-4 Kg/day	No	Last week: Don Nork Last month: Sam kha	Sell to same trader	Day: ≈ 400-500 B Night: ≈ 400 B	Not change
F2	2-2.5 kg/day	No	Last week: Lhang Don Last month: Sam Kha	Sell to same trader	Day: ≈ 250-300 B Night: ≈ 250 B	Not change
F3	2 kg/day	No	Last week: Lhang Don Last month: Sam Kha	Sell by myself	Day: ≈ 400-500 B Night: ≈ 400 B	Not change
F4	2.5-3 kg/day	Yes	Last week: Don Nork Last month: Sam kha	Sell to same trader	Day: ≈ 200-300 B Night: ≈ 250 B	Not change

Table 4.3 Summary results of the 2nd group of question (Con.)

	Q12	Q13	Q14
F1	No	Decreasing	- Forbidden caustic soda - Closing some zone
F2	No	Decreasing	- Forbidden caustic soda
F3	No	Decreasing	- Guarantee price
F4	Not really	Decreasing	- Limit clam size to catch

Remark: Q6: How much razor clam can you harvest in each day?

Q7: Do you keep record your harvest?

Q8: Where did you go to harvest?

Q9: What did you do with harvested clam?

Q10: How much can you earn from razor clam in each day (average)?

Q11: In the recent, did you change the way you decide to go harvesting razor clam?

Q12: Can you specific harvesting location in each month in year round if you continue harvesting?

Q13: Regarding the way of your harvesting, how do you feel about razor clam at Don Hoi Lord since you started harvest until now?

Q14: What will you suggest to solve the razor clam reduction?

During interview was taking place in August 2009, fisherman could harvest razor clam around 2.5-4 kg/day/person, while comparing with the previous studies. For instance, Sriburi and Gajaseni (1996) who reported that fisherman had ability to harvest razor clam at 1 kg/hr, the current harvesting rate was lowest than the previous study at day-time low tide was 3-4.5 hrs/day (Worrapimphong, 2005).

The 4th family was the only one family who has been keeping their harvesting records and their records were analyzed in chapter 4.3.2. There were some similarities in harvesting place where fisherman go to harvest. Every fisherman referred one harvesting place namely "Sam Kha" for their harvesting place in the last month and there were 2 harvesting places are mentioned namely "Lhung Don or Klang Don" and "Don Nork" for their harvesting place last week. Regarding harvesting place, there are many specific harvesting places on the sandbar both inside and outside the ecological study area. In summary, the razor clam harvesting place at Don Hoi Lord was presented in chapter 5.3.3.

Razor clam productions from fisherman usually were sold to the same trader except the 3rd family who switched to small trader and sometime fisherman sold razor clam by himself to his friends or relatives. Fisherman could earn 200-500 baht/day during day-time low tide and 250-400 baht/night during night-time low tide. Fisherman could earn from razor clam harvesting during day-time low tide much more than night-time low tide due to low supply with high demand and some difficulties of harvesting during the night. Generally, the razor clam price is set by a trader (Thanomchart : **Interview**, 9 August 2009;Worrapimphong, 2005).

All fishermen did not change the way to make decision to go to harvest razor clam. There was only one criterion for fisherman to make a harvesting decision based on total earning from harvesting. The factors affected to total earning from razor clam are razor clam density and razor clam price. As long as high razor clam density, fisherman still goes to harvesting until their earning less than 100-150 baht/day, then they will consider switching from razor clam harvesting to another aquatic species on the sandbar or go to get another work as labour. From the interview indicated that even they might switch to harvest other aquatic species on sandbar but they still keep checking the abundance of razor clam. Until the abundance is recovery, then the fisherman will switch back to harvest razor clam again.

Only the 3rd family tended to identify a specific harvesting location in each month because they have been recorded their harvesting information regularly. It is so interesting that they looked at their record for searching the productive location to go for razor clam harvesting. Third family also shared their experiences that sometime it worked out as they expected the high abundance but sometime not. Nevertheless, by referring their records it was useful and effective strategy for razor clam harvesting. While the other families did not record any harvesting information and they could not specific harvesting place effectively.

All of fisherman agreed on current situation of razor clam population at Don Hoi Lord which was decreased rapidly over the time. They explained that around 20-30 years ago they could harvest razor clam at least 15 kg/person/day comparing with presently it just 2-4 kg/person/day. The worst circumstance for razor clam population was the last year (in 2008) that almost all fishermen could not harvest razor clam because there was no razor clam on the sandbar. The 3rd family who is a small trader provided more information about the razor clam production in 2008 that the processed razor clam sold at Don Hoi Lord came from Chumporn province, South of Thailand and Cambodia.

The last question in this group of question is regarding fisherman's suggestions for solving razor clam reduction. There were 4 suggestions from the fishermen in the following:

1. Closing some areas and do not allowed to harvest razor clam;
2. Forbidding the use of caustic soda in harvesting practice;
3. Implementing the policy to guarantee razor clam price; and
4. Setting up a regulation of marketable size of razor clam for harvesting.

Following the suggestions on closing some areas and implementing the policy to guarantee razor clam price, both were used for discussion in the ComMod workshop in 2005 as the acceptable razor clam management (Worrapimphong et al., 2007). It is clear that the above suggestions have been still considered by fishermen who used to participate in the workshop.

Table 4.4 Summary results of the 3rd group of question (Connection among group of fisherman)

	Q15	Q16	Q17	Q18	Q19
F1	≈ 10-15 people	Yes	≈ 10-20 people	60-80%	Less number
F2	≈ 15-20 people	Yes	≈ 20-25 people	≈ 70%	Adequate number
F3	≈ 20 people	Yes	≈ 30-35 people	70-85%	Adequate number
F4	≈ 20 people	Yes	≈ 20 people	60-80%	Adequate number

Remark: Q15: How many fishermen who harvest razor clam do you know?
Q16: Do you usually see other fisherman when you are harvesting?
Q17: How much fisherman do they harvest razor clam in average?
Q18: How much percentage do you know them?
Q19: How do you feel about the number of fisherman who harvests razor clam?

The 3rd group of question emphasizes on the connection among fishermen. Fishermen have known other fisherman who also harvested razor clam on the same sandbar area around 10-20 people. Most of fisherman felt that current number of fisherman harvest on razor clam is adequate number and it is harmoniously with current razor clam density. There was only one family (1st family) felt that the current number of fisherman on the sandbar was less than the past situation when razor clam was very high abundance more than 10 years ago.

The answers in this group of question were more empirical information that fisherman provided it based on their experience even sometime it was difficult to estimate to exactly number. For example, “Q18 regarding percentage of knowing fisherman on the sandbar”, fishermen told that they know them and their village, but only some fishermen who they don’t know their name. Even though they could be collected razor clam information from those fishermen, they also provided a counting percentage.

Regarding number of fisherman on the sandbar, the number of fisherman in this study was lowest from other study. In 2005, there were around 80 fishermen harvesting razor clam on the sandbar the sandbar (Worrapimphong, 2005) and in 1996, there were around 150 -200 fishermen on the sandbar (Sriburi and Gajaseni, 1996). Trend of fisherman number on the sandbar had been decreasing significantly due to the razor clam density from scientific studies. Suwanna (2003) reported that total fisherman harvested razor clam around 2,000 people, some of them harvest as major career while some of them harvest as an additional career. Therefore, the decreasing of razor clam population affected widely to fisherman around Don Hoi Lord in term of earning money from razor clam.

Table 4.5 Summary results of the 4th group of question (the effect of ComMod on fisherman opinion regarding to razor clam management)

	Q20	Q21
F1	- Yes, we participated - No one follow it because Gov. didn't force on problem	- Difficult to justify should or should not
F2	- Yes, by village headman told the story - Some argument among fisherman and no action from Gov. implemented	- Should be introduced - Forbidden caustic soda and closing some zone and Gov. help to force the regulation
F3	- Yes, participated - No one follow it because Gov. didn't force on problem	- Should be introduced - Guarantee price to reduce harvesting
F4	- Yes, participated - No one follow it because Gov. didn't force on problem	- Should be introduced - GOV should participate in this problem

Remark: Q20: Have you heard about the companion modeling workshops organized 5 years ago?
Q21: In your opinion, should management rules of RZC fishery be introduced?

The last group of question is regarding the effects of ComMod on fisherman's opinion in razor clam management at Don Hoi Lord. Three of 4 families in the interview already participated in ComMod process since 5 years ago and the 2nd family have known ComMod process by former village headman. All of fishermen in the interview have known the possible management policies which came out from ComMod process and still considering as the management option if it can be implemented in the future. Most of the suggestion for introducing management regulation had to request support from the government. However, the fisherman believed that because both TAO (Tumbon Administrative Organization) and provincial authority did not pay real attention to implement some regulations for solving razor clam problem. Thus, anyone who did not participate in the ComMod process still do the same practices. Even though fisherman who participated in ComMod process also did as normal fisherman but they would ready to follow the regulation if it implemented.

There was only one family did not justify should or should not introduce razor clam management rule. However, this family was participating at the beginning of ComMod process at Don Hoi Lord and they would agree on the regulation if every fisherman agreed.

4.3.2 Harvesting record analysis

4.3.2.1 Fisherman activity

From 2,477 daily records since July 2003 – March 2010 by the couple fisherman, it can be separated their activities as shown in figure 4.2.

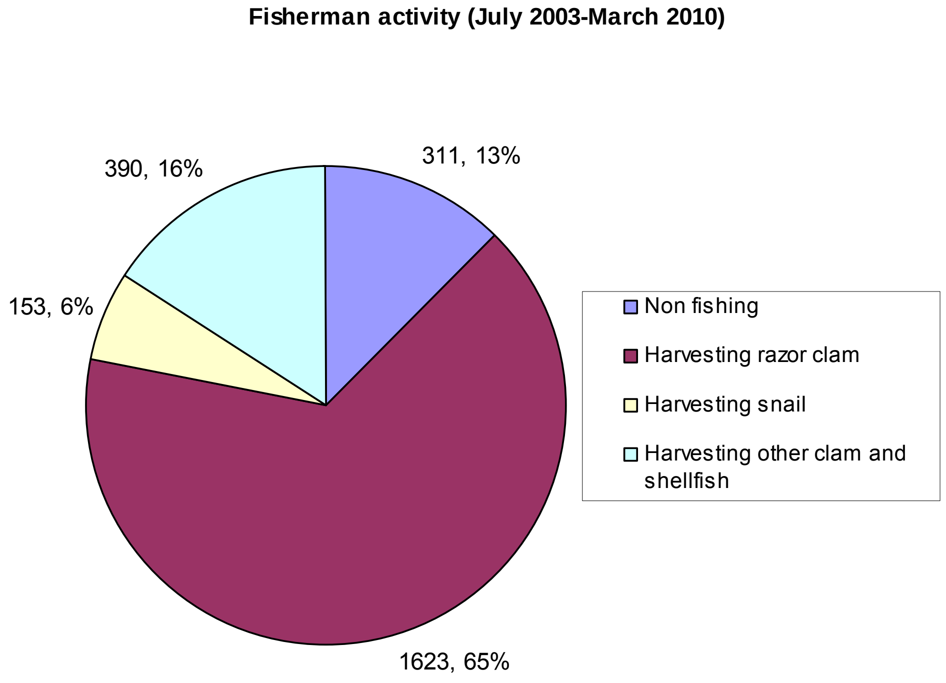


Figure 4.2 Activity of one fisherman family from 2003 -2010

There were 4 major activities in this family, the majority of activity was razor clam harvesting at 65%. Harvesting on other clams and shellfish such as cockle, wedge shell, prawn, etc. was at 16 %. By doing non fishing at 13 %, it consisted of stay at home due to unsuitable tidal cycle and be hired as a labor in other fishery activities such as blue swimming crab. The last activity was harvesting on the tiger moon snail the other economically species on the sandbar.

From Figure 4.2, it is clearly that razor clam harvesting was the major activity of fisherman at Don Hoi Lord. Due to the interview, the razor clam would be the first priority for them if they can go to harvest. However, if the abundance of razor clam was low level, they will start considering another species instead of razor clam (Aim-Augsorn: **Interview**, 7 August 2009).

4.3.2.2 Razor clam harvesting day

Regarding razor clam harvesting is the first priority for fisherman. The number of razor clam harvesting day in each month in the records has showed in Figure 4.3 to represent the fisherman's preference of harvesting.

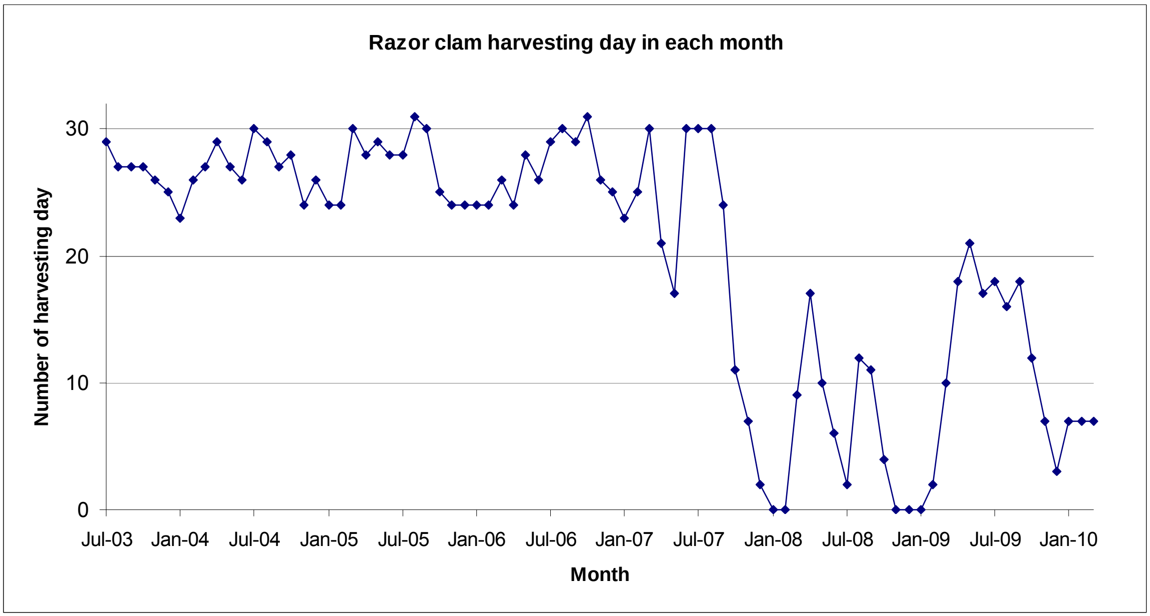


Figure 4.3 Number of razor clam harvesting day in each month from 2003 – 2010

From Figure 4.3, the number of razor clam harvesting day was higher than 20 days/month since 2003. It was concurrent with interviewing that the number of harvesting day was a range of 20 – 25 days/month (chapter 4.3.1). However, in some months this family could harvest for a whole month due to the low tide was low enough including time interval of low tide was long enough. This family harvested razor clam more than 20 days/month until early 2007 even the number of razor clam harvesting day clearly fluctuated due to the abundance of razor clam. The density of razor clam scattered in 2007 and was decreasing. This fisherman started considers harvest other aquatic species instead of razor clam as in chapter 4.3.2.1. In some months such as November 2008 - January 2009 in concurrent with this study period; this family did not go to harvest razor clam during that period (Figure 4.3).

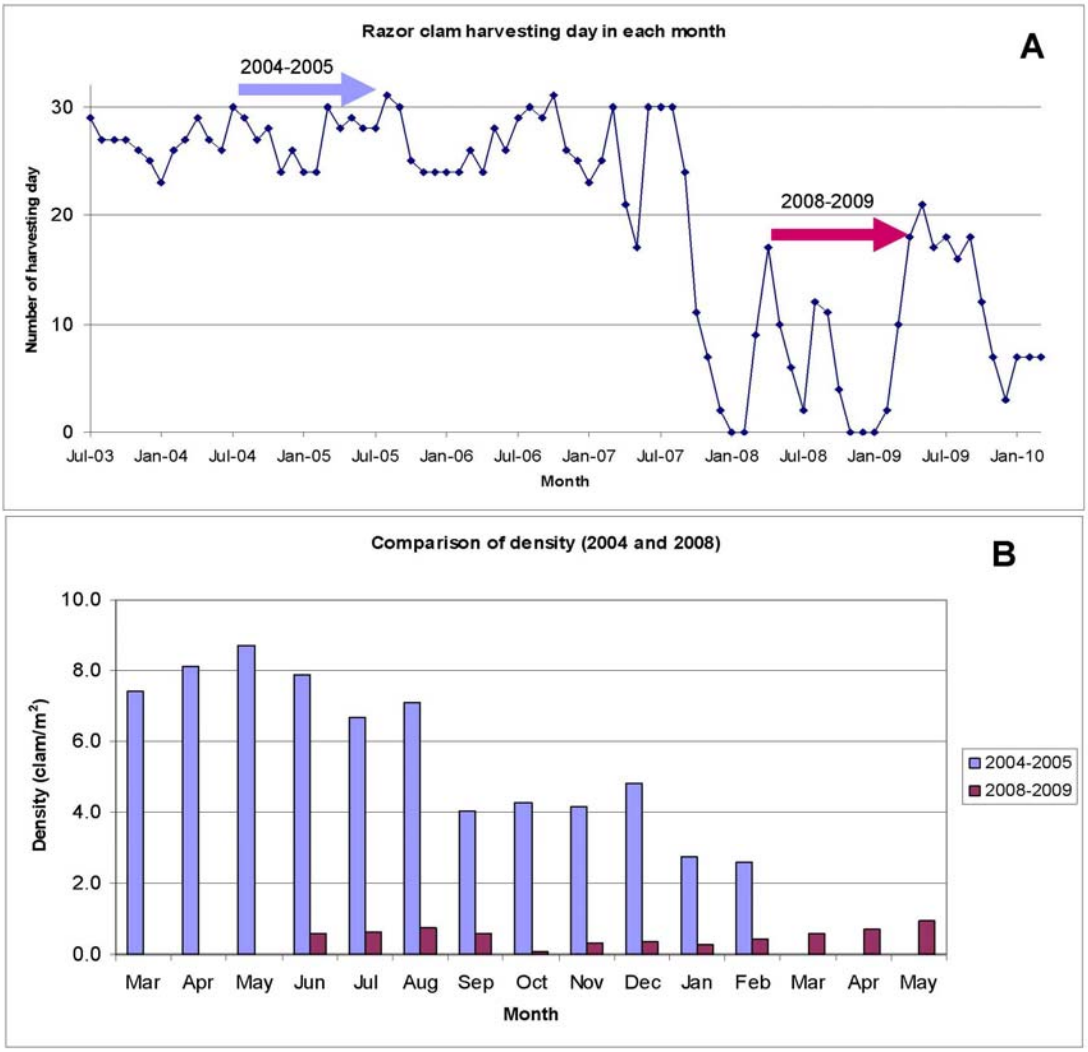


Figure 4.4 Comparison between scientific data and social data from fisherman by (A) Number of razor clam harvesting day in each month with arrows indicator of interval of scientific study between 2004 and 2008 and (B) Comparison of razor clam density between 2004 and 2008

Comparison of number of harvesting day in each month between 2005 and 2009 regarding razor clam density (Figure 4.4), it showed that both number of harvesting day and razor clam density were related to each other by; during 2005 razor clam density was not low as 2009 and the fisherman was harvesting on razor clam more than 20 days/month whereas in 2009 razor clam density was very low and fisherman went to harvest razor clam less than 20 days/month. This concurrent between scientific data and social data from fisherman also confirmed the resource degradation problem at Don Hoi Lord regarding the lowest density of razor clam from scientific records, but it was the first time for fisherman to stop harvest razor clam for long time (Aim-Augsorn : **Interview**, 7 August 2009).

4.3.2.3 Razor clam harvesting place

Name of the harvesting area where this family went to harvest was recorded every harvesting day. Thus, the first map of harvesting place was created in Figure 4.5.

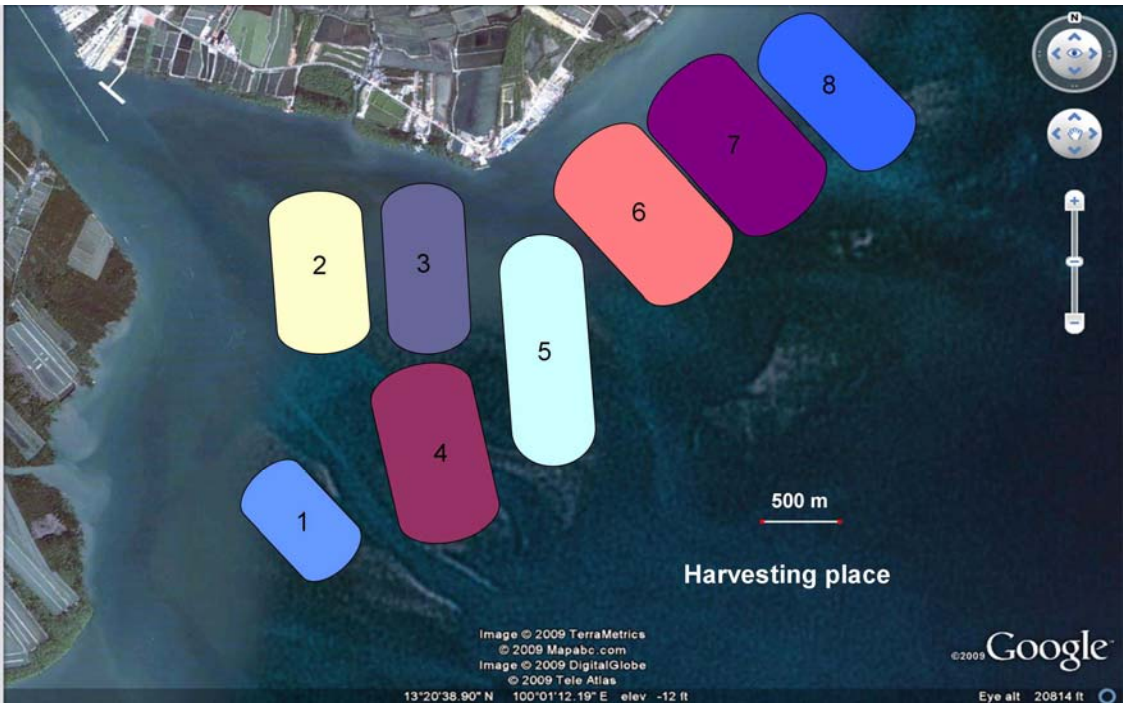


Figure 4.5 First harvesting place map based on researcher understanding

There were 8 harvesting places from the interview and be interpreted by researcher. Some harvesting places contributed from aggregate few harvesting places in the records due to those were connected to each other.

The harvesting places were named as:

1) Sam Kha
2) Khun Lin
3) NarSarn
4) Don Klang, Don Nok

5) Phoe, Yor Ta Vean, Krasar
6) Lam
7) Sume
8) Muan Han, Park Marp

Based on the principle of ComMod (Barreteau et al., 2003b) that it was accepted as a new finding in the field and refute the old one. Once, the map was created as 8 harvesting places. Researcher had to go back to the field for validation of this map of harvesting place by asking for suggestion from the fisherman at Don Hoi Lord. The purpose of validation of the map was to use the harvesting map for Agent - based simulation model development (see chapter 5).

4.3.2.4 Harvesting rate, razor clam price and earning from razor clam

From the records 2003-2010 harvesting rate from this family (2 fisherman) and razor clam selling price to a trader can be separated into 2 dimensions, first is monthly and, second is yearly (Figure 4.6 and 4.7)

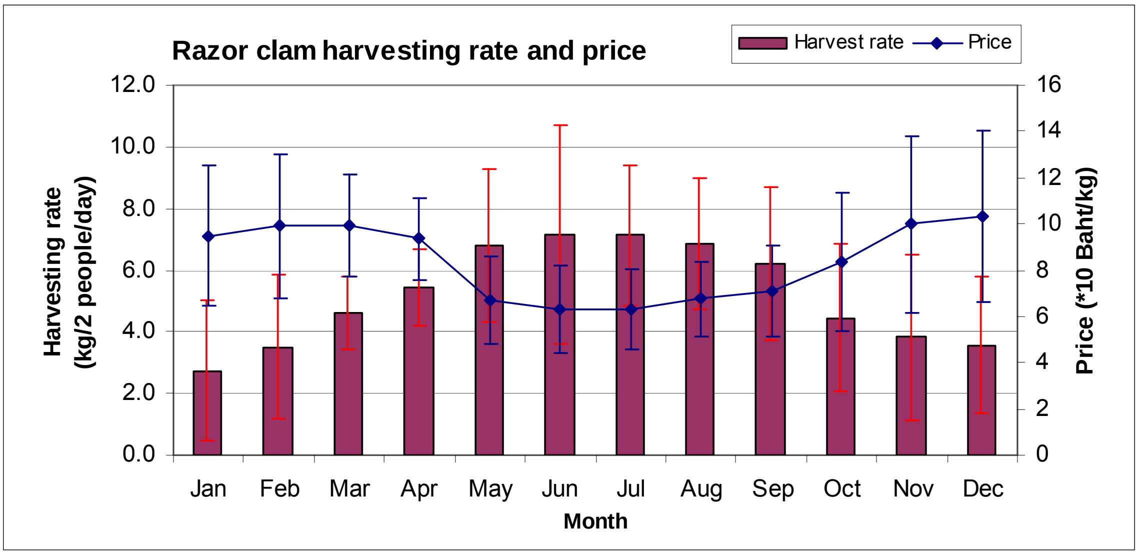


Figure 4.6 Mean razor clam harvesting per 2 people and razor clam price in each month from 2003 -2010

There were some differences in razor clam harvesting rate and razor clam selling price to a trader in each month (Figure 4.6). At the beginning of a year, harvesting rate was lowest and continued increasing every month until June and then, it had decreased every month until the end of year. By contrast, razor clam mean price was high at the beginning of the year it was almost 100 baht/kg and decreased when fisherman harvesting rate increased.

Considering tidal cycle and razor clam breeding season with harvesting rate, around January – March low tide usually occurs during night-time and low razor clam density due to harvesting from previous season.

During March – August low tide it usually occurs during day-time and have high razor clam density due to the breeding season and recruitment period. On the other hand, around August to the end of a year low tide turn back to occur during night-time and harvesting rate was decreased. Due to decreasing of harvesting rate, it may imply that ability of razor clam recruitment during the beginning of day-time low tide had a limitation and it could not maintain the population under high harvesting pressure.

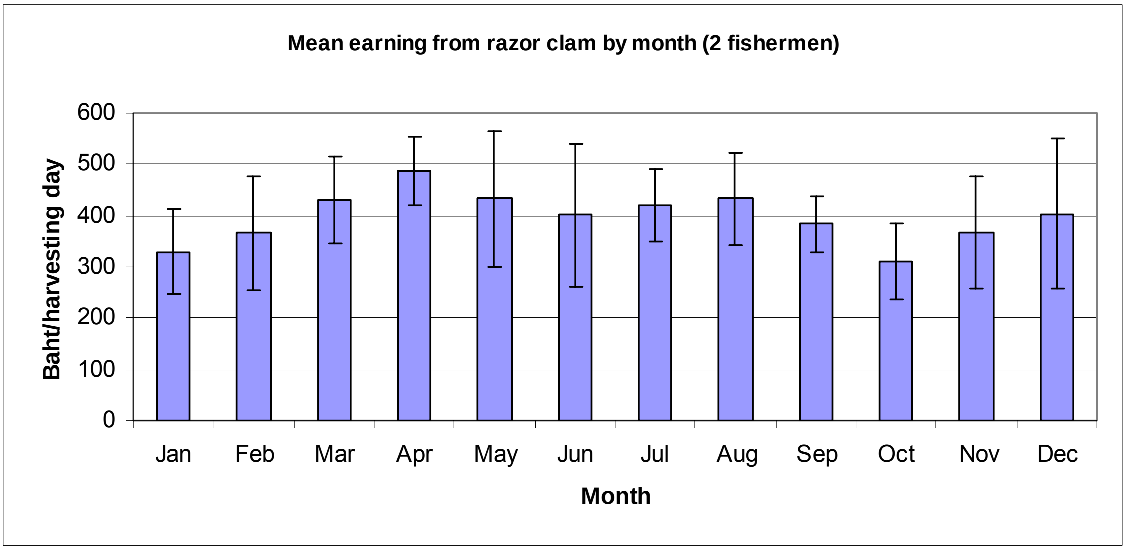


Figure 4.7 Mean earning from razor clam harvesting in each month from 2003 – 2010

Although both harvesting rate and razor clam selling price to a trader were dynamics in year round, fisherman earning money from razor clam harvesting was not dynamics as selling price due to the price control by traders. This family could earn money from razor clam around 300 - 500 baht per day. During day-time low tide from March – August they could earn more than 400 baht/day higher than the night-time low tide because they could harvest less razor clams even the price was high almost 100 baht/kg (Figure 4.6).

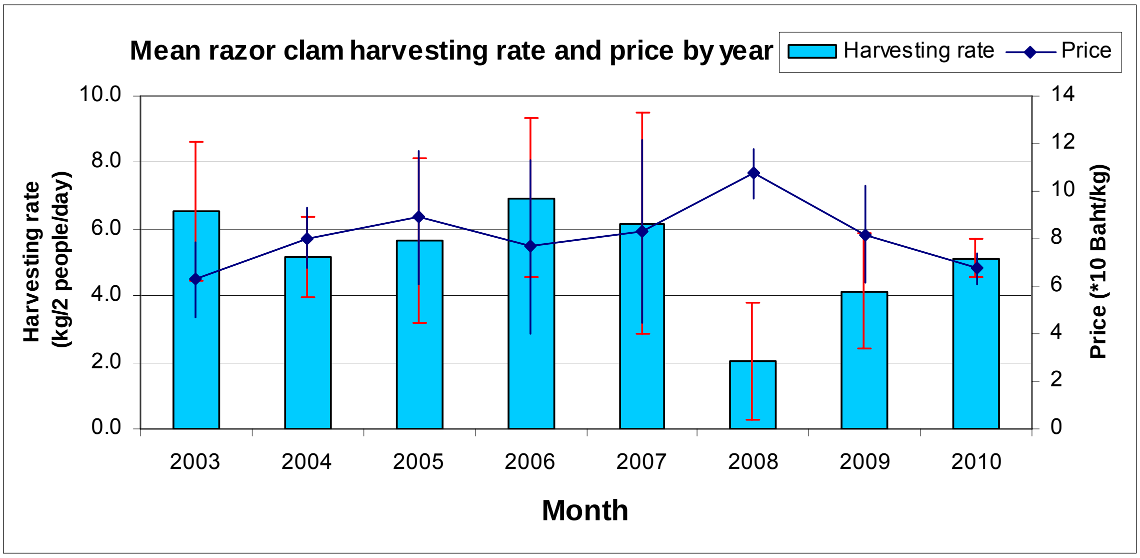


Figure 4.8 Mean razor clam harvesting per 2 people and razor clam price in each year from 2003 -2010

Figure 4.8 shows the relationship between razor clam harvesting rate and razor clam selling price to a trader. From 2003 – 2007 both mean razor clam harvesting rate and mean selling price was fluctuating by harvesting rate were ranged from 5-7 kg/2 people/day and selling price were ranged from around 60-90 baht/kg. Considering the relationships between harvesting rate and selling price, the harvesting rate was high while the razor clam selling price to a trader was low such as in 2003 and 2006 as well as vice versa in 2004 and 2005. However, razor clam selling price was independently set by a trader who is a razor clam distributor in the razor clam market. The criterion of setting razor clam selling price will be presented in Chapter 4.3.3.

In 2008 mean harvesting rate was sharply decreased, this family could harvest razor clam around 2 kg/ 2 people/day at selling price more than 100 baht/kg. They satisfied with this earning but from their records indicated that they went to harvest razor clam muh less number of razor clam harvesting day, even though the selling price was very high but they decided to stop harvesting on razor clam for some months (see chapter 4.3.2.2) due to a very low abundance of razor clam. Mostly of harvesting time, they went to harvest other aquatic species such as tiger moon snail, shrimp and other bivalves.

From 2009-2010 harvest rate was increased year by year but selling price was seemingly decreased and it was not related to harvesting rate and selling price during

2003-2007. The reason behind the decreasing razor clam price after 2008 was the introducing of razor clam from other area (Siricome : **Interview**, 8 August 2009).

The interview of trader showed that during 2008 she could not buy razor clam from fisherman due to the decreasing of population while the market demand was still at the same level. Therefore, she had to order razor clam from Chumporn province and Cambodia instead of razor clam from Don Hoi Lord and that razor clam from outside was cheaper than from the local razor clam. Then, in 2009 -2010 she has been still ordering razor clam from outside from time to time and it made her to reduced buying price from local fisherman. However, there were arguments that razor clam from another area is not tasty as razor clam from Don Hoi Lord and it may affect the distribution of processed razor clam to the market if a consumer know that the razor clam was not came from Don Hoi Lord (Chaloklang :**Interview**, 28 March 2009).

4.3.2.5 Harvesting rate and number of harvesting day

To better understanding of fisherman behavior in razor clam harvesting, the investigation was carried out more on behavior of this fisherman family. The correlation between harvesting rate in each month and number of razor clam harvesting day in each month was tested to confirm that as long as they can harvest razor clam in a high yield they would continue harvesting on razor clam in that month. The results show in Figure 4.9.

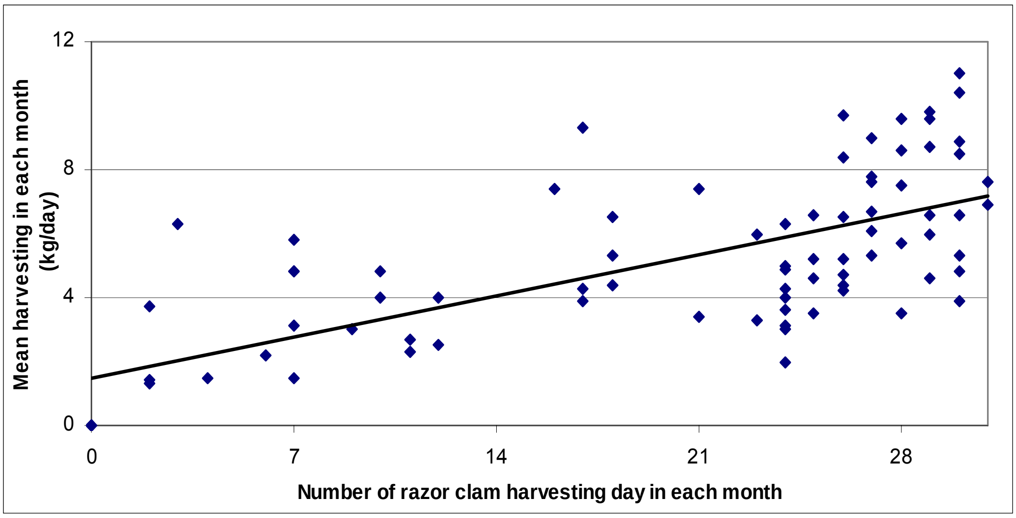


Figure 4.9 Correlation between harvesting rate in each month and number of razor clam harvesting day in each month

From Figure 4.9 shows the statistical analysis that mean harvesting rate in each month and number of harvesting day in each month had significantly positive correlation in a linear regression (p<0.05, r = 0.746). Thus, it can conclude on fisherman behavior that if they still have a high razor clam production, they would not switch to other species. As in 2008, razor clam density was very low, fisherman did not go to harvest razor clam frequently. They went for other clams or shellfish but they still keep monitoring razor clam density and if the density was high enough they will harvest on razor clam again.

4.3.2.6 Harvesting rate and low tide level

To understand the relationship between razor clam harvesting rate and level of low tide daily-time, the information at Tha Chin river mouth (Mobile Geographic, 2009) far from Don Hoi Lord around 30 km was used instead of the information at Mae Klong river mouth due to unavailable data. The correlation between razor clam daily harvesting rate and tide level was tested and the result showed in Figure 4.10.

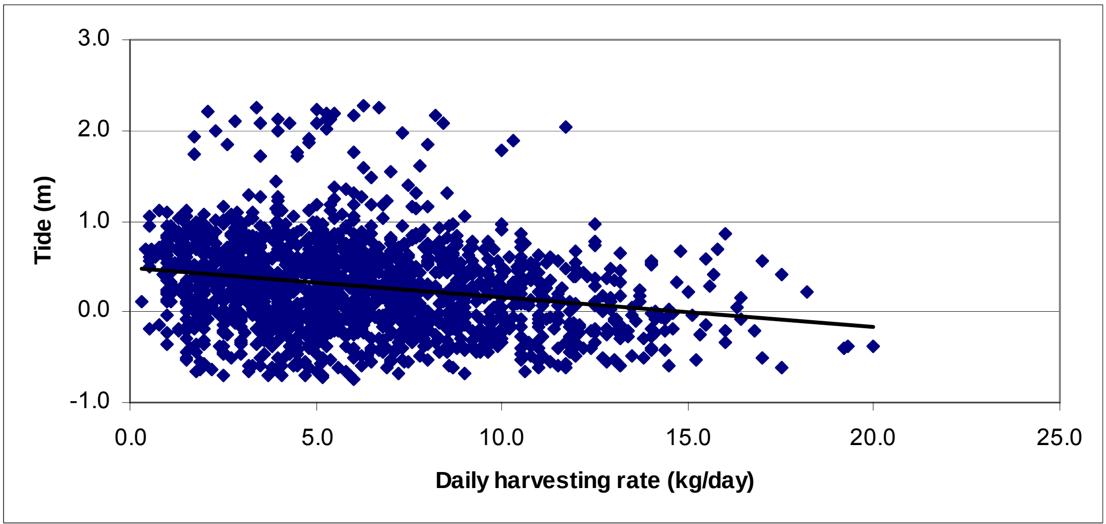


Figure 4.10 Correlation between daily harvesting rate and daily tide level

From Figure 4.10, the statistical analysis indicated that harvesting rate and tide level had significantly negative correlated in a linear regression (p<0.05, r = - 0.223). It can imply that the lower tide level would give more change to fisherman to harvest more razor clam. However, based on empirical experience of fisherman, those areas have many factors affected razor clam harvesting rate such as rainfall, sunlight, water temperature, sea breeze, and tide (Thanomchart : **Interview**, 9 August 2009). The reason is that a very low tide level could making some areas in which normally submerged underwater to be exposed to the air and fisherman could access to harvest in those areas. Consequently, result in high harvesting rate due to razor clam density (Aim-Augsorn : **Interview**, 4 October 2004).

Regarding the analysis of harvesting records, this data came from only one family or two fishermen from a hundred of harvesters both professional and unprofessional but the data was high reliability due to the continuous record since 2003. In addition, the analysis could indicate and confirm that the fisherman behavior helped the researcher to understand better on overview their behavior and razor clam market.

4.3.3 Razor clam market mechanism

From 2 traders, one is a big trader who distributes processed razor clam to inside and outside Samut Songkhram province and another one is a fisherman who does a small business for razor clam distribution inside Don Hoi Lord. The razor clam market mechanism can be divided into 2 scales: first at the provincial level, and second at local level.

4.3.3.1 Provincial razor clam market

Information in this part came from the empirical experiences of a trader. Her name is Mrs. Junram Siricome. She is one of several big traders who has been run razor clam business for more than 10 years at Don Hoi Lord.

Firstly, the trader buys fresh razor clam from fishermen daily. There were around 50 fishermen come to sell razor clam to this trader. The trader usually waits near the pier for razor clam buying (figure 4.11) or fisherman can go to sell razor at her place as well. This trader is the only one trader who buys razor clam near the pier while other traders buys razor at their place. This trader normally bought razor clam from fishermen around 70 – 300 kg/day depending on the abundance and the number of fisherman also was vary from 5-50 fishermen.

Figure 4.11 A trader (sitting woman) buying razor clam from fisherman and a basket with razor clam from harvesting

The trader buys all of razor clam from fishermen. As in chapter 4.3.2.4, razor clam price has dynamic through the time. The price was set by the trader herself by considering:

- Current market demand
- Current razor clam stocking

The trader will decrease price when the market demand is low and she also currently has enough stock. The reason of buying of all razor clam from the fisherman is the trader would like to keep fisherman in her business and control buying price. For the surplus product, she rented a deep freezer to keep the processed razor clam when the market demand increased. Sometime the market demand was not increased then she had to discard that razor clam due to it kept in freezer for too long time. The increasing price aims to tempt fisherman to harvest more razor clam or induce some fisherman who stop harvest razor clam back to harvest again.

Regarding razor clam processing before distributed to the market by the trader, all razor clams were boiled then removed clam meat from its shells. The clam meat or processed clam which ready to cook was kept in a refrigerator until distribution to the market. One kg of clam meat was made from 2.5-3 kg of fresh razor clam depend on fresh razor clam size.

The trader distributes processed razor clam by herself to a restaurant and a merchant in a fresh market in the area of Samut Songkhram province, Nakhon Pathom province, Samut Sakhon province, and Bangkok Metropolitan. Generally, the trader distributes processed razor clam twice a week and the amount of processed clam which delivered to a restaurant usually around 1-10 kg, to a merchant in fresh market around 20-40 kg depending on a business size (how big of restaurant or merchant) and demand at that time. Due to razor clam market demand, razor clam is well known as a delicacy food when compare to other seafood clams in Thailand such as cockle, green mussel, and undulated surf clam. The demand of razor clam is stimulated by tourist activities when people visit this area. The trader usually gets more razor clam order from restaurant during weekend especially long weekend. In addition, in a year round razor clam demand is usually increased during March – May as the holiday season for Thais.

During field data collection in 2008, there was very less razor clam harvesting production from Don Hoi Lord. The trader tried to increased razor clam buying price (chapter 4.3.2.4) and aimed to enhance fisherman harvesting but there was no razor clam in natural stock. The trader solved this problem by cooperating with 2 other traders to order fresh razor clam from Chumphon province and/or imported fresh razor clam from Cambodia in large amount around 1-2 tons and kept in deep freezer at a frozen company. The razor clam price from Chumphon and Cambodia was around 50 baht/kg, it was cheaper than razor clam from Don Hoi Lord at that time. Practically, razor clam from outside Don Hoi Lord was ordered in to Don Hoi Lord for temperately. The trader prefers razor clam from Don Hoi Lord because there some argument among fisherman and trader that razor clam meat from razor clam out side Don Hoi Lord was not tasty comparing with native razor clam. Due to the argument on razor clam test, it might be cased from the different of species by Department of Fishery (1995) reported that razor clam in the south of Thailand found another species which was *Solen abbreviatus.* Moreover, the trader feels familiar when buy razor clam from fisherman who harvested at Don Hoi Lord. It makes her business secured in razor clam supplying in the future both of fishermen in her network and amount of razor clam because razor clam from outside was not guaranteed in availability for longtime.

4.3.3.2 Local razor clam market

The in–depth interview of one fisherman who has worked as fisherman and a small trader since 2 years ago. He has been distributed processed razor clam in the village. This small trader used his relationship with friends and relatives to buy fresh razor clam from them in the village. However, the small trader had to get razor clam demand from small restaurants around the village before start buying razor clam.

Generally, the small trader distributed processed razor clam around 5–20 kg/day depending on the demand from the restaurants. In addition, during weekend the small trader by his wife directly sold both fresh razor clam and/or processed razor including other shellfishes which was harvested on Don Hoi Lord to the tourist at the pier (Figure 4.12).

Figure 4.12 Processed razor clam or clam meat (red circle) and other shellfishes on the sandbar were directly sold by small trader at Don Hoi Lord

Regarding small scale demand of razor clam, the small trader usually got high demand in a weekend when a lot of tourists visit Don Hoi Lord. In addition, there were some fishermen also directly sold fresh razor clam to a tourist because it could earn more than direct selling to the traders.

4.3.4 Harvesting behavior

Three fishermen consist of 1 male and 2 female were selectd to study harvesting behavior. Figure 4.13 shows that the harvesting location of each fisherman/day (1st, 2nd, and 3rd location). The location was selected by fisherman regarding their real harvesting. All 3 harvesting locations located near the stations for ecological field data collection.

Figure 4.13 Three locations for study fisherman harvesting behavior

The 1st and 2nd location located in almost the same area (recording date was on 8th and 9th August 2009) and the 3rd location located near the Chu Chi village (recording date was on 31st August 2009). The fisherman selected harvesting location by considering razor clam abundance as a first priority factor. Each fisherman went to harvest with only one plastic basket with maximum harvesting capacity around 5 kg of razor clam. Fishermen were going out to the sandbar when the tide was lowering and they waited until the tide low enough for harvesting. Following annual oceanographical table of the Royal Thai Navy (2009) and field observation, it indicated that the sandbar at Don Hoi Lord was emerged from water when the tide level was around 1.4 m from MSL (Mean Sea Level) and fisherman will start harvesting razor clam when tide level was around 1.1-1.2 m from MSL. From observing fisherman during harvesting, there were 2 postures of harvesting. Researcher would like purpose to called “Sitting harvest” and

“Walking harvest” (Figure 4.14 and 4.15). Sitting harvest is the normal harvesting posture which could normally see at Don Hoi Lord. Walking harvest is the posture that fisherman uses when the abundance of razor clam scattered. Fishermen would practice walking harvest posture to search for high abundance razor clam area and they would practice sitting harvest posture when they found area high razor clam abundance.

Figure 4.14 Sitting harvest posture fisherman moving around himself while sat to harvest razor clam

Figure 4.15 Walking harvest: (a and b) fisherman walks for searching razor clam hole, (c and d) when fisherman found razor clam hole he sits and harvest it then, stand up and walks for searching another clam’s hole

Harvesting posture directly affected to the harvesting distance of each fisherman. Figure 4.16 and Table 4.6 show details of each fisherman in razor clam harvesting.

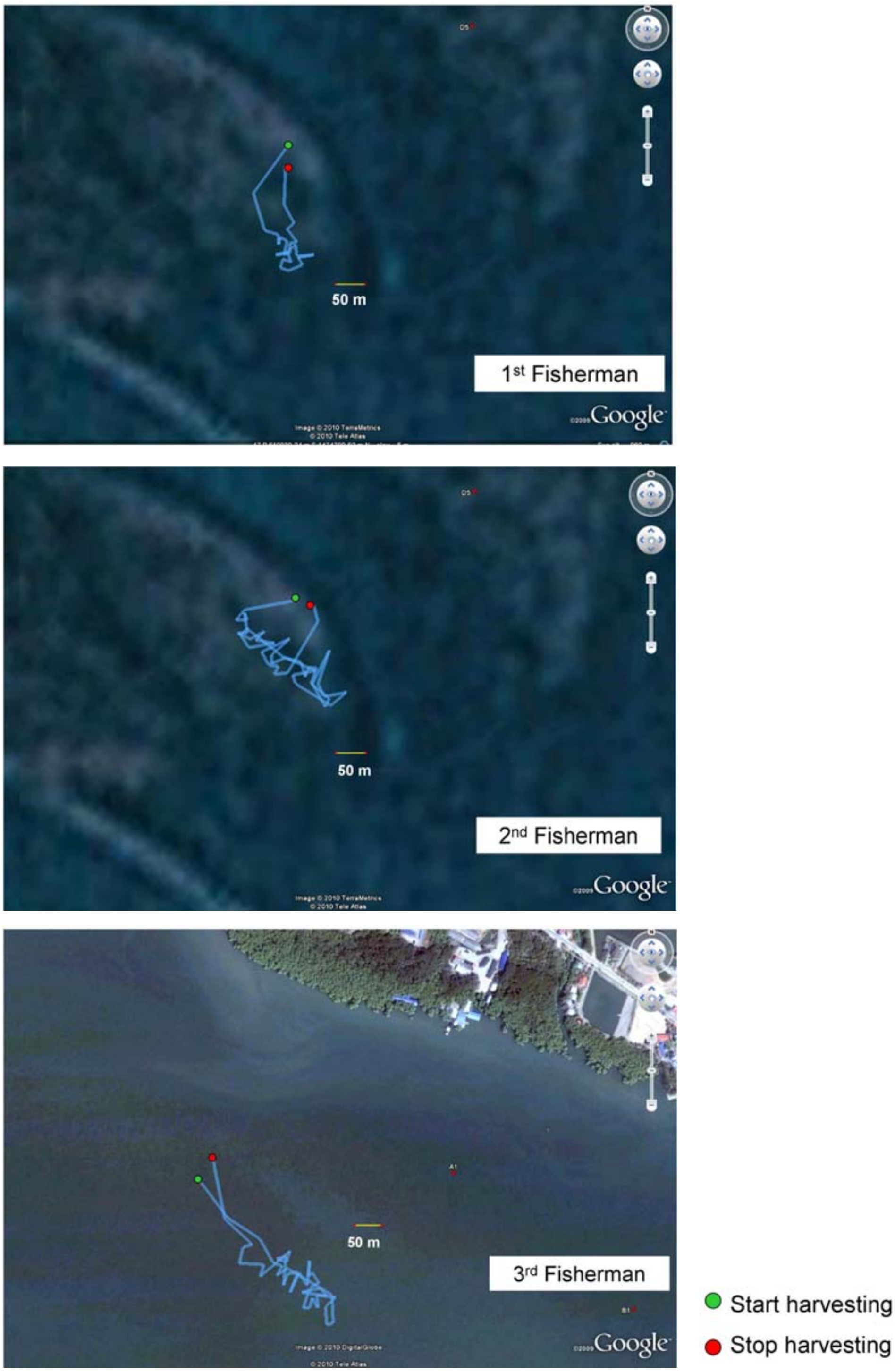


Figure 4.16 Harvesting track from 3 fishermen in 1 day

Table 4.6 Harvesting details from 3 fishermen in 1 day

Name	Sex	Harvesting time (hr)	Distance covered (km)	Harvest posture	Harvesting production (kg)
1st (Mr. Chalor Thanomchart)	Male	4.00	1.07	Sitting harvest	3.5
2nd (Mrs.Nongyao Thanomchart)	Female	3.50	1.96	Walking harvest	3.5
3rd (Mrs Rungruang Arthaya)	Female	3.00	1.86	Walking harvest	3.0

Three harvesting tracks of razor clam harvesting (Figure 4.16) from 3 fishermen showed the similarity of harvesting pattern that fisherman walked forth and back on the harvesting area. During harvest razor clam, they did not consider direction of harvesting but searching for the area with high abundance of razor clam. The fishermen did not spend whole low tide interval to harvest razor clam because fisherman would consider the sign of high tide such as sea breeze changed its direction, a local fisherman's boat heading back from the sea, etc. Fisherman would head their harvesting direction back also to where was they start harvesting razor clam in that day. Fishermen stopped harvesting and go back to sell razor clam or go back home around 1 – 1.5 hr before the sandbar submerged under high tide water.

Distance covered of razor clam harvesting had ranged around 1 – 2 km. The covering distance depends on razor clam density which related to harvesting posture. Sitting harvest posture made covered shorter distance and smaller area than walking harvest posture. From Table 4.6, the 1st fisherman moved only 1 kg to harvest 3.5 kg of razor clam while the 2nd fisherman moved almost 2 km to harvest 3.5 kg of razor clam.

Fisherman at Don Hoi Lord can harvest razor clam for all year long with no limitation of razor clam size. The only one harvesting regulation at Don Hoi Lord is to allow the suitable harvesting method. Comparing of razor clam harvesting here with other parts of the world where razor clam occurring. For example, in Oregon State, USA, many regulation were applied to razor clam harvesting comprising harvesting license, closing some areas from harvesting razor clam, retained some parts of harvesting production regardless size, and control harvesting method (Oregon Department of Fish and Wildlife, 2010). In Europe, the limited razor clam harvesting size was implemented as the EU regulation and harvesting license was applied for commercial harvesting by vassel in Ireland (Marine Institute Fords na Mara, 2009). In Spain, diving without air supplied device to harvest razor clam is only one method allowed in Galicia (NW Spain) (Couňago, 2006).

Comparing with previous social study at Don Hoi Lord, Oiamsomboon (2000) studied people opinion by using the set of questionnaires and the results showed only the details of people around Don Hoi Lord and she concluded that people awarded on the importance of resources in the area. In addition, Suwanna (2003) studied on the ability of Don Hoi Lord community to manage razor clam resource and the results showed that the community at Don Hoi Lord had many factors to support community for resource management. Meanwhile, this study is more deeply investigated on fisherman harvesting behavior and razor clam market mechanism and it revealed some socio-economic aspects which go through the details of the razor clam system including the factors affected fisherman and trader's decision on razor clam harvesting and distribution. The finding in this study can be used in order to supporting and suggesting the management option that might apply in the future such as to control harvesting yield of fisherman during May – August. The reason is when razor clam production was surplus, a trader had to reduce razor clam price. So it is possible to considering a forbidden area for razor clam harvesting during winter season due to fisherman has possibility to have a job in crab fishery or they can harvest on other bivalve species.

4.4 Conclusion

4.4.1 Understanding of fisherman harvesting behavior

From the study the understanding of fishermen harvesting when they made their decision to go to harvest razor clam can be illustrated in Figure 4.17.

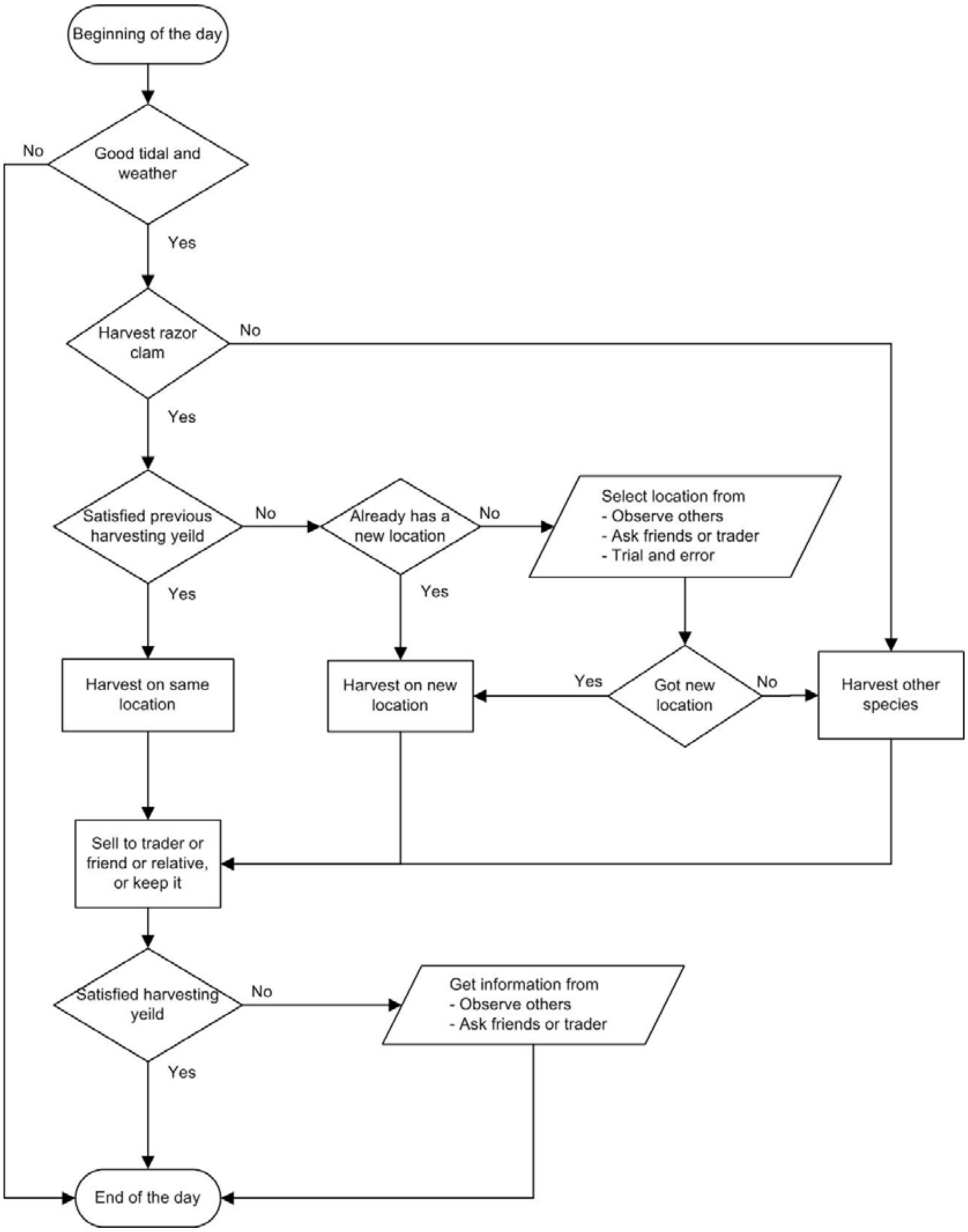


Figure 4.17 Understanding of fisherman's decision on razor clam harvesting

Figure 4.17 illustrates the fisherman decision on razor clam harvesting. At the beginning of each day, they consider the tide level and weather, which are good or not for go harvesting. Then, they chose harvesting choice to harvest razor clam or other species such as tiger moon snail, ridged venus clam. In this step, fishermen will use their previous information on razor clam or other species harvesting yield to make a decision. Regarding selection where to go harvesting razor clam, fisherman may have a location in their mind due to previous razor clam harvesting yield and they just go directly to harvest razor clam there. However, they may get further information from their friend or trader, or observe other, or just randomly select (very less chance for this choice). When they got more information they may select a new location or switch to harvest other species instead of razor clam.

Both razor clam and other species harvesting production will be mainly sold to a trader, or fisherman's friend who is a small trader, or keep it in household consumption if they got very low production. After selling harvesting production, fisherman assessed their harvesting production either they satisfy their earning or not. If they satisfied they will continue for next harvesting following today choice. On the other hand, if they do not satisfied they may ask for some information from their friends or traders, or observe other fisherman. In this step fisherman may or may not get a decision for next harvesting day.

From the interview indicated that fisherman considered razor clam as the first choice of harvesting depending on its price because its harvesting consumed less time and energy when compare with other species. As long as fisherman could earn from razor clam harvesting enough they would not switch to target other species (Aim-Augsorn : **Interview**, 7 August 2009;and Thanomchart : **Interview**, 9 August 2009).

The Fishermen who harvest shellfish (razor clam, other bivalves, snail, etc.) on the sandbar at Don Hoi Lord had always exchanged harvesting information among each other. In addition, a trader was also one of information distributor due to having more opportunities to meet and get information from fishermen. This network could accelerate razor clam population decreasing by the fishermen could go directly to high abundance of razor area after they get information from the network and razor clam population

4.4.2 Razor clam market mechanism

4.2.2.1 Provincial razor clam market

Razor clam market mechanism can be divided into 2 levels which are provincial level, and local level. Understanding of each market level illustrated in Figure 4.18 and 4.19.

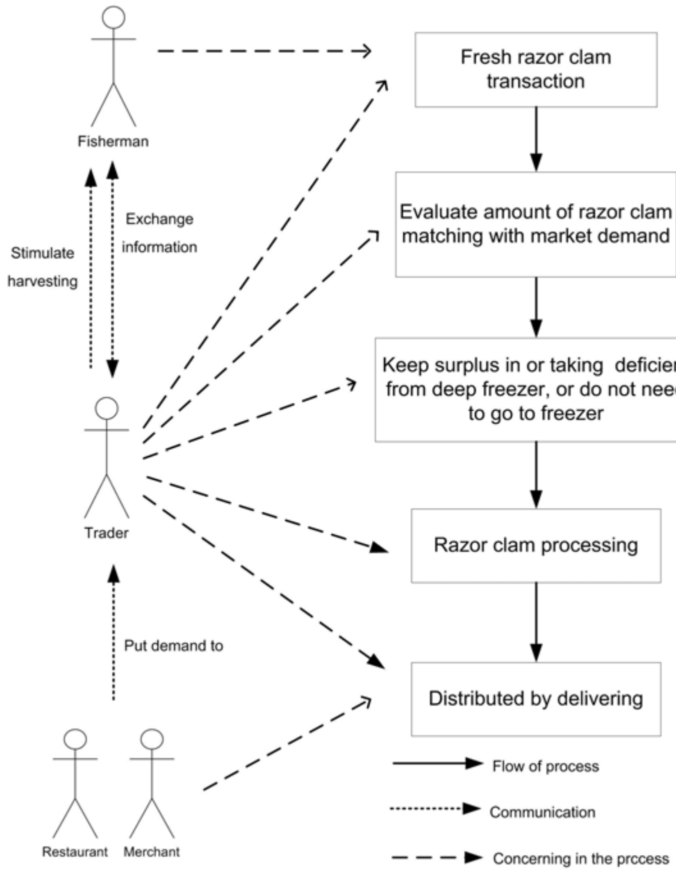


Figure 4.18 Understanding of razor clam market mechanism in provincial level

Razor clam market in provincial level, a trader plays core role in the market, the traders buy all fresh razor clams from fisherman with dynamics price which depends on the total production of razor clam and market demand. After finished fresh razor clam transaction between fisherman and trader, the traders will control the razor clam production based on market demand pressure. Generally, the trader is renting a deep freezer at frozen company to keep fresh razor clam as their stocks. From trader assessment, if razor clam production is surplus a market demand, then the trader will keep exceeding razor clam in the deep freezer for selling during the high market demand in the future.

The trader processes fresh razor clam to razor clam meat and distributing the meat to the market. The customers of the trader are restaurant owners and merchants in a fresh market around Sumut Songkhram province. Those trader's customers can control a market demand. Therefore, a trader will communicate with fisherman in order to stimulate fisherman to go harvesting more on razor clam if the demand is increased.

4.2.2.2 Local razor clam market

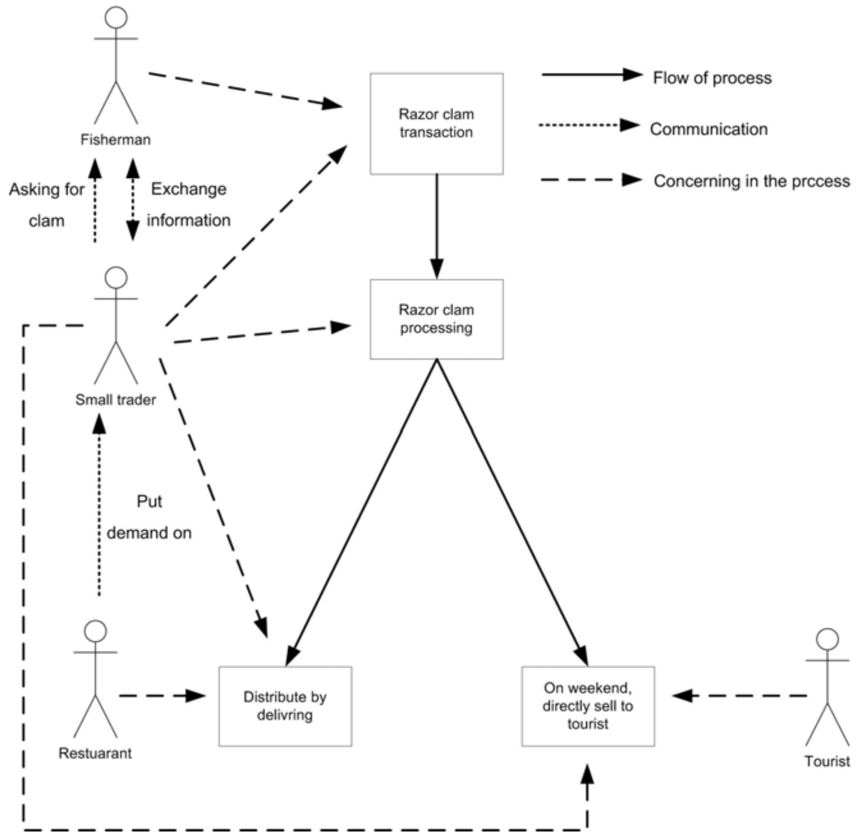


Figure 4.19 Understanding of razor clam market mechanism in local level

Figure 4.19 shows the local razor clam market mechanism, a small trader also plays a major role at provincial market level. A small trader buys fresh razor clam from his friends or relatives with the price as sell to a big trader. Then, a small trader will process fresh razor clam to get razor clam meat and deliver directly to a restaurant around Don Hoi Lord.

Restaurants may increase or decrease their demand to a small trader depend on the current number of tourist at that moment. In addition, during weekend a small trader usually sells fresh or processed razor clam directly to tourists at Don Hoi Lord. Regarding razor clam demand at local level, if market demand is increased, a small trader will buy more razor clam from his friends and relatives. It also causes more harvesting pressure.

From both market levels, there were some similarities between 2 markets. Market demand was increased during weekend and in a year round, the demand was increased during March – May due to the summer holiday in Thailand. In addition, there was no conflict between a big trader who distributing processed razor at provincial level and a small trader who distributing at local level even they have the same fisherman selling fresh razor clam to them.

CHAPTER V

AGENT-BASED SIMULATION MODEL AND PARTICIPATORY SIMULATION WORKSHOP

5.1 Introduction

It is now widely recognized that ecosystem studies require a holistic interdisciplinary approach in order to integrate biological, environmental and social components within a research framework (Turner and Carpenter, 1999). Advancing the present-day concept of “integrated renewable resource management”, the challenge is now to develop a new “integrative science for resilience and sustainability”. This should focus on the interactions between ecological and social components and take into account the heterogeneity and interdependent dynamics of these components (Berkes and Folke, 1998;Costanza, Wainger, Folke et al., 1993;Funtowicz and Ravetz, 1994).

At the same time, modelling has become an essential tool for the study of ecological systems as it provides an opportunity to explore ideas and scenarios, which for logistical, political, or financial reasons would not be possible under practical field study conditions (Jackson et al., 2000). As a result there is now a wider spectrum of objectives for how models are being designed and applied, in addition to their standard role as decision-support tools. Models should ideally be flexible, user-friendly for all the participants and easily adaptable for unforeseen situations and new ideas. It could be said that models are no longer mainly intended for predicting outcomes, but rather for promoting and encouraging creativity, facilitating discussion, clarifying communication, and thereby contributing to the collective understanding of problems and potential solutions among involved stakeholders through the exploration of simulation scenarios (Carpenter, Brock and Hanson, 1999).

The companion modelling approach has been implemented at Don Hoi Lord since 2004 through an iterative process. This chapter describes the latest stage of the process, made of 3 successive steps. First, the design of a prototype of an agent based simulation model (AMB); second, the use of this ABM to run simulation scenarios that were purposed by the fishermen; third, the organization of a participatory simulation workshop with local stakeholders. The methodological aspects of each step are first describes. The results are then presented and discussed. Finally, an assessment of the effects of this final stage of the ComMod process on razor clam management concludes this chapter.

5.2 Methodology

5.2.1 Agent-based simulation model development

According to the principles of the ComMod approach, the ultimate objective is to develop a simulation model for collective learning and assessment of scenarios (Bousquet and Trébuil, 2005: Cited in Dung, 2008). Following a first agent-based simulation model prototype for Don Hoi Lord developed from 2005 (Worrapimphong, 2005), a new version was developed within the same simulation platform which is Cormas (Bousquet et al., 1998). Cormas is a software for modelling multi-agent systems, with agents that may communicate among themselves and move on a spatial grid on which some resource can be located (Cormas is freely available from the internet at http://cormas.cirad.fr).

The objective of developing a new version of the ABM was to integrate more detail into the model and to make it more realistic. Additional literature review and some new knowledge from field study (chapter 3 and 4) were used to improve the ABM. The process of ABM development can be divided into 3 parts:

I Development of razor clam biological module structured as an i-stage distribution model (Caswell and John, 1992)

II Implementation of virtual fishermen with special focus on the harvesting function

III Calibration

5.2.2 Scenarios tested

Once the ABM was successfully calibrated, it has been used to test razor clam management scenarios. The scenarios were identified from previous ComMod process (Worrapimphong et al., 2007). These 4 scenarios are:

I Baseline scenario (Baseline)

II Reserve zoning rotation for 3 months (Rsr)

III Individual quota (IQ)

IV Reserve zoning rotation together with individual quota (Rsr+IQ)

These four scenarios were tested with various numbers of fishermen to account for various harvesting pressures. Razor clam density and razor clam size were considered to determine the effects of each management scenario.

5.2.3 Upgrade of the spatial representation

From new findings on razor clam harvesting places (chapter 4.3.2.3), the representation of space in the ABM was reconsidered in order to integrate the harvesting places as mentioned by the fishermen. A discussion was held at Head of village office on 24th December 2009 to brainstorm a standard understanding of razor clam harvesting places.

Three fishermen from 3 families who gave interview to us and the ex-head of village participated in this activity (figure 5.1(A)). A whiteboard with makers and a simple map with first research's understanding from Google earth™ were employed to refine the razor clam harvesting places (5.1 (B)). After the workshop, a harvesting map was simply drawn and the researcher went back to the village again to verify the harvesting map with the villagers. Then, the ABM was developed again by integrating the razor clam harvesting places into the spatial setting of the model interface.

Figure 5.1 (A) Participants in small workshop to define razor clam harvesting places; (B) A whiteboard with makers and a simple Google map™: the tools used during this workshop.

5.2.4 Participatory simulation workshop

The participatory simulation workshop was organized at Chu-Chui village on 30 March 2010. Twelve participants participated in this simulation workshop. The participatory simulation workshop aims at 3 objectives as followed:

I To present the scientific findings to stakeholders

II To present and verify the new version of the ABM to stakeholders (social validation)

III To envision and to discuss options for the sustainable management of the razor clam resource, based on the outputs of the simulation model

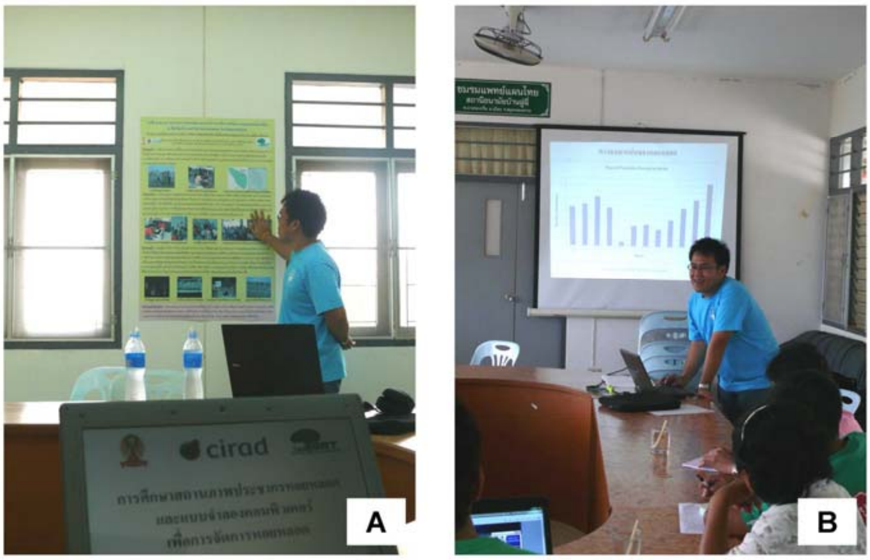


Figure 5.2 Two kinds of communication support used during the participatory simulation workshop: (A) a poster to restate the whole ComMod process, (B) a bar chart to present scientific findings

The workshop lasted half a day; first, the whole ComMod process was summarized by using a poster (figure 5.2(A)) and then the scientific findings about razor clam population dynamics and razor clam market mechanism since 2003 (figure 5.2(B)) were presented. In a second step, the ABM with the new definition of razor clam harvesting places was presented to stakeholders for them to express their opinion about the relevance of the representation provided by this new version of the ABM. Finally, a general discussion on sustainable razor clam management between stakeholders and researcher was conducted.

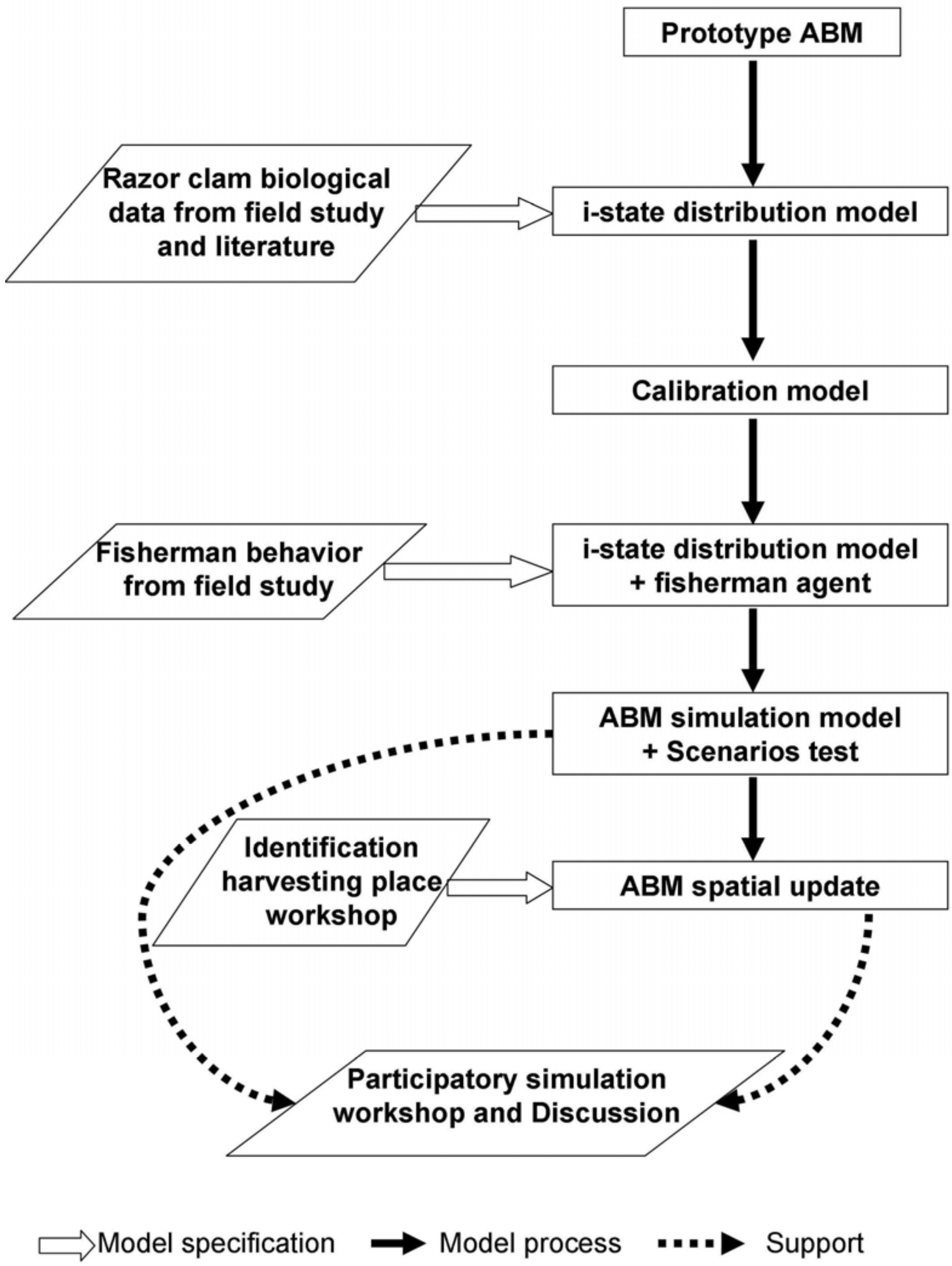


Figure 5.3 Overview of the methodology used to develop the Agent-based simulation model and to use it during a participatory simulation workshop

Figure 5.3 provides an overview of the methodology used to design the ABM, as described in this chapter.

5.3 Results and discussion

5.3.1 Agent-based simulation model

The model has been implemented by using the Cormas platform developed by the Green research unit from Cirad (Bousquet et al., 1998). The code of the model, written with the Smalltalk object-oriented programming language, is available and it can be imported into Cormas at http://cormas.cirad.fr/logiciel/DHL.zip.

5.3.1.1 A razor clam dynamics model

A population dynamics model was constructed by integrating razor clams population biology data from literature and field studies done from 1981 to 2009 (the monitoring was not continuous) and as part of the present study. Clams are represented in the model as a subpopulation divided into size classes with distribution ranges from 3 to 7 cm. The width of a size class was set to 1 mm. The population dynamics is driven by three biological functions: growth, natural mortality and reproduction. Only reproduction was set density-dependant by referring to the carrying capacity of the sand bar.

5.3.1.1.1 Growth and mortality rates

Constant (size-independent) rates have been defined for growth and mortality. The growth rate was set to 1 cm/month from the study by Ruffolo et al. (1999).The natural mortality was set as a daily probability to die equal to 2% for all size classes. This value was also suggested by Ruffolo et al. (1999), but the authors mentioned a higher level of uncertainty for this parameter than for the growth rate. Therefore, researcher decided to test the sensitivity of the model to 5 different values (0.01 to 0.05 incremented by 0.01) of the natural mortality rate (see chapter 5.3.1.4).

5.3.1.1.2 Carrying capacity

The carrying capacity of the sandbar is unknown as there is no data for unexploited razor clam populations in Thailand; furthermore the existing data on razor clams densities are extremely variable. The maximum observed density, of over 200 individual clams per m^2, was reported by Pradatsundarasar et al. (1989). A cluster analysis made from the data collected (clam density) in 2005 revealed that the suitability of the habitat is related to the sand grain size (Worrapimphong, 2005). In addition, laboratory analysis of soil type found 3 soil types and density of razor clam correlated significantly in each soil type (chapter 3.3.3.2). In the model, 3 categories of grain size were defined (namely fine, medium, coarse) and associated to a specific carrying capacity threshold (respectively set to x=30, 2*x=60 and 3*x=90 individuals/m^2). When the population exceeds this threshold, the recruitment is lowered. Different values for the carrying capacity parameter (x=30; 40; 50) were also included in the sensitivity analysis of the model.

5.3.1.1.3 Reproduction

Razor clams, as most shellfish, have complex life cycles with the process of physical transport of planktonic larval stages to appropriate recruitment habitats leading to unclear relationships between the number of recruited new clams (size between 3 and 4 cm) and the existing abundance of the reproducing clam population (size over 4 cm) (Freire and Garcia-Allut, 2000). The recruitment of small clams was represented in the model as a stochastic process related to the population of adult females and to the space left available by resident clams (defined as the difference between the local carrying capacity depending on the grain size and the actual local density). In addition, the literature as well as field results indicate that that some months are better than others for small razor clam recruitment. To account for this seasonal modulation, a seasonal pattern has been included in the model as a set of monthly coefficients: (1, 1, 1.5, 1.5, 1, 1, 1.5, 1.5, 1, 1, 1, 1). This implies that March and April, then July and August, are providing 50% more recruits than the other months of the year. This reproduces the pattern observed in our field data. Several values (25; 35; 45) giving the number of recruited clams produced by each adult female were also tested to calibrate the model.

5.3.1.2 Spatial setting

A spatial grid, consisting of 141 * 141 regular 1 m^2 cells, was defined (figure 5.4).The justification for choosing 1 m^2 as the elementary spatial unit of the ABM is related to the observations of the fishing activity: when a fisherman makes a stop on the sandbar to apply lime into what is seen as a razor clam’s hole, she/he will systematically also scan the immediate surroundings (approximately 1 m^2). The extent of the spatial grid (141*141) was chosen as it realistically represents the area which one fisherman can cover (between 100 and 200 m length) in one day (the chosen time-step). This is not related to the actual size of the dune. The topological properties of the spatial grid are defined by von-Neumann neighborhoods (each cell has neighbors in 4 cardinal directions) and closed boundaries. To be able to simulate scenarios referring to the 4 management units discussed during the RPG sessions from the previous ComMod process, four zones were also defined splitting the whole spatial grid into quarters. To account for spatial heterogeneity, each quarter was divided into 3 patches of grain size (figure 5.4, the darker the coarser).

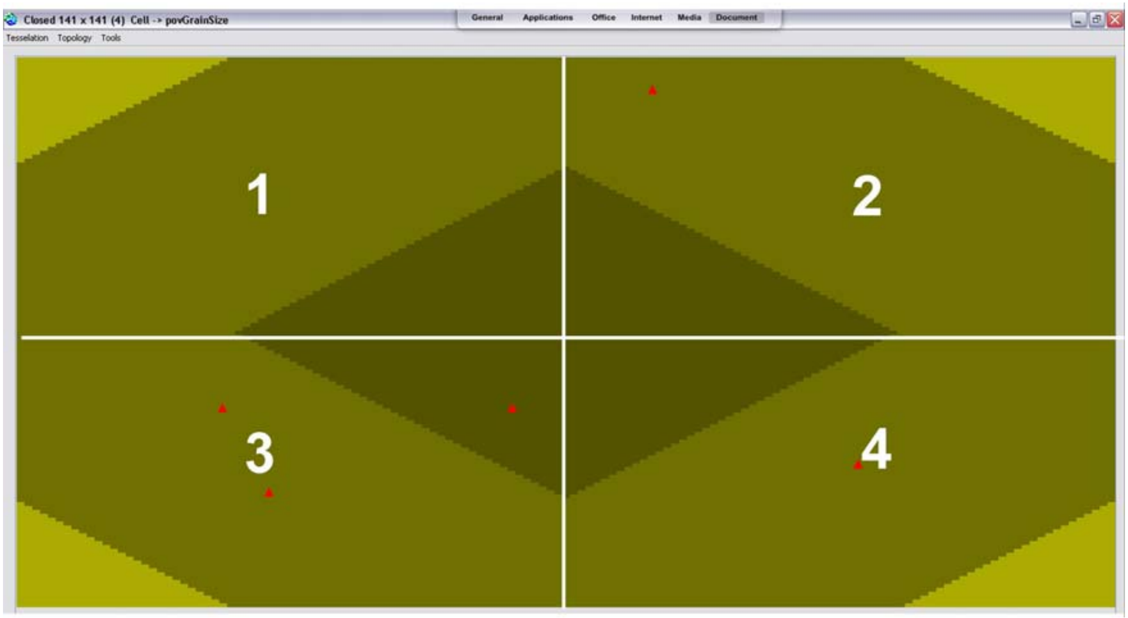


Figure 5.4 Spatial setting of the ABM. The types of grain size are indicated by different colors (the darker the better) and 4 management unit zones with virtual fisherman agents (red triangles)

5.3.1.3 Virtual fishermen

According to the principles of Agent-Based Modelling, virtual fishermen were designated as computer agents (figure 5.4). All behavioral characteristics (number of cells harvested, harvest rate) have been derived from the interviews and direct observations of local fishermen. In addition, specific investigations were undertaken, such as systematic digging of 1 m^2 areas of the sandbar after a fisherman had finished harvesting that specific location, thus evaluating the proportion of clams harvested (Worrapimphong, 2005 and current study). The daily step of a fisherman agent is specified as follows: first the decision to harvest clams is made with a probability of 2/3.

The number of cells visited by a fisherman agent in one day is set between 100 and 200, the actual number being randomly determined (uniform distribution) for each fisherman, for each day. For each visited cell, the proportion of clams (size > 4 cm) harvested is then randomly (uniform distribution) set between 0.3 and 1. Finally, a fisherman agent is able to detect the neighboring cell with the highest razor clams density, and moves from one harvested cell to the next one.

5.3.1.4 Calibration and validation of the model

Because of the above mentioned high level of uncertainty for three major parameters (natural mortality rate, carrying capacity and number of recruits per female), A sensitivity analysis was conducted to identify which combination of parameters lead to a simulated population dynamics that could be considered as realistic. This realism was assessed according to three criteria proposed by Pradatsundarasar et al. (1989), namely (i) the maximum density of clams should remain lower than 200 individuals /m^2; (ii) the density of clams should not reach values close to zero; (iii) two peaks of higher density should be visible in each year, to represent the two breeding seasons. Out of the 45 combinations of the three parameters that were tested by running the model, one set of values which was found to provide the best fit for the three criteria was selected (mortality rate = 0.01; carrying capacity = 30 and number of recruits = 25). With these parameters, the mean density of the simulated razor clam population is around 120 individuals / m^2.

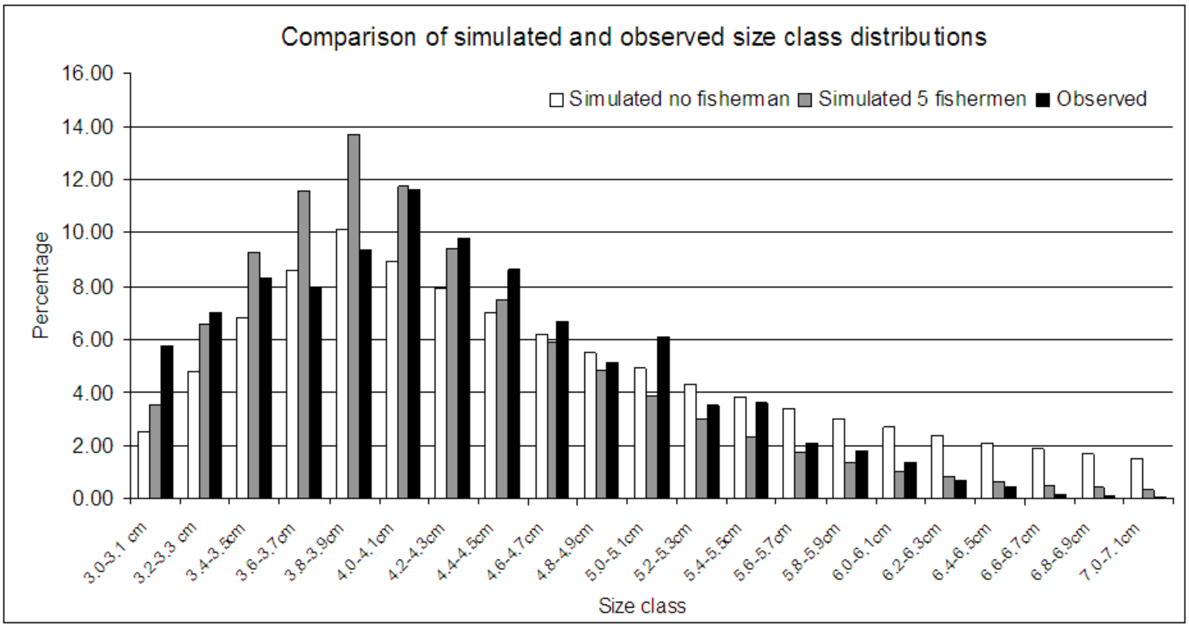


Figure 5.5 Comparison of simulated and observed (Worrapimphong, 2005) razor clams size class distribution

Additionally, to check the size structure of the simulated razor clams population, the distribution of size classes obtained after ten years of simulation without fishermen and with five fishermen was plotted and compared to the distribution observed in Don Hoi Lord (Worrapimphong, 2005). With fisherman agents added to the biological model, the simulated distribution (gray-colored bars in figure 5.5) is accounting for harvesting effects: the abundance of big size classes is less, thus being closer to the real data. The shape of the three distributions is similar (figure 5.5). The similarity of distributions was tested with a Kolmogorov-Smirnov test, the differences being non-significant (p= 0.463, 0.358, 0,194). However, it is difficult to further compare the two distributions as the real population of clams was harvested over many years and therefore its distribution is distorted by the effects of this long term harvesting.

However, field data collection in this study showed that razor clam population structure had a big size of razor clam in high percentage (chapter 3.3.1.3) when fisherman did not go to harvest. The results of the simulation run without fishermen in figure 5.5 are consistent regarding this positive impact on the frequency of big clams.

5.3.2 Exploration of scenarios by running simulation

Firstly, a baseline scenario was run in ABM to represent the current situation of razor clam harvesting. Then, the scenarios identified by the participants to previous ComMod workshops were implemented, run and analyzed. Two scenarios allowed comparing the effects of individual quotas (*IQ*) versus the effects of a reserve (*Rsr*) with a short-term rotational rule. In addition, a scenario combining both aspects (reserve and individual quotas) was implemented. Qualitatively, the IQ scenario produces better results for both indicators (density and mean size of razor clam), however as the number of fishermen increases, the effects of quotas progressively vanishes (fishermen harvest less than the quota), but the reserve scenario still has a small effect.

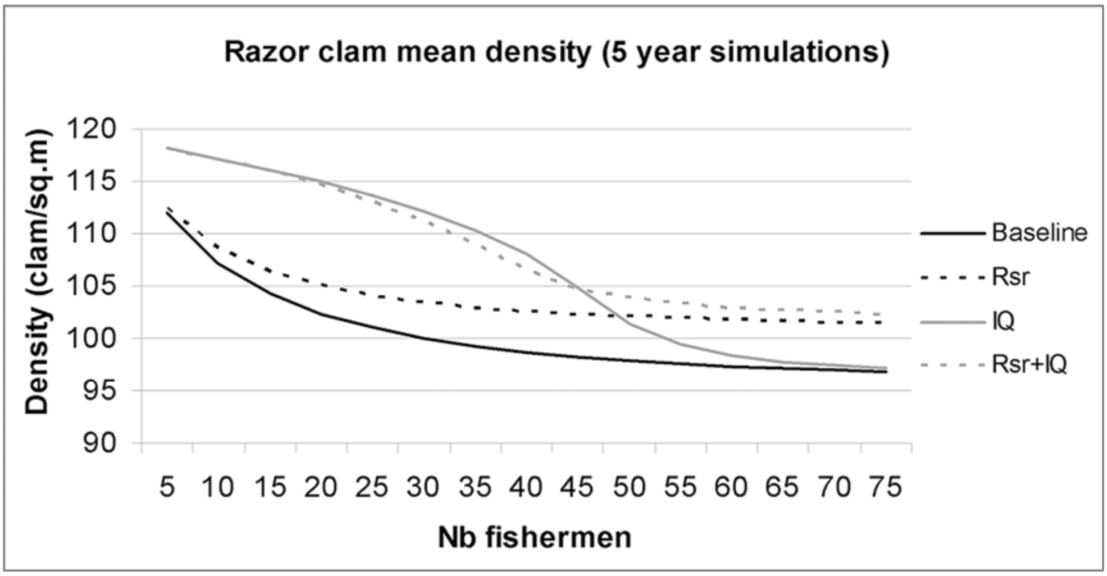


Figure 5.6 Results from the ABM simulation. Razor clam mean density (clam/m^2) for 4 scenarios: reserve short rotation (Rsr), individual quota (IQ) and reserve short rotation plus individual quota (Rsr + IQ) over 5 years

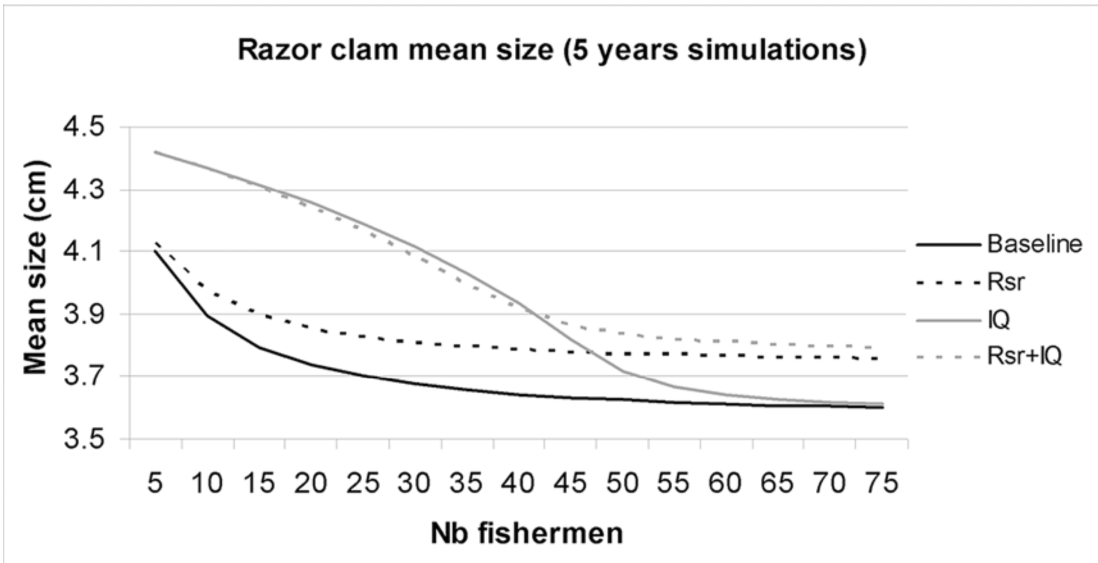


Figure 5.7 Results from the ABM simulation. Razor clams mean size (cm) for 4 scenarios: reserve short rotation (Rsr), individual quota (IQ) and reserve short rotation plus individual quota (Rsr+IQ) over 5 years

Razor clam mean density and mean size from the simulation run with 4 scenarios at 15 levels of harvesting pressure (introducing 5 more fisherman agents from 5 up to 75) were considered to assess the benefit of each scenario; both mean density and mean size responded to the different scenarios with the same general pattern of the population being impacted by fishing (Figures 5.6 and 5.7). IQ scenario seems to be the best scenario for the population when the number of fisherman is not so high. However, as this number increases, IQ scenario reaches the level of the Baseline scenario.

Simulations run with a high harvesting pressure (above 40 fisherman agents) show that Rsr+IQ scenario is the best scenario regarding the impacts on the razor clam population. Not surprisingly, the effect of a reserve is insignificant when the number of fisherman agents is low: Rsr+IQ scenario is very similar to IQ scenario on the left side of figure 5.7.

5.3.3. From simulation experiments back to the real socio-ecosystem: implications for further studies and management

In Don Hoi Lord, more and more fishermen both male and female harvest razor clams, but on a temporary basis: when this activity is becoming less profitable (due to lower market price for razor clam or fewer clams on the sandbar), they can switch their target species to another aquatic animal such as tiger moon shell, blood cockle, shrimp etc.; and they usually switch back to harvest razor clam as soon as they can earn more money from razor clam than from other aquatic animals. In the reality, the trend of increasing the intensity of harvesting is less continuous and systematic than the one used to design the simulation experiments presented in the previous subsection.

Regarding reserved area for clam management, it was suggested from surveys conducted in another clams fishery in Arcachon Bay (France) that a large reserved area could protect a larger clam population, the reserve being identified as a seed stock for the future (Bald, Sinquin, Borja et al., 2009).

As it came out of the previous ComMod process, the individual quota option was well accepted by every participant except the clam trader (Worrapimphong, 2005). In theory, a direct effort regulation by creating reserves represents a suitable regulatory tool for species with limited mobility or which aggregate in predictable locations at certain times in their life (Lauck, Clark, Mangel et al., 1998). However, the decision making related to the location, size and time period for the reserve areas is a scientific problem that requires accurate and specific knowledge about the species' biology. The challenge is to ensure that the reserve area will be a metapopulation source (rather than a sink) of larvae (Perry, Walters and Boutillier, 1999).

Our field study between 2008 and 2009 showed a dramatic decrease of clam population (chapter 3.3.1). Given the fact that the fishing effort increased slightly and progressively during that period, this collapse may be due to an ecological event or due to the fact that fishermen started to harvest lower size clams. In the model, the recruitment function represents a sensitive point regarding the ability to observe abrupt and drastic changes in population abundance (Bald et al., 2009). The recruitment process in the model is maybe too productive, making the simulated population more resilient than it should be. Due to lack of knowledge about the razor clam recruitment in Don Hoi Lord, the recruitment of small clams was represented in the model as a stochastic process depending on the number of females and related to the space left available by resident clams (defined as the difference between the local carrying capacity related to the grain size and the actual local density).

It is now widely recognized that the recruitment of benthic invertebrates like razor clams relies on a combination of density-dependent (biological) and density independent (physical and chemical) factors that all have the potential to influence the settlement of larvae (André and Rosenberg, 1991;André, Jonsson and Lindegarth, 1993;Whitlatch and Osman, 1998). Such a complexity gives rise to the observed spatio-temporal patterns which are characterized by high variability (Raffaelli, Bell, Weithoff et al., 2003). Benthic organisms display patchiness at a range of scales, from millimeters to kilometers and from seconds to years (Hall, Raffaelli and Thrush, 1994). The interconnection between the local populations of post-larval stages along the coast mainly exists through the planktonic larval stage. This aspect determines a decoupling between the local stocks of adults and the subsequent recruitment in the same local population. In some cases there is even evidence of source-sink dynamics in which only some of the local adult populations contribute reproductively to the next generation (Freire and Garcia-Allut, 2000). In the case of Don Hoi Lord, deeper investigations at both smaller and larger scales may provide key information to better understand how the recruitment is operating.

5.3.4 Spatial upgrade in agent-based simulation model

The representation of space in the first version of the ABM was purely abstract, while during role-playing game sessions, it was more realistic as it was related to the portion of the sandbar where the field work has been achieved. Nevertheless, researchers and fishermen had different points of view on razor clam harvesting places (chapter 4.3.2.3). To build a shared representation, three hours discussion between the research team and some fishermen helped to identify a set of harvesting places, with agreement on their name, shape and extent. As a result, they were drawn on a simple Google map™ (figure 5.8 (B)).

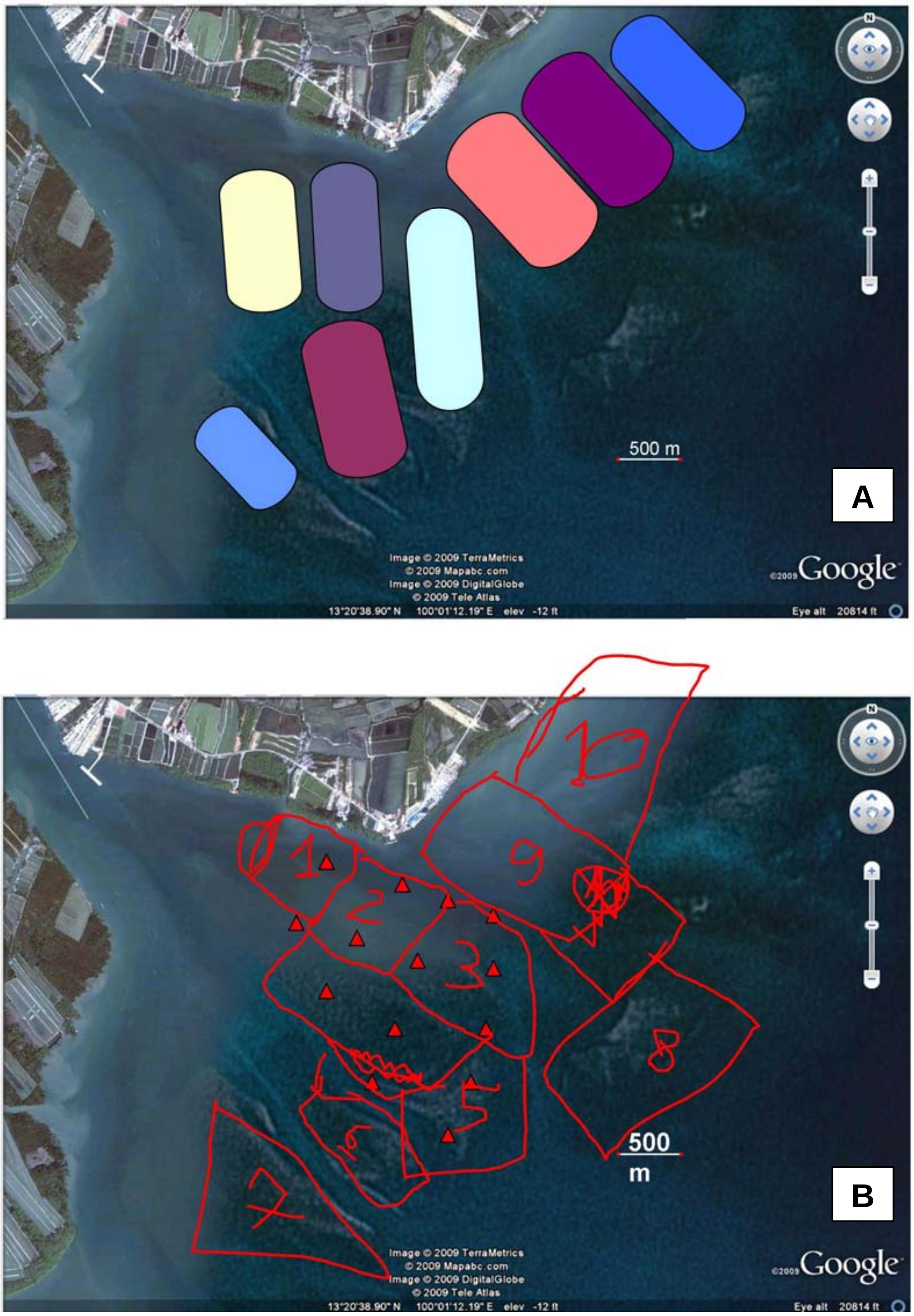


Figure 5.8 (A) Researcher initial point of view on the main razor clam harvesting places before the workshop; (B) Collaboratively designed map of main harvesting places, with ID and estimated boundary, after discussion with fishermen (small red triangle: station for field data collection)

The objectives of this discussion were to validate researcher understanding on harvesting places (figure 5.8(A)) and to name each harvest place. During the discussion, each participant (including researcher) expressed her/his point of view, with a special focus on harvesting places. Firstly, the researcher presented to all fishermen a map drawn from his own understanding. Participating fishermen then criticized it by claiming that in reality, there are more than just 8 harvesting places. In All fishermen and ex-head of village discussed together to agree on each razor clam harvesting place. Sometimes they asked the researcher for clarifications about the map. The final map was collectively drawn.

Figure 5.8 (B) shows the result obtained after 3 hours of discussion. Ten harvesting places were indentified with for each of them a name and an estimated area. Table 5.1 showed the place ID and names as given by the fishermen . All these 10 harvesting places are the places where fishermen usually go harvesting. However, one harvesting place that they mentioned was not included here because it remained unvisited for a long time and furthermore this place belongs to another administrative area.

Table 5.1 Razor clam harvesting places from discussion with fishermen

Place ID	Name (Thai name)
1	Khun Lin, Rung Rong Rean
2	Nar Sarn, Klang Don
3	Phoe, Yor Ta Vean
4	Don Klang
5	Krasar
6	Khode Kham Num
7	Sam Kha
8	Don Nork
9	Lam, Don Kwang, Don Tea
10	Sume

Some harvesting places in table 5.1 have several names (1,2,3,9). It is because those harvesting places consist of small areas connected to each other and the fishermen usually visit all of them when he/she harvest on those places. From figure 5.8 (B) and table 5.1, the map of razor clam harvesting places was finalized (figure 5.9) and the researcher went back to the village again to validate it with fishermen.

Figure 5.9 Validated map of razor clam harvesting places from discussion with fishermen

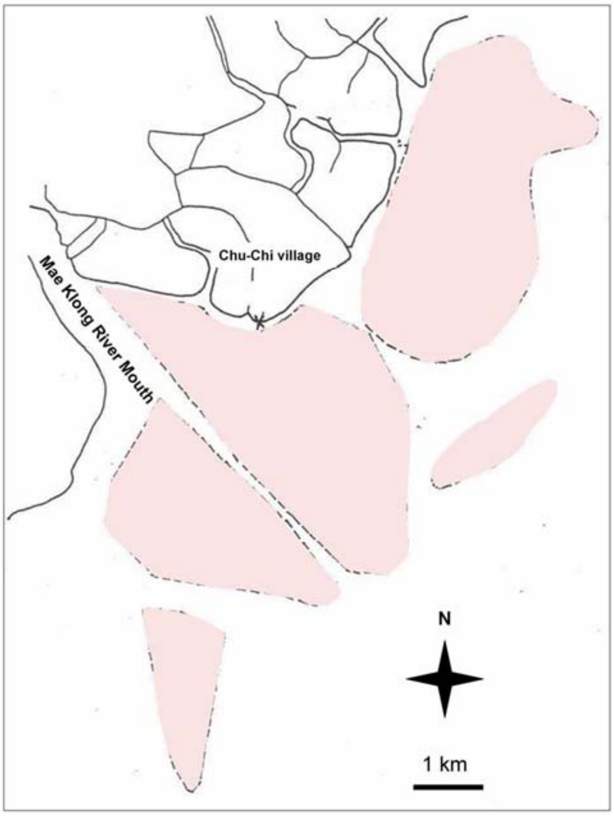


Figure 5.10 Map of Don Hoi Lord sandbars in 1995

(source: Department of fishery 1995 and Suwanna 2003)

In 1995, the Department of Fishery stated that that Don Hoi Lord was made of 5 sandbars. Neither the name nor the area was defined for each of them (figure 5.10). The matching between this map and the new one that was collectively produced with the fishermen appears clearly: The merging of harvesting places ID 1-5 correspond to a first sandbar, each ID from 6-8 represents 1 three sandbars, and the merging of harvesting places ID 9-10 corresponds to a fifth sandbar. The 10 identified harvesting places can be considered as management units easily understandable to any fisherman. Therefore the new map collectively produced could be useful if a management policy was to be implemented in the near future.

After fishermen validated the map of harvesting places, this document was used to upgrade the spatial interface of the ABM. The objective of this upgrade was to introduce some realism into the ABM, to make it less abstract so it would become more suitable to be used as the communication platform in razor clam management discussion at Don Hoi Lord.

The ABM as described in section 5.3.1 was upgraded by importing the map of harvesting places into the spatial grid of the Cormas simulation tool. To keep the model simple, the grain size parameter that existed in the previous version was discarded by assigning the medium value (2) everywhere. During the discussion, fishermen mentioned that they could not perceive any difference among harvesting places in terms of sand texture. To them, the grain size is different near the edge of the sandbars, and it can be related to the razor clam density, but they usually did not take into account because it is a natural phenomenon that can be observed in a similar way in all harvesting places.

Apart from this change in the definition of the environment, the new version of the ABM did not change compared to the previous one. The biological module described in chapter 5.3.1 is still used, with the same parameter values.

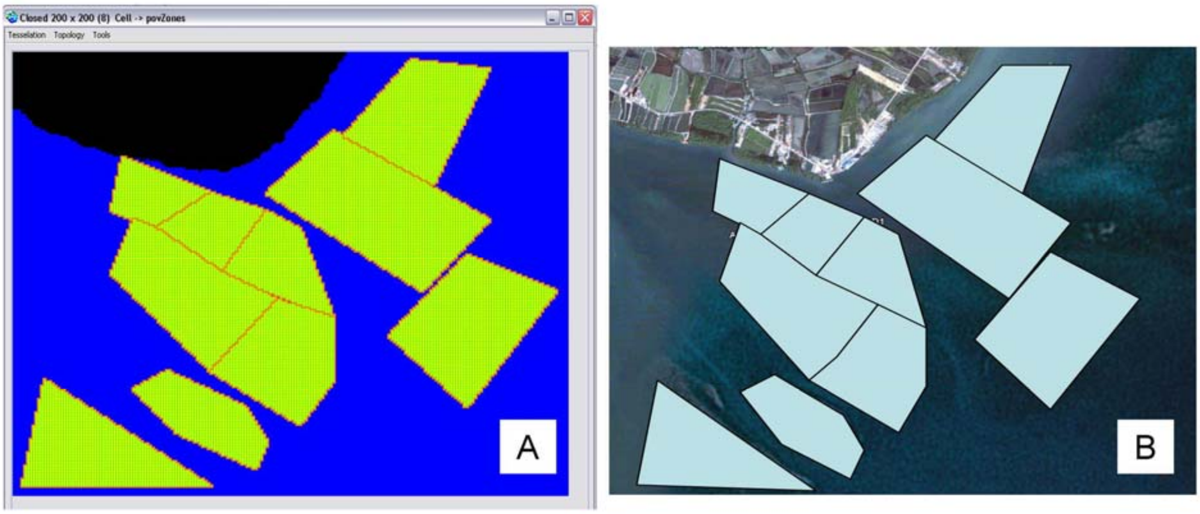


Figure 5.11 Comparison of the new spatial grid of the ABM (A) and the validated map of harvesting places (B)

Figure 5.11 shows the spatial interface of the ABM after initialization by importing the map of harvesting places. The new map of razor clam harvesting places is is clearly related to the map previously produced by the Department of fishery (figure 5.10) (Department of Fishery sited in: Suwanna, 2003).

To deal with the modification in the ABM of the spatial setting, the harvesting function of fisherman agents had also to be modified in the ABM. However, to validate how a virtual fisherman is implemented in the ABM, elicitation of the criteria used by real fishermen to make decisions in the reality is essential in order to compare the harvesting behavior of the virtual fisherman with actual harvesting behaviors on the sandbars. Therefore, a new participatory simulation workshop was organized to provide an arena for further discussion on that topic with the local stakeholders.

5.3.5 Participatory simulation workshop

5.3.5.1 Participants in the participatory simulation workshop

Twelve participants with various occupations attended the workshop, with some of them having a role in social services. Table 5.2 shows the details of each participant.

Table 5.2 Details of each participant in the participatory simulation workshop

No.	Occupation	Role in social service
1	Employer	Chief of sub-district, RZ group*
2	Fisherman	RZ group, Local facilitator, Ex-head of village
3	Employer	RZ group
4	Merchant	RZ group, Village volunteer
5	Fisherman, Employer	RZ group
6	Fisherman, Employer	RZ group
7	Fisherman	
8	NGO	RZ group
9	Media	
10	Media	
11	Fisherman, Trader	RZ group
12	Fisherman	

* RZ group: Razor clam Conservation Group

6 out of 12 participants were fisherman with supplementary occupation for 3 of them; and the other occupations consisted of employee merchant, NGO, and media. Regarding the roles in social services, the chief of sub-district, who is an administrative person, participated in this workshop.

One interesting point in this workshop was that most of the participants were involved in the razor clam Conservation Group. This group is the fruit of the ComMod process implemented at Don Hoi Lord. Following the last step of this collaborative process in 2005, possible razor clam management scenarios were identified as described in chapter 5.2.2. Later on, the research team and the local facilitator had a chance to present the results to Samut Songkharm governor in 2006. The governor expressed his interest and committed to take care of the razor clam resource. Unfortunately, he was moved out from the province due to turnover in the administrative system, with no follow-up by his successor, so this high-level support could not be maintained (Worrapimphong, Gajaseni, Le Page et al., 2010). Activities started again to reactivate the ComMod process at Don Hoi Lord in 2008. During monthly field data collections performed in 2008-2009, the researcher and the local facilitator regularly exchanged razor clam knowledge while working on the sandbar.

The results from our new stage of field study showed a drastic collapse of the razor clam population (chapter 3.3.1), leading a lot of villagers to stop harvesting razor clam ant to switch to some other activities. Scientific information on razor clam population and socio-economic aspects of razor clam harvesting were distributed by the local facilitator to government agencies such as the Fishery office of Samut Songkhram province and the Department of Marine and Coastal Resources (DMCR). These two governmental agencies also called the researcher by phone during the ongoing field study and discussed about the decrease of razor clam population.

Figure 5.12 During the meetings organized by DMCR, the researcher was invited to participate

To tackle the issue of razor clam population collapse, the researcher was invited to meetings like the one organized by DMCR (figure 5.12) to disseminate the scientific information produced during the implementation of the ComMod process on razor clam management. With the ability and the financial resource of DMCR and the help from researcher and NGO, the Razor clam Conservation Group at Don Hoi Lord was instituted on 28th June 2009. It comprised 28 members, some of them being fulltime fishermen and the others having various occupations. Among theses 28 members, some of them were involved from the beginning in the ComMod process. Moreover, the local facilitator, also someone playing a key role in the ComMod process, was selected by the members to head the group. The Aim of this group is to preserve razor clam population at Don Hoi Lord in a sustainable way.

5.3.5.2 Structure of the participatory simulation workshop

The first activity conducted during the workshop was a presentation of the ComMod process at Don Hoi Lord. The razor clam management scenarios which came out along the ComMod process were presented in a poster that was specially produced to provide feedbacks to the participants and refresh their memories. Then, key scientific findings related to the biology and ecology of razor clams and socio-economic aspects of razor clam harvesting (chapter 3 and 4) were presented. A special focus on the spatial characteristics of harvesting places resulted in the production of a new map, as described in the previous subsection (Annex G shows details of the presentations).

After the discussion on specific topics was completed, a short general discussion on the possible reasons to explain the collapse on the decreasing of razor clam population was conducted. One fisherman said that it was the first time in her life she had to stop harvesting razor clam for several months. In addition, all fishermen agree on the results of our field study showing how dramatically the razor clam decreased while at the same time horse mussel had invaded the sandbar. However, some fishermen mentioned that horse mussel started to dissolve from the sandbar in some area. They suggested that it was due to the impact of fishermen from another area who came with special gears to harvest. Nevertheless, most of the area occupied by horse mussel as reported by our field work (chapter 3.3.1) is still in such a condition by now.

5.3.5.3 ABM presentation and validation with fishermen

The ABM with its revised representation of space was presented to the participants to assess whether they would accept it as a fair representation of their socio-ecosystem or not.. Fishermen who participated in discussion leading to the production of a new map of harvesting places (chapter 5.3.3) did not participate in the workshop, with the notable exception of the former head of village. The name of each harvesting place was told to new comers and the researcher checked the consistency of each name by asking all participants if they were familiar with the names and if the location and extent of each harvesting place was coherent with their own understanding and representation.

Names and locations of the 10 harvesting places were accepted by all participating fishermen. They could follow and understand the new map easily.

The ABM was then introduced, by first showing the spatial grid from the Cormas software being initialized with the map previously validated. Five virtual fishermen were also created and represented on the spatial grid as red triangles located on a given harvesting place. A simulation was then run in front of the participants (Figure 5.13). The researcher asked fishermen to watch the movement of the virtual fisherman agents on the screen of the computer and to comment on the degree of realism of the observed daily (the time step of the model is one day) movements, as compared to how real fishermen move on the sandbar while looking for razor clams during one day.

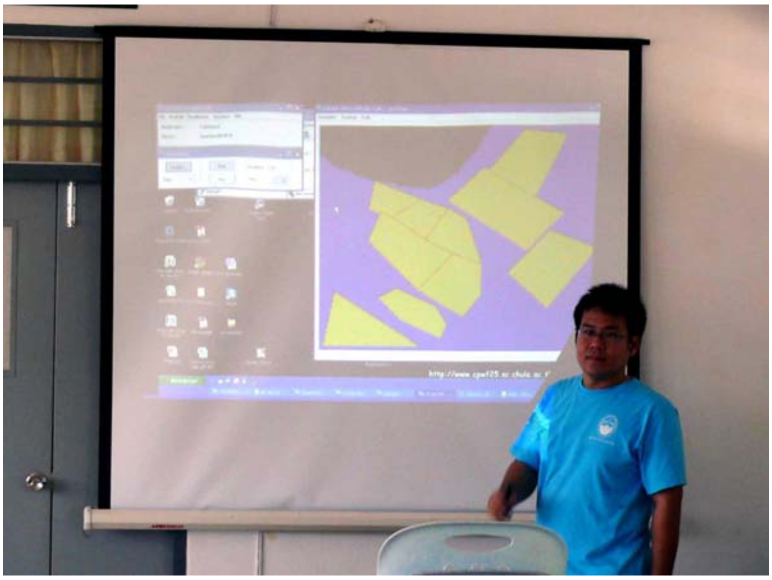


Figure 5.13 Presentation of the ABM with new harvesting places

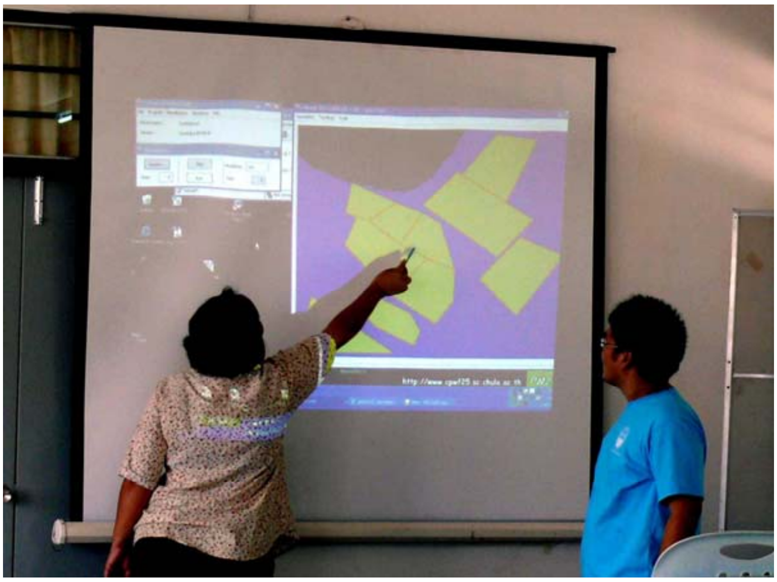


Figure 5.14 A participating fisherman pointing a harvesting place on the ABM interface

The participating fishermen accepted the movements of virtual fisherman agents as exhibited by the AMB. They considered the movements of the virtual fisherman agents with what they are used to do in reality. They said that in one day, they can move from one harvesting place to a connected harvesting place or they can also stay in the same harvesting place. According to them, it depends on the density of razor clam. They usually move to a connected place if the density is low, whereas they keep on harvesting in the same place as long as the density is high. Moreover, to verify fishermen understanding on the new spatial configuration on ABM, we asked them to point harvesting places on the ABM spatial representation and they were able to do it correctly (figure 5.14).

Fishermen were identified as of the key stakeholders in razor clam harvesting at Don Hoi Lord. To check that their expertise was correctly taken into account in designing the AB was therefore crucial for the ABM to be useful to tackle the issue of razor clam management. The ComMod approach promotes the concept of social validation by engaging stakeholder in the modelling and validation process (Moss, 2008). Several cases in ComMod describe how stakeholders are involved in validating the simulation model, for example the cases of sugar cane plantation in Northeastern Thailand (Suphanchaimart et al., 2005), irrigation management in central Bhutan (Gurung et al., 2006), land management in tribe village in Northern Thailand (Barnaud, Promburom, Bousquet et al., 2006), and labor migration in Northeastern Thailand (Naivinit, Le Page, Trébuil et al., 2010). Such a way to validate the model (by asking knowledgeable individuals if they praise the model as a fair representation of the real system) was defined as one validation technique, namely “facing validity”, by Sargent (2005).

5.3.5.4 Discussion on razor clam management

The last step of ABM presentation and validation was to conduct the discussion on razor clam management by using the ABM as a mediator. In this section, firstly, we assess the usefulness of the ABM for discussing razor clam management and then we report the experience from the Razor Clam Conservation Group (the RZ group), who is now effectively working on razor clam management at Don Hoi Lord.

How to use the ABM in razor clam management? The question was straightforwardly asked during the workshop to bring all participants brainstorming. A short discussion among themselves lead to a general agreement: the ABM should in priority be used in to educate the new generation of fishermen at Don Hoi Lord and/or other people from other areas, including tourists. The main purpose they mentioned was to induce a sense of conservation. This identification by the local stakeholders is not surprising: Epstein (2008) defined using the model for educating general public as one out of 16 reasons other than prediction for model building.

The priority for the ABM usage suggested by the participants is related to the experience of the RZ group. The group has been worked with real fishermen since it was created. They picked one razor clam management scenario from the ComMod process (reserve zoning) to test its implementation on the sandbar. However, proving their understanding of the Don Hoi Lord fishery system, they acknowledged that there are many activities on the same sandbar. Would they only focus on razor clam to introduce some change in Don Hoi Lord, other activities could be affected and fishermen harvesting on other species would not accept them. In addition, they also perceived the situation of resources harvesting at Don Hoi Lord as an example of the “Tragedy of the Common” (Hardin, 1968). Additionally, if the ABM was just presented to other fishermen, they would probably just look at it but not change their perception of the real system. Only fishermen who participated in the ComMod process would be able to make the linkage. Therefore, they found out that building a good sense in resource management has be the priority in order to secure the future of razor clam population at Don Hoi Lord. Moreover, the group explained to us that the ABM could help the kid and/or other people understand the sandbar and the fisherman harvesting, providing them a global perspective of the system. To them, the ABM represents a better way than a report on paper to disseminate to other regions razor clam harvesting knowledge.

Three fishermen and the local facilitator who attended this workshop also participated in the ComMod process from the beginning in 2005. They now belong to the RZ group and they dedicate part of their time and money to concretely tackle the issue of razor clam management, by for instance going to other villages to communicate with other fishermen. However, they still use the same method than other fishermen (lime power mixing with caustic soda) to harvest the clams. They told us that by not using this technique, they would harvest less than others and consequently they would earn less than others because the selling price of razor clam price is the same for clams caught pure lime or lime mixing caustic soda.

The RZ group tried to use the experience from the ComMod process that some of them had accumulated to set up an action plan aiming at mitigating the decrease of razor clam population. During the last stage of the workshop, the group presented their experience on razor clam management (figure 5.15).

After the group was instituted in June 2009, they decided to implement a regulation for razor clam management. Several informal meetings among members were held during 3 months. Then in August 2009, the group made the decision to create a reserved area on the sandbar and the facilitator called the research team by phone, requesting some support(GPS technical help) to decide for the location of the reserve (Figure 5.16 (A)). The total area of this reserved area was around 12 ha. Then, in late September 2009, the group started to install the reserved area by using bamboo poles with flags (Figure 5.17 (B))

Figure 5.15 One member of Razor Clam Conservation Group showing their work to the research team

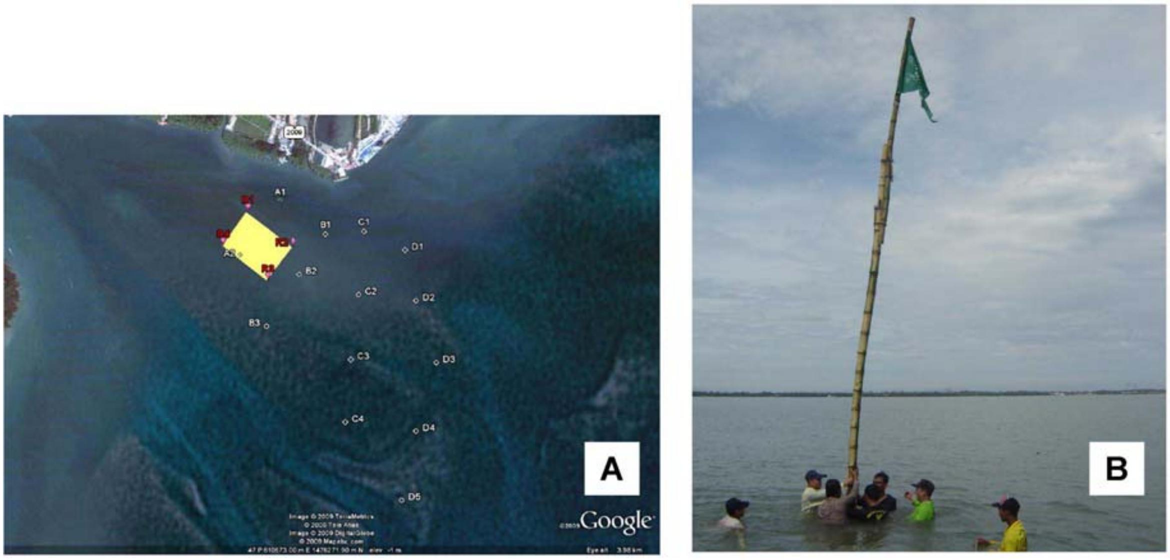


Figure 5.16 (A) Reserve area (yellow) and stations used during field data collection, (B) Installing of reserved area by using bamboo poles and flags on the sandbar

Unfortunately, the installation of the reserved area was interrupted by fishermen from Laem Yai village, a village located opposite Mae Klong river mouth of Chu Chu village. Around 10 people from Laem Yai village aboard a boat came to besiege the group installing the reserve and asked for the reasons behind the creation of a reserved area (figure 5.17(A)). These fishermen harvest on ridged venus clam, a species that lives in the same habitat than razor clam. The RZ group tried to explain to them for a while but fishermen from Laem Yai village were still reluctant to accept the idea of creating a reserved area. Hence, the reserved area installation was paused and the RZ group invited the fishermen from Laem Yai village (figure 5.17 (B)) to negotiate with them on the land at Chu Chi village health center (figure 5.17 (C, D)).

Figure 5.17 (A) Confrontation between fishermen from Laem Yai village (red circle) and the RZ group, (B) Fishermen from Laem Yai village at Chu Chi health center, (C and D) Negotiation between RZ group and fishermen from Laem Yai village on the creation of a reserved area on the sandbar at Don Hoi Lord

(Source of figures: the RZ group)

The results of these negotiations with fishermen from Laem Yai village lead the RZ group to move the reserved area far from its initial location and to reduce its size. of They made an appointment 2 weeks later to create the reserved area together. In addition, both groups also invited fishermen from Bang Keaw sub-district (connected to Bang Ja Kreng, the sub-district of Chu Chi village) to be involved in the creation of the reserved zone At least one fisherman from Bang Keaw sub-district also comes and harvests razor clam and other aquatic animals at Don Hoi Lord. However, there were only fishermen from Laem Yai village who came and participated in the creation of the reserved area. Fishermen from Bang Keaw sub-district communicated that they may accept the reserved area because it was to be created in Chu Chi village area. Figure

5.18 showed the reserved zone finally installed at Don Hoi Lord. The area of the reserved zone is around 3.5 hectares. This reserved area was co-created by the RZ group and fishermen from Laem Yai village, after they were nearly fighting each others 2 weeks before.

Figure 5.18 Completed reserved area on the sandbar at Don Hoi Lord after negotiation between The RZ group and fishermen from Laem Yai village

Even if the accepted reserved area was smaller than the one decided in their initial plan, the RZ group was satisfied to have reached an agreement. Despite the relative small size of the reserve area, it was the first time at Don Hoi Lord that a reserved area was established and implemented. Actually a reserved area at Don Hoi Lord was declared since July 1998 by the governor (Suwanna, 2003), but it was only a declaration: nobody took it into account and there was no local or provincial governmental agency working on it.

In addition, to monitor and evaluate the effects of the reserved area, the RZ group conducted a field study aiming at assessing the razor clam population inside the reserved area. They used the same methodology as researcher used for the field data collection described in chapter 3. The method of quadrat sampling was used by the group (figure 5.19). They started to monitor the razor clam population 1 month after the reserved zone was created. Seven random quadrat samplings covering the reserved zone were performed monthly from October 2009 to January 2010. The mean density of razor clam inside the reserved area was found around 5 clams/m^2 (Muakcum : **interview**, 30 March 2010). Comparing with the field data collection from our study during 2008 – 2009, the reserved area had higher density. It may be a benefit of the reserved area that protects and provides secure habitat for razor clam.

Figure 5.19 Quadrat sampling to explore razor clam density inside the reserved area, performed by the RZ group

(Source of figures: the RZ group)

The RZ group had a plan to move the reserved area to another area in the next 3-5 months and reopen the current one. In addition, the group expressed their willingness to set up another reserved area, with the same size or a bit bigger than the current one, in any area of Don Hoi Lord. They explained that the process and results from the experience with the current reserve area showed to other fishermen that the group operated for the sake of the whole community and did not just take personal interest from the reserved area. They are eager to build trust between their group and other fishermen who initially did not accept the reserved area. Beside, the RZ group suggested disseminating the knowledge produced during the ComMod process and particularly the scientific findings. To provide them the material to reach this objective, the poster used in the workshop was given to the group.

Presently (March 2010), around 20-30 fishermen harvest razor clam on the sandbar. There is some evidence that the razor clam population starts recovering. Yet, researchers and stakeholders agreed by the end of the workshop that cooperation among researchers, fishermen and the RZ group was not enough to secure an effective management. To decide for new regulation will remain inefficient as long as there is no enforcement: most fishermen will not respect the regulation. Nowadays, there is a campaign to convince fishermen to stop using caustic soda mixed in lime powder. Actually, caustic soda is forbidden by law but in reality, fishermen never considered to stop using it. This is clearly related to the lack of the law enforcement, with police or fishery officers not paying any attention on the harvesting of clams. On the other hand, he RZ group has no legitimacy and no practical means to tackle by itself the problem of law enforcement. Some fishermen seemed to be ready to stop using it if the law enforcement was functional because they used to stop using it at the beginning of the last campaign whereas other fishermen continued using caustic soda. Consequently, the fishermen who followed the regulation earned less than the fishermen who broke the rule and continued to use caustic soda.

The socio-ecosystem of Razor clam harvesting at Don Hoi Lord can be classified as a small-scale fishery as described by FAO (2007) in the sense that it make an important contribution to nutrition, food security, sustainable livelihoods and poverty alleviation. The first operation of managing the razor clam at Don Hoi lord was the establishment of a reserved area in one of the existing harvesting places. This method is commonly part of small-scale fisheries management plan in many part of the world such as Australia, South America, Africa (McClanahan, Castilla, White et al., 2009). The success of setting up a reserved area at Don Hoi Lord can be related to some extent to the ComMod process that was implemented at Don Hoi Lord. ComMod helped various stakeholders to collectively discuss and define scenarios since 2005 (Worrapimphong et al., 2010). The final participatory simulation workshop provided an arena for discussing several topics, the ABM being used as an intermediary object to foster and enforce collaboration between stakeholders and researchers. Such a participatory meeting where opinions from various stakeholders are shared allowed clarifying and integrating the various needs of resource users, paving the way to ecosystem sustainability (McClanahan et al., 2009).

The whole process of ComMod at Don Hoi Lord was structured by a succession of participatory workshops. During the first stage, the workshops were mainly based on role-playing games, whereas by the end, the main tool was an agent-based model. Along the process, an institution (the RZ group) emerged with the objective to define an action plan to start managing operationally the razor clam resource. The RZ group was inspired by the scenarios discussed during the ComMod process. The group was proactive in initiating negotiation with other stakeholders having different points of view on the razor clam management. The whole process enabled social learning and the ABM serves as a tool of communication in this process of social learning (Hare et al., 2003;Pahl-Wostl and Hare, 2004).

5.4 Conclusion

5.4.1 Agent-based simulation model and scenarios runs

The ABM described in this chapter was developed from the prototype that was developed in 2005 (Worrapimphong, 2005). The razor clam population dynamics model , a kind of Individual state (i-state) distribution model (Caswell and John, 1992), was connected to a module representing harvesting by virtual fisherman agents. A first update in the ABM was a re-calibration with actual size distribution from a new field data collection. With this improved version, simulation runs with a wide range of number of fisherman agents number were carried out to investigate the effects of an increasing harvesting pressure on the various management scenarios that were identified during the first stage of the ComMod process. The results showed that a combination of individual quotas and a reserve with short-term rotation was the best scenario for razor clam population, individual quotas alone having a strong positive impact on razor clam population only when the harvesting pressure is low. A last improvement of the ABM consisted in providing a realistic representation of Don Hoi Lord sandbar by replacing the abstract representation used in the first version of the ABM by a map of the actual razor clam harvesting places that was co-designed with the fishermen. The local stakeholders recognized this final version as a promising tool for education and communication, to be used to sensitize other stakeholders directly involved in the razor clam fishery of Don Hoi Lord as well as scholars and tourists to the need for an effective management of the resource.

The design of the AMB from its prototype version to the final one, with the results of simulation runs, reached the standard for publication in an international journal with impact factor: it was already published in the journal namely “Environmental Modelling & Software” (Worrapimphong et al., 2010).

5.4.2 Participatory simulation workshop

Following ABM verification, fisherman and other stakeholders agreed on razor clam harvesting place and behavior of fisherman agents on ABM. Further discussion between researcher and participants on how to use ABM in razor clam management was conducted. Stakeholders have defined further use of ABM is giving education and inducing conservation and/or management sense to new generation at Don Hoi Lord and other people who visit Don Hoi Lord.

The workshop can be an arena for discussion and exchange experiences of the RZ group in razor clam management at Don Hoi Lord. Finally, enforcement by government is needed in order to better management of razor clam resource.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

6.1.1 Razor clam population and environmental factors

The study of razor clam population showed that the population sharply decreased when compared with the previous scientific studies since 1982. The density in the study was only 0.51±0.30 clam/m^2. This density was the lowest in the record of razor clam density at Don Hoi Lord. However, it was found that population structure consists of all razor clam size classes and razor clam recruitment into its population was able to find all year round. Mean size of razor clam in the study was 5.34±1.21 cm/clam; which this size has ability to breed successfully. In addition, Fishermen were not going to harvest razor clam regularly during the study due to the low density. Therefore, razor clam population may recover itself based on their breeding ability and the absent of harvesting pressure.

Basic parameters such as water pH and Dissolve Oxygen, which directly affected to razor clam and its value was below the standard in some months. The cause of the decreasing of those parameters was still unclear for that moment. However, the parameters were recovering to meet the standard in the month after.

Due to the investigation of relationship between razor clam and variation of sediment including particulate sediment and particulate organic carbon (POC) in water column, it was found that organic matter in sediment and particulate sediment in water column were a negative correlation with razor clam density. Meanwhile, POC was not correlated with razor clam density. Particulate sediment in water column is one of sediment supply to the sandbar surface and also it is a source of soil organic carbon at Don Hoi Lord. As razor clam is a filter feeder, it lives near sandbar surface and filters food from water column; therefore, too much sediment can be negatively direct affected to its filtering system.

A crucial environmental change at Don Hoi Lord was found during the field data collection. The surface on the sandbar was changing to be more muddy and a horse mussel *Musculus senhousia* actively invaded into razor clam habitat. At the end of field study the horse mussel has occupied 7 of 14 stations of data collection. The invasion of horse mussel was covering almost a haft of the study sandbar at Don Hoi Lord. It was the first occurrence for horse mussel invasion at Don Hoi Lord based on local fishermen experiences. Furthermore, a port for a sea ship was build 2 years ago at the location near the river mouth and not far from the sandbar, which the port is seemingly obstructing a part of water current from Mae Klong River and might cause the change of soil sediment as well as particulate sediment flowing to sandbar.

Due to horse mussel invasion, the soil composition in the area occupied by horse mussel consists of more silt and clay than the area without horse mussel. Razor clams were found in the area without horse mussel in Fine sand type, whereas it could not be found razor clam in the area occupied by horse mussel. It is clear that the soil types for horse mussel habitat were identified as Fine sandy loam and Loamy fine sand.

6.1.2 Socio-economic of razor calm and market mechanism

Firstly, fishermen who harvest razor clam at Don Hoi Lord considers razor clam harvesting as their first priority to harvest even they can harvest on another species. Fisherman exchanges harvesting information mainly in harvesting location and razor clam production with other fisherman and a trader in order to increase their harvesting potential. There were 2 factors affected fisherman' decision that were razor clam density and razor clam price.

A trader would buy razor clam from fisherman and processed fresh razor clam to razor clam meat before distributing to the market such as a restaurant and a merchant in fresh market around Samut Songkhram province. Trader bought all of razor clam production from fisherman by controlling a price. The price was independently set by trader based on existing fresh razor clam stock in a deep freezer and market demand. Due to demand of razor clam from market, it was increased during weekend all year long and it was higher a bit during the end of summer season in Thailand around March – May. In addition, there was a small trader plays a role similar to a big trader but a small trader has distributed processed razor clam to restaurant in a village and sometime sold directly to a tourist during weekend because a small trader did not have a deep freezer to stock razor clam.

The decreasing of razor clam population in 2008 made huge effects to the fisherman. They had to harvest on other species instead of razor clam. However, the fisherman would switch to harvest razor clam again, if the population density recovered.

In addition, horse mussel invasion also effected to fisherman behavior. They could not go through horse mussel occupying area to harvest other species on the sandbar so they had to go further more from the shoreline to the area without horse mussel. In 2008, the production of fresh razor clam was not enough for distributing to a market. A trader had to order razor clam from outside Don Hoi Lord with a cheaper price than the local razor clam. However, a trader would prefer to buy local razor clam instead of importing from other areas if the razor clam production was enough for the market demand.

The finding from harvesting recorded of fisherman and the direct observation by researcher during fisherman harvesting that could help researcher to understand better on their razor clam harvesting and their communication among fisherman themselves. The harvesting place map was created from the records and it also used in Agent-based simulation model development. The harvesting place map was one of tool to use in razor clam management discussion.

6.1.3 Agent-based simulation model and participatory simulation workshop

Prototype of agent-based simulation model from 2005 was further developed regarding new knowledge finding. The development emphasized on more reliability of the result from simulation such as razor clam growth rate, population structure and its size distribution. Then, scenarios which came out from ComMod process at Don Hoi Lord were tested in the ABM. The results from simulation suggested that reserved zone accompany with individual quota was the best scenario for razor clam population.

From fisherman record data and in – depth interview, ABM was modified again in order to upgrade spatial setting based on a share representation of harvesting place between researcher and fisherman. The spatial upgrades version of ABM was used as a mediator in participatory simulation workshop.

The participatory simulation workshop has succeeded to distribute the scientific finding in the field data collection and the workshop can be an arena for ABM discussion and validation. Regarding ABM, fisherman could understand the simulation model easily and they validated on the behavior of fisherman agent in the simulation in term of its movement. Moreover, the fisherman and other stakeholders in the workshop have identified the use of the simulation is for giving education to new generation at Don Hoi Lord and other people who would like to know about razor clam harvesting.

6.1.4 ComMod effects on razor clam management at Don Hoi Lord

Companion modelling at Don Hoi Lord could help stakeholders identified razor clam conservation and implemented in the real system. As ComMod process have been implemented at Don Hoi Lord since 2005, possible manage regulations were a fruit from ComMod and stakeholders could earn some experiences from the process. However, the management regulation was not implementing due to political reason. In this study, the scientific finding revealed the tragedy of razor clam population in 2008 and a local facilitator who has been working with researcher since 2005 instituted a group of stakeholders at Don Hoi Lord by additional help from NGO and DMCR. The group aims to conserve razor clam and they consider reserved zoning as the first regulation for razor clam management. In October 2009, around 3.5 ha of reserved zoning which was the management option came out from ComMod process. The reserved area was implemented for razor clam breeding size on the sandbar. In addition, with scientific method which is quadrat sampling to assess razor clam population fisherman could do this method themselves in the reserved area. Finally, the work of the group showed that razor clam population has showed sign of population recovering.

6.2 Recommendation for razor clam management

“Freedom in a common brings ruin to all”

(Hardin, 1968)

Razor clam population at Don Hoi Lord from this study showed the tragedy of the population that it was very low density. However, local stakeholders have been instituted the local conservation group. The group is working with fisherman and other stakeholders to protect razor clam and the reserved area was one of the successes in conservation management. Following ComMod process at Don Hoi Lord, this study would like to propose a precisely recommendation for razor clam management as follows:

- Government should support the conservation group both budget and law enforcement; the group consists of local stakeholders and they can actually work with the most fishermen around Don Hoi Lord. From their current works showed that there are some problems regarding law enforcement such as using caustic soda mixing in lime for razor clam harvesting, using caustic soda is forbidden by law but the group do not have legitimacy power to tackle and reinforce with is issue. Regarding financial support, the group is now working by their own budget and it would be better if government can support some budgets or materials such as boat fuel in order to make the group work effectively and smoothly.

- Reserved area should be enlarged and/or duplicated to another area on the sandbar; based on razor clam life history in some stage of life it is a planktonic form and remained in the water column before settle on the sandbar. Therefore, if the reserved area is enlarged enough the opportunity of razor clam breeding can have higher than the present situation and it may produce more razor clam recruitment. Consequently, the density of razor clam may increase and possibly sustain for the future.

- Regarding razor clam market mechanism and harvesting rate of fisherman, it should be intervened razor clam harvesting by setting a limited harvesting yield or giving a quota to fisherman during day-time low tide. Due to a trader buys all fresh razor clam from fisherman with dynamic price because a trader has to reduce their risk in a business. Thus, if the razor clam harvest productions are not exceeding the market demand the trader may not need to reduce price. Then, fisherman can earn enough money from razor clam harvesting with a certain amount without putting more pressure to harvesting razor clam.

- Government or Research or University funding organization should provide financial support the conservation group in order to protect and monitor environmental condition at Don Hoi Lord; based on the success of ComMod in sharing and distributing knowledge. The conservation group now has ability to carry out basic scientific investigation but they do not have some adequate scientific devices for those activities such as DO meter and pH meter. From field study found that, basic environmental factors were below the standard in some months and it clearly affected to all aquatic species not only razor clam. Therefore, if fisherman can monitor basic environmental factors themselves, it may help them to protect their resources effectively.

6.3 Perspectives

Although the implementation of ComMod process at Don Hoi Lord was seemingly archived the objective to help stakeholders explore a sustainable management policies at Don Hoi Lord. However, the interesting topics for further study were found and should be studied in the future regarding razor clam sustainable management. The topics consist of the following themes;

- The effects of mixed caustic soda on environmental condition and in razor clam meat; as a general knowledge that caustic soda is a strong base and now is widely used in razor clam harvesting. Therefore, the study of caustic soda will provide more concrete scientific evident for policy-making and consumer safety.

- The study of water current and soil sedimentation on the sandbar. As environmental changes were found during the study such as a muddy surface including horse mussel invasion and a new sea vessel port near the sandbar, they might cause impacts to razor clam habitat. The study of water current and sedimentation will help stakeholders to understand better on the change of environment and also prepare better planning for tackle this problem in the future.

- The study of razor population in each harvesting place on the sandbars; as a new finding in current study that there are 10 razor clam harvesting places at Don Hoi Lord. To monitor the actual razor clam population situation at Don Hoi Lord would be very important to test the scenarios that were proposed by the ComMod approach from collective agreement of stakeholders at Don Hoi Lord. It may confirm the possibility of success implementation of sustainable management in the future.

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APPENDICES

Appendix A: Method to analyze soil organic matter and Soil texture

Estimating organic matter content by Modified Walkley-Black titrametric analysis

- Reagents

A) Potassium dichromate solution ($K_2Cr_2O_7$) 1.0 N; Dilute $K_2Cr_2O_7$ 49.04 g in distilled water and making volume to 1 liter.

B) Concentrate Sulfulic acid (H_2SO_4)

C) Ferous sulfate ($FeSO_4$) 0.5 N; dilute $Fe(NH_4)_2$ $(SO_4)_2$ $6H_2O$ 196.1 g in distilled water then, add conc. Sulfulic acid 15 ml. and cool reagent. Making total volume to 1D) liter.

D) O-phenantholine ferrous sulfate indicator (0.025 M); dilute O-phenantholine 1.48 g and Ferous sulfate in 100 ml distilled water.

E) Distilled water

- Procedure

1. Using an analytical balance, weigh dried soil (approximately 0.5-2 g) into two 500 ml Erlenmeyer flask. Record your exact weight.
2. Using the autopipette, add 5.0 ml of 1 N Potassium dichromate ($K_2Cr_2O_7$). Swirl the flask to mixing well between soil and reagent.
3. Add 10 ml Concentrated sulfuric acid (H_2SO_4) quickly. Swirl the flasks for 1 min and place in the hood. "**CAUTION: This is a very exothermic reaction and the flasks will becomeextremely hot. Wear gloves, lab coats, safety glasses, and work in the hood!"**
4. Let sample stand approximately 30 min, swirling occasionally.
5. Using a graduated cylinder, add 15 ml distilled water.
6. Add 3-5 drops O-phenantholine ferrous sulfate indicator and titrate with 0.5 N Ferrous ammonium sulfate ($Fe(NH_4)_2(SO_4)_2$) in the burets. As you approach the endpoint, the solution will turn dark green. Titrate slowly until the endpoint is reached, indicated by a wine red or maroon color in reflected light against a white background. Record Ferrous ammonium sulfate volume in each titration.
7. Repeat the procedure as blank by do not put soil into the flask at the beginning.

Calculation

Percentage of Organic carbon (%OC) and percentage of Organic matter (%OM) can be calculate from the equation

$$\%OC = \frac{(Vblank - Vsample) \times N \times f\ 0.003 \times 100}{M}$$

$$\%OM = \frac{100(\%OC)}{C}$$

Where: V_{blank} = Volume of $FeSO_4$ using in blank titration (ml)

Vsample = Volume of $FeSO_4$ using in soil titration (ml)

N = Concentration of $FeSO_4$ (Normal)

M = Soil weight (g)

F = Correlation factor (usually 1.33)

C = Percent by weight of Carbon in organic matter (usually 58%)

(Modified from: http://www.agry.purdue.edu/courses/agry365T/04lab4om.pdf and Gomontean, 1996)

Method to analyze soil texture (Hydrometer method)

Soil texture analysis (percentages of Sand, Silt and Clay)

- Reagents

1. Calgon solution 5% ; dilute sodiumhexametaphosphate 50 g and sodium carbonate 8.3 g in 1 liter of distilled water
2. Hydrogen peroxide (30 %)
3. Distilled water

- Special equipments

1. Soil hydrometer
2. Milk shake mixer

- Procedure

1. Sieve dried soil sample through 2 mm mesh sieve.

2. Weigh out 50 g of sieved sample. If soil sample contains a considerable amount of organic material continue with step 3, otherwise continue with step 4.
3. Put sieved sample into a 1 liter Erlenmeyer flask. Add 15 ml hydrogen peroxide (30%) to destroy organic matter. If organic matter is high more peroxide may be added. Let stand until foaming ceases or overnight. Because of the odor, place samples under the hood.
4. Transfer sample into milk shake mixer cup and dilute to within 1 ½ inches of the top with distilled water.
5. Add 10 ml calgon solution 5%
6. Stir in the milk shake mixer (sandy soils ~ 5 min, loess soils ~ 10 min, clay soils ~ 25 min).
7. Pour and wash the dispersed sample into 1 liter graduated cylinder and fill the cylinder to the 1000 ml mark with distilled water.
8 Stir the soil solution with plunger then, immediately place cylinder on the table and note the time using a stopwatch. If the sample is foamy after being mixed and shaken so thet the hydrometer would be difficult to read, add 1 or 2 drops of amyl alcohol to the suspension before adding the hydrometer.

"DO NOT MOVE THE CYLINDER FOR THE NEXT 2 HOURS"

9. After ~ 10 sec. begin inserting the hydrometer slowly, without unnecessary mixing, so that a hydrometer reading be taken after 40 sec.
10. Measure the temperature of the solution using thermometer.
11. After 2 hours, take another hydrometer and temperature reading.
12. Repeat the procedure as blank by do not putting soil in the experiment.

Calculations

Following hydrometer reading it has specific temperature to corrected reading (usually 20ºC). Thus, hydrometer reading at 40 s, 2 hr , and Calgon solution has to corrected if the experiment does not taking place at 20ºC by;

$$Rs = Rt + 0.36(t\text{-}L)$$

$$Cs = Cr + 0.50\ (T_c\text{-}L)$$

Where Rs = Corrected reading from soil solutionvalue by hydrometer (g/l)
Rt = Reading value from soil solution at time 40 s (a) and 2 hr (b) (g/l)
Cs = Corrected reading value from Calgon solution by hydromrter (c) (g/l)

Cr = Reading value from Calgon solution at time 40 s and 2 hr (g/l)

t = Temperature when experiment is took place at 40 s and 2 hr

L = Specific temperature at hydrometer

t_c = Calgon solution temperature

From equation above, corrected value from soil solution at 40s which consist of Silt, Clay and Calgon;

Rs, 40 s = Rt + 0.36(t-L)

= a + 0.36(t_{40s} - L)

Corrected value from soil solution at 2 hr which consist of Clay and Calgon;

Rs, 2 hr = Rt + 0.36(t-L)

= b + 0.36(t_{2hr} - L)

Corrected value from Calgon solution;

Cs = Cr + 0.50(t_c-L)

= c + 0.50(t_c - L)

If subtract Calgon value from Rs 40 s the value will consist of Silt and Clay

= Rs 40 s – Cs

= A

Thus, Clay value = Rs 2 hr – Cs

= B

Then, Sand value = X-A

And Silt = A-B

Finally, percentage of Sand, Silt, and Clay from soil x gram can calculate by;

Sand (%) $= \frac{100}{x}(X\text{-}A)$

Silt (%) $= \frac{100}{x}(A\text{-}B)$

Clay (%) $= \frac{100B}{x}$

(Modified from: http://www.geobotany.uaf.edu/teaching/biol475/biol475-06_lab06.pdf and Department of Soil Science, KMITL)

Appendix B: Razor clam population details and it environmental factors

Razor clam density in each station along 12 months

Month / station	Mean density ± SD (clam/sq.m.)												
	Jun-08	**Jul-08**	**Aug-08**	**Sep-08**	**Oct-08**	**Nov-08**	**Dec-08**	**Jan-09**	**Feb-09**	**Mar-09**	**Apr-09**	**May-09**	**Mean**
A1	0.00	0.00	0.67±0.58	0.00	0.33±0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.08±0.20**
A2	0.00	0.67±0.58	1.33±0.58	0.33±0.58	0.33±0.58	0.00	0.00	0.00	0.00	0.00	0.00	1.00±0.00	**0.31±0.44**
B1	0.00	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	**0.14±0.37**
B2	0.67±0.58	0.33±0.58	1.00±0.00	1.00±0.00	0.00	0.00	0.00	0.67±0.58	0.00	2.00±1.00	2.00±1.00	3.67±2.08	**1.00±1.07**
B3	1.33±0.58	0.00	1.00±0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33±0.58	1.00±0.00	**0.31±0.48**
C1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
C2	0.33±0.58	1.00±1.00	1.00±0.00	0.33±0.58	0.00	0.67±0.58	0.33±0.58	0.33±0.58	0.00	0.00	0.00	0.00	**0.33±0.36**
C3	1.00±0.00	1.00±1.00	0.67±0.58	0.67±0.58	0.00	2.67±0.58	1.33±1.53	0.67±0.58	3.33±2.52	2.33±1.15	1.33±0.58	2.33±1.15	**1.44±0.96**
C4	0.67±0.58	0.33±0.58	1.00±0.00	0.67±0.58	0.00	0.00	1.00±0.00	0.33±0.58	1.00±0.00	1.33±0.58	1.67±0.58	1.67±1.15	**0.81±0.55**
D1	0.67±0.58	0.00	0.33±0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.08±0.20**
D2	0.00	0.00	0.33±0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.03±0.09**
D3	0.00	1.00±0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.08±0.28**
D4	1.00±0.00	1.00±1.00	1.00±1.00	1.33±0.58	0.33±0.58	0.00	0.33±0.58	0.67±0.58	0.33±0.58	1.00±0.00	2.67±1.53	2.00±1.00	**0.97±0.73**
D5	1.67±1.15	2.00±1.00	1.67±1.15	3.67±1.53	0.00	1.00±0.00	1.67±0.58	1.00±0.00	1.33±0.58	1.33±0.58	1.67±0.58	1.33±0.58	**1.53±0.81**
Mean	**0.57±0.61**	**0.62±0.63**	**0.73±0.49**	**0.57±0.99**	**0.07±0.14**	**0.31±0.74**	**0.33±0.57**	**0.26±0.35**	**0.43±0.94**	**0.57±0.85**	**0.69±0.96**	**0.93±1.16**	

Razor clam population structure in number and percentage in each month

Month / Size	Jun-08		Jul-08		Aug-08		Sep-08		Oct-08		Nov-08		Dec-08		Jan-09		Feb-09		Mar-09		Apr-09		May-09	
	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%	Num	%
≤ 2.0 cm	0	0.0	0	0.0	0	0.0	0	0.0	1	33.3	0	0.0	0	0.0	0	0.0	0	0.0	1	4.2	2	6.9	0	0.0
2.1-3.0 cm	1	4.5	0	0.0	0	0.0	1	4.2	0	0.0	1	7.7	1	7.1	2	18.2	1	4.5	0	0.0	3	10.3	0	0.0
3.1-4.0 cm	2	9.1	0	0.0	1	3.2	0	0.0	1	33.3	1	7.7	1	7.1	1	9.1	2	9.1	5	20.8	1	3.4	8	20.5
4.1-5.0 cm	3	13.6	5	19.2	4	12.9	1	4.2	1	33.3	6	46.2	4	28.6	3	27.3	3	13.6	10	41.7	2	6.9	12	30.8
5.1-6.0 cm	13	59.1	12	46.2	14	45.2	12	50.0	0	0.0	1	7.7	4	28.6	1	9.1	13	59.1	3	12.5	6	20.7	12	30.8
≥ 6.1 cm	3	13.6	9	34.6	12	38.7	10	41.7	0	0.0	4	30.8	4	28.6	4	36.4	3	13.6	5	20.8	15	51.7	7	17.9

%OM in each station along 12 months

	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09
A1	0.75±0.06	0.82±0.06	0.55±0.03	0.60±0.03	0.49±0.00	0.75±0.06	0.99±0.01	0.85±0.05	0.86±0.01	0.77±0.04	0.87±0.08	0.73±0.00
A2	0.57±0.07	0.46±0.02	0.41±0.02	0.35±0.00	0.29±0.02	0.44±0.06	0.41±0.02	0.45±0.05	0.39±0.02	0.32±0.01	0.44±0.04	0.31±0.01
B1	0.65±0.05	0.59±0.02	0.48±0.01	0.45±0.01	0.50±0.00	0.57±0.01	0.67±0.01	0.69±0.01	0.64±0.04	0.60±0.01	0.60±0.02	0.80±0.03
B2	0.42±0.12	0.42±0.02	0.38±0.08	0.31±0.02	0.29±0.01	0.34±0.02	0.39±0.02	0.35±0.01	0.39±0.05	0.39±0.02	0.37±0.02	0.32±0.00
B3	0.37±0.02	0.40±0.01	0.32±0.01	0.29±0.02	0.28±0.01	0.34±0.01	0.76±0.46	0.40±0.01	0.42±0.05	0.31±0.00	0.37±0.04	0.38±0.00
C1	0.67±0.04	0.75±0.01	0.61±0.02	0.61±0.01	0.64±0.01	0.61±0.00	0.74±0.43	0.84±0.02	0.81±0.03	0.80±0.02	0.80±0.07	0.84±0.02
C2	0.43±0.00	0.44±0.02	0.34±0.05	0.35±0.00	0.34±0.01	0.41±0.01	0.43±0.01	0.48±0.02	0.62±0.07	0.49±0.01	0.79±0.00	0.63±0.01
C3	0.35±0.03	0.52±0.03	0.38±0.01	0.38±0.01	0.33±0.01	0.48±0.01	0.49±0.06	0.42±0.02	0.34±0.06	0.31±0.00	0.38±0.09	0.30±0.00
C4	0.44±0.03	0.37±0.02	0.37±0.01	0.34±0.02	0.37±0.02	0.38±0.01	0.74±0.27	0.51±0.01	0.33±0.07	0.54±0.02	0.38±0.05	0.35±0.01
D1	0.98±0.02	0.66±0.01	0.60±0.02	0.56±0.02	0.83±0.00	0.96±0.04	0.87±0.08	0.85±0.02	0.93±0.00	0.84±0.02	0.84±0.04	0.86±0.02
D2	1.00±0.02	0.89±0.06	0.78±0.03	0.94±0.00	1.20±0.03	0.77±0.01	0.81±0.01	0.89±0.03	1.14±0.05	0.99±0.00	1.04±0.07	0.97±0.01
D3	0.64±0.02	0.72±0.02	0.57±0.00	0.62±0.05	0.53±0.01	0.50±0.03	0.56±0.37	0.75±0.05	0.93±0.03	0.65±0.00	0.73±0.05	0.68±0.03
D4	0.37±0.09	0.31±0.01	0.29±0.02	0.26±0.02	0.27±0.03	0.33±0.03	0.29±0.07	0.32±0.01	0.27±0.04	0.26±0.00	0.34±0.03	0.32±0.01
D5	0.26±0.01	0.29±0.00	0.36±0.02	0.21±0.01	0.27±0.02	0.34±0.00	0.26±0.02	0.28±0.01	0.15±0.03	0.21±0.00	0.26±0.05	0.27±0.03

Particulate sediment (mg/l) in each station along 12 months

	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09
A1	33.55±11.47	34.66±3.38	24.50±1.45	33.50±0.76	131.60±6.68	47.83±1.45	37.94±2.39	34.83±1.04	42.50±12.70	36.94±0.79	30.88±2.26	33.00±1.67
A2	31.55±0.96	35.05±2.34	23.16±1.33	30.16±1.76	130.93±1.67	39.50±0.33	35.50±2.03	32.27±2.78	121.07±33.01	33.61±0.67	33.16±1.64	30.61±2.11
B1	35.33±1.30	34.05±1.78	25.72±1.51	34.05±0.35	105.00±1.78	42.77±2.83	36.662.29	33.77±1.78	53.98±1.59	29.50±11.72	32.05±1.11	32.61±2.34
B2	35.72±0.69	32.22±1.46	22.33±0.60	38.83±2.05	146.55±16.28	40.00±3.87	38.11±1.51	31.77±2.30	87.43±0.68	35.83±1.32	31.72±0.51	33.66±1.09
B3	38.44±0.98	28.77±1.69	20.66±0.88	34.83±2.75	163.88±40.36	30.88±0.96	36.44±0.63	34.77±1.29	98.05±20.21	36.05±1.55	33.94±0.54	31.00±0.93
C1	36.16±0.33	30.44±0.77	24.11±0.35	33.66±1.36	71.83±2.75	35.88±3.77	32.11±0.35	32.61±1.49	102.00±2.70	36.55±1.06	30.11±1.11	35.61±0.25
C2	34.50±3.32	32.72±1.00	21.61±0.67	37.77±5.68	85.91±10.92	33.50±1.80	32.00±2.52	32.66±1.83	63.63±10.44	34.27±1.49	34.11±1.83	45.16±0.60
C3	36.33±2.62	29.55±1.97	23.27±1.64	36.55±1.11	65.25±1.09	30.50±0.60	37.66±5.92	34.72±0.84	97.76±1.64	40.55±1.55	33.22±2.80	30.94±2.51
C4	36.00±0.33	28.33±1.01	24.33±2.92	32.88±2.12	69.00±1.32	28.83±2.52	34.55±3.76	33.61±0.38	30.19±0.68	33.88±0.69	32.50±1.64	28.38±2.38
D1	38.16±0.93	34.16±2.89	24.05±2.30	32.22±2.67	62.98±5.94	26.83±0.17	33.88±0.82	33.00±1.09	71.18±4.79	36.55±3.02	33.44±1.21	36.38±1.75
D2	34.55±1.44	55.11±4.55	23.61±1.60	34.77±2.31	65.25±1.73	31.11±0.48	34.16±0.33	32.83±0.73	119.49±1.36	37.94±0.19	33.77±3.47	34.00±0.44
D3	40.77±3.70	33.33±2.59	25.16±1.42	35.55±2.34	68.25±2.54	27.94±4.39	26.88±2.37	30.83±1.42	95.37±0.50	34.94±0.35	33.33±2.35	31.61±2.10
D4	36.27±0.67	39.77±2.27	24.72±1.34	38.50±1.01	67.58±2.79	30.22±1.68	35.72±2.74	31.94±1.13	41.50±2.00	36.61±1.84	32.83±2.17	32.22±1.67
D5	36.94±0.69	33.83±1.42	25.05±0.69	31.05±1.73	66.58±2.10	31.55±1.51	32.83±2.68	32.00±2.89	55.15±1.53	36.00±1.67	31.94±1.67	31.11±2.26

Particulate sediment (µg/l) in each station along 12 months

	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09
A1	661.94±14.89	742.94±81.40	696.83±28.91	1415.50±34.55	2408.93±30.87	1326.72±85.01	429.38±41.67	512.66±18.61	2620.00±42.51	516.61±7.72	318.83±29.76	539.11±9.95
A2	731.44±108.24	592.72±1.18	595.61±21.91	1158.22±85.52	2226.00±265.80	1088.50±70.18	304.11±14.86	310.94±21.01	1975.11±121.07	407.50±12.17	318.77±11.05	407.00±8.52
B1	627.16±57.64	534.50±22.26	652.22±4.13	1326.44±56.30	1663.93±33.29	1401.61±84.80	312.11±15.93	451.50±29.98	2370.66±53.98	460.55±10.30	307.61±35.87	462.88±19.14
B2	600.38±30.51	500.94±4.85	543.61±29.60	1279.44±129.06	2227.05±158.88	1330.88±46.59	322.61±27.82	366.50±38.49	3656.66±87.43	415.38±26.71	328.16±50.52	494.33±4.58
B3	744.44±60.97	423.72±35.29	564.05±25.67	1237.33±38.92	2801.61±655.50	1298.27±67.79	281.66±1.92	371.94±27.14	2298.44±98.05	431.61±18.95	341.88±40.02	398.72±13.50
C1	607.88±31.12	471.33±13.09	642.66±38.61	1391.94±142.05	1089.16±78.25	1488.27±140.13	309.83±5.20	429.72±41.86	2786.00±102.00	566.83±53.22	348.83±30.51	861.33±64.37
C2	589.41±3.65	553.00±0.35	623.94±19.33	1503.33±410.83	1499.30±6.01	1310.44±6.01	284.83±16.62	415.72±13.20	3109.16±63.64	465.16±66.82	414.38±24.87	915.50±24.98
C3	616.61±19.45	506.27±119.20	597.38±3.52	1259.11±37.61	920.00±36.56	836.72±87.71	302.55±46.10	449.27±8.78	3384.22±97.76	832.27±50.22	356.66±27.27	487.72±59.06
C4	850.94±159.94	448.16±26.93	546.22±22.96	1103.44±30.23	974.50±21.47	626.66±93.18	378.77±12.57	414.44±10.10	2102.77±30.20	445.11±9.17	344.22±4.86	442.27±26.00
D1	727.00±21.45	798.38±101.23	579.61±24.16	1301.44±16.26	1062.71±22.45	715.88±3.89	324.22±7.07	393.44±16.97	3006.33±71.18	527.05±0.71	383.77±25.34	521.66±45.96
D2	666.27±23.49	1478.22±44.83	434.11±9.74	1295.38±32.10	939.58±18.12	881.22±152.16	289.72±21.95	466.94±21.95	3180.55±119.49	618.33±102.95	377.83±31.56	435.94±25.31
D3	800.33±187.35	817.88±156.31	626.27±15.25	1276.55±51.19	939.66±23.91	923.72±66.31	217.38±4.19	373.16±4.19	2565.66±95.38	436.11±19.88	349.00±22.41	417.33±34.14
D4	735.88±35.77	1160.77±143.16	549.50±30.14	1432.77±51.71	971.50±33.51	695.16±78.61	327.55±13.91	411.55±15.91	2835.88±41.50	424.27±3.68	391.38±19.59	439.55±51.58
D5	596.83±10.5	1066.11±36.18	575.22±20.50	1005.66±12.62	907.50±15.88	748.00±70.57	248.88±12.20	346.16±17.76	1576.00±55.15	459.55±5.55	351.83±36.39	393.44±51.30

Water pH in each station along 12 months

pH	A1	A2	B1	B2	B3	C1	C2	C3	C4	D1	D2	D3	D4	D5
Jun-08	7.58	7.28	7.67	7.28	7.29	7.63	7.51	7.43	7.45	7.63	7.64	7.55	7.52	7.52
Jul-08	7.69	7.73	7.73	7.73	7.73	7.73	7.73	7.68	7.67	7.58	7.54	7.49	7.52	7.71
Aug-08	7.71	7.77	7.63	7.76	7.77	7.60	7.79	7.76	7.75	7.82	7.66	7.76	7.77	7.74
Sep-08	5.71	5.82	5.29	6.50	6.04	5.97	5.99	6.13	6.23	5.88	6.60	6.01	7.52	5.65
Oct-08	6.31	6.80	6.42	6.31	5.82	5.47	5.71	5.64	7.09	4.92	5.07	5.11	5.90	6.24
Nov-08	7.34	7.23	7.18	7.16	7.15	7.07	7.03	7.21	6.81	6.98	6.46	6.80	7.39	6.80
Dec-08	7.49	7.45	7.50	7.38	7.38	7.32	7.40	7.26	7.39	7.29	7.21	7.29	7.17	7.32
Jan-09	7.57	7.60	7.65	7.67	7.55	7.69	7.67	7.66	7.62	7.72	7.69	7.68	7.64	7.62
Feb-09	7.57	7.62	7.62	7.67	7.61	7.64	7.61	7.63	7.66	7.61	7.66	7.66	7.68	7.76
Mar-09	7.55	7.57	7.55	7.60	7.62	7.55	7.60	7.62	7.61	7.51	7.62	7.62	7.62	7.61
Apr-09	7.01	6.67	6.67	6.76	6.93	6.81	7.26	6.83	7.40	6.89	7.54	7.29	7.47	6.91
May-09	6.32	6.80	6.86	7.03	6.67	7.29	7.37	6.79	6.98	6.92	7.30	6.95	7.25	6.84

Salinity (psu) in each station along 12 months

Sal	A1	A2	B1	B2	B3	C1	C2	C3	C4	D1	D2	D3	D4	D5
Jun-08	9.0	10.0	7.0	9.0	8.0	8.0	9.0	8.0	10.0	8.0	5.0	6.0	11.0	11.0
Jul-08	25.0	23.0	26.0	25.0	24.0	25.0	25.0	26.0	27.0	27.0	27.0	27.0	28.0	27.0
Aug-08	27.0	22.0	26.0	22.0	23.0	25.0	26.0	23.0	22.0	20.0	18.0	23.0	22.0	22.0
Sep-08	22.5	22.0	24.0	25.0	21.0	24.0	24.0	23.0	21.0	24.0	24.0	24.0	24.0	22.0
Oct-08	8.0	10.0	8.0	12.0	11.0	2.0	13.0	10.0	5.0	3.0	5.0	5.0	5.0	5.0
Nov-08	25.0	25.0	26.0	26.0	24.0	25.0	26.0	25.0	25.0	25.0	25.0	24.0	24.0	25.0
Dec-08	24.0	23.0	25.0	26.0	25.0	26.0	26.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Jan-09	20.0	20.0	20.0	21.0	20.0	21.0	21.0	20.0	21.0	21.0	20.0	20.0	20.0	20.0
Feb-09	20.0	20.0	20.0	19.0	20.0	26.0	25.0	25.0	24.0	24.0	25.0	27.0	27.0	28.0
Mar-09	6.0	13.0	8.0	14.0	15.0	7.0	14.0	14.0	15.0	5.0	17.0	15.0	15.0	14.0
Apr-09	19.0	20.0	19.0	12.5	13.0	19.0	14.0	14.0	14.5	15.0	18.0	15.0	15.0	15.0
May-09	15.0	15.0	12.0	11.0	10.0	12.0	10.0	7.5	8.0	12.0	10.0	9.0	8.0	7.5

DO (mg/l) in each station along 12 months

DO	A1	A2	B1	B2	B3	C1	C2	C3	C4	D1	D2	D3	D4	D5
Jun-08	5.32	4.16	4.53	4.14	3.98	4.22	3.64	3.53	3.87	4.21	4.53	3.78	3.78	3.23
Jul-08	5.92	5.53	5.83	5.87	5.59	5.74	5.90	5.76	5.60	6.03	6.24	6.57	7.07	7.43
Aug-08	4.52	3.50	5.42	5.75	4.51	4.10	5.06	4.31	5.14	3.35	3.85	3.01	3.00	4.94
Sep-08	5.86	5.25	5.53	5.26	5.02	5.74	5.32	5.21	4.90	5.30	5.35	5.32	4.93	4.75
Oct-08	2.45	2.13	2.07	2.12	1.86	2.64	1.88	2.24	2.80	3.22	3.21	3.10	2.85	3.07
Nov-08	4.18	4.13	4.19	4.27	4.35	4.42	4.54	4.33	5.57	5.60	5.01	4.97	4.97	5.60
Dec-08	4.80	5.30	5.20	5.20	5.10	5.40	5.60	4.50	4.70	4.80	4.90	4.50	4.80	4.50
Jan-09	7.20	6.70	8.00	6.90	7.80	7.40	7.80	8.00	7.60	7.80	8.00	7.30	7.40	8.30
Feb-09	4.97	5.31	5.41	5.56	5.45	5.92	5.44	5.65	5.85	5.50	5.38	5.16	5.34	5.94
Mar-09	4.21	4.07	4.03	4.11	4.15	4.04	4.03	4.08	4.06	3.83	3.93	4.09	4.43	4.18
Apr-09	4.72	3.74	4.05	3.79	4.27	4.39	4.25	4.11	4.33	4.22	4.28	4.42	4.45	4.29
May-09	3.64	3.30	3.44	3.47	3.29	3.63	3.31	3.53	3.59	3.56	3.60	3.61	3.75	3.74

Water temperature in each station along 12 months

Temp	A1	A2	B1	B2	B3	C1	C2	C3	C4	D1	D2	D3	D4	D5
Jun-08	29.1	29.7	29.1	29.6	29.6	29.1	29.7	29.6	29.8	29.2	29.2	29.3	29.8	29.8
Jul-08	30.5	30.4	30.5	30.3	30.2	30.4	30.0	30.1	30.3	30.3	30.2	30.2	30.1	30.1
Aug-08	31.9	31.5	31.5	31.3	31.3	31.5	31.2	31.1	31.2	31.4	30.8	30.7	28.6	31.0
Sep-08	30.0	29.9	29.9	29.9	30.0	30.0	29.9	29.9	29.9	29.7	29.8	29.8	29.9	29.8
Oct-08	28.2	28.6	28.5	28.6	28.8	28.2	28.8	28.6	28.1	27.9	27.5	27.9	28.1	28.0
Nov-08	27.3	27.4	27.5	27.5	27.3	27.1	27.6	27.4	27.3	27.4	27.3	27.3	27.3	27.5
Dec-08	26.2	26.1	26.2	26.2	26.3	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.2	26.3
Jan-09	27.4	26.4	27.1	26.7	26.7	26.9	27.0	27.0	26.5	27.2	27.4	26.9	26.8	26.4
Feb-09	29.1	29.3	29.1	29.2	29.2	29.2	29.1	29.2	29.4	29.1	29.2	29.2	29.2	29.3
Mar-09	29.4	29.9	29.5	29.8	29.9	29.4	29.8	30.0	30.1	30.0	30.0	30.0	30.0	30.1
Apr-09	29.7	30.5	30.2	30.5	30.3	30.2	30.4	30.7	30.6	30.8	30.6	30.6	30.6	30.4
May-09	29.4	29.8	29.7	29.7	29.7	29.2	30.2	29.8	30.1	29.4	29.5	29.5	29.5	29.6

Appendix C: Statistical analysis

Mean density in each month

Kruskal-Wallis Test

Ranks

	Month	N	Mean Rank
Density of razor clam/sq. m. in each station	June 08	14	94.64
	July 08	14	98.36
	August 08	14	113.50
	September 08	14	86.46
	October 08	14	58.89
	November 08	14	66.32
	December 08	14	75.68
	January 09	14	75.71
	February 09	14	72.54
	March 09	14	83.43
	April 09	14	89.82
	May 09	14	98.64
	Total	168	

Test Statistics[a,b]

	Density of razor clam/sq. m. in each station
Chi-Square	18.976
df	11
Asymp. Sig.	.062

a. Kruskal Wallis Test

b. Grouping Variable: Month

Mean length and weight in each month

Kruskal-Wallis Test

Ranks

	Month	N	Mean Rank
Razor clam length	June 08	22	115.84
	July 08	26	147.06
	August 08	31	158.23
	September 08	24	163.92
	October 08	3	24.00
	November 08	13	110.88
	December 08	14	120.75
	January 09	11	120.05
	February 09	17	110.65
	March 09	24	92.67
	April 09	29	140.72
	May 09	39	107.94
	Total	253	
Razor clam weight	June 08	22	109.77
	July 08	26	136.65
	August 08	31	151.26
	September 08	24	176.04
	October 08	3	47.33
	November 08	13	113.54
	December 08	14	114.82
	January 09	11	111.77
	February 09	17	118.74
	March 09	24	85.77
	April 09	29	142.22

Test Statistics[a,b]

	Razor clam length	Razor clam weight
Chi-Square	30.826	30.429
df	11	11
Asymp. Sig.	.001	.001

a. Kruskal Wallis Test

b. Grouping Variable: Month

Length and weight relationship

Power

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.977	.954	.953	.059

The independent variable is Weight.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	17.846	1	17.846	5.157E3	.000
Residual	.869	251	.003		
Total	18.714	252			

The independent variable is Weight.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
ln(Weight)	.343	.005	.977	71.811	.000
(Constant)	3.397	.024		144.468	.000

The dependent variable is ln(Length).

Razor clam growth rate in natural

3-4 cm.

Group Statistics

	Status of sample	N	Mean	Std. Deviation	Std. Error Mean
razor clam length 3-4	Before	20	3.4600	.38987	.08718
	After a month	8	4.0000	.29761	.10522

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
razor clam length 3-4	Equal variances assumed	.597	.447	-3.514	26	.002
	Equal variances not assumed			-3.952	16.964	.001

4-5 cm.

Group Statistics

	Status of sample	N	Mean	Std. Deviation	Std. Error Mean
razor clam length 4-5	Before	20	4.5150	.25397	.05679
	After a month	9	4.9556	.20683	.06894

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
razor clam length 4-5	Equal variances assumed	.472	.498	-4.555	27	.000
	Equal variances not assumed			-4.932	18.879	.000

> 5.0 cm.

Group Statistics

	Status of sample	N	Mean	Std. Deviation	Std. Error Mean
razor clam length >5	Before	20	6.0200	.45837	.10250
	After a month	9	6.2444	.36094	.12031

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
razor clam length >5	Equal variances assumed	2.169	.152	-1.295	27	.206
	Equal variances not assumed			-1.420	19.501	.171

Environmental factors by station

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	1.034	13	.080	.176	.999
	Within Groups	69.640	154	.452		
	Total	70.674	167			
DO	Between Groups	2.962	13	.228	.122	1.000
	Within Groups	287.198	154	1.865		
	Total	290.161	167			
WaterTemp	Between Groups	1.255	13	.097	.040	1.000
	Within Groups	372.163	154	2.417		
	Total	373.418	167			
Salinity	Between Groups	30.507	13	2.347	.043	1.000
	Within Groups	8417.229	154	54.657		
	Total	8447.737	167			

Soil composition in each station

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Sand	Between Groups	5383.174	13	414.090	32.869	.000
	Within Groups	1940.146	154	12.598		
	Total	7323.320	167			
Slit	Between Groups	1667.650	13	128.281	16.935	.000
	Within Groups	1166.562	154	7.575		
	Total	2834.213	167			
Clay	Between Groups	1264.821	13	97.294	37.462	.000
	Within Groups	399.958	154	2.597		
	Total	1664.780	167			

Mean OM in each month

ANOVA

OM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.421	11	.038	.716	.722
Within Groups	8.347	156	.054		
Total	8.769	167			

Mean OM in each station

ANOVA

OM

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.053	13	.543	48.687	.000
Within Groups	1.716	154	.011		
Total	8.769	167			

Mean particulate sediment and POC in each month

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
PS	Between Groups	65873.874	11	5988.534	31.456	.000
	Within Groups	29699.114	156	190.379		
	Total	95572.988	167			
POC	Between Groups	7.034E7	11	6394288.449	73.179	.000
	Within Groups	1.363E7	156	87378.306		
	Total	8.397E7	167			

Mean particulate sediment and POC in each station

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
PS	Between Groups	3012.003	13	231.693	.385	.973
	Within Groups	92560.985	154	601.045		
	Total	95572.988	167			
POC	Between Groups	1395100.925	13	107315.456	.200	.999
	Within Groups	8.257E7	154	536188.882		
	Total	8.397E7	167			

Correlation between particulate sediment and POC

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.718[a]	.516	.513	494.77508

a. Predictors: (Constant), PS

b. Dependent Variable: POC

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.333E7	1	4.333E7	177.004	.000[a]
	Residual	4.064E7	166	244802.377		
	Total	8.397E7	167			

a. Predictors: (Constant), PS

b. Dependent Variable: POC

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-10.908	77.080		-.142	.888
	PS	21.293	1.600	.718	13.304	.000

a. Dependent Variable: POC

Nonparametric correlations test between razor clam density and environmental factors

Correlations

			Density of razor clam/sq. m. in each station	pH in each station	Dissolve oxygen in each station (mg/l)
Kendall's tau_b	Density of razor clam/sq. m. in each station	Correlation Coefficient	1.000	.120*	-.013
		Sig. (2-tailed)	.	.039	.822
		N	168	168	168
	pH in each station	Correlation Coefficient	.120*	1.000	.299**
		Sig. (2-tailed)	.039	.	.000
		N	168	168	168
	Dissolve oxygen in each station (mg/l)	Correlation Coefficient	-.013	.299**	1.000
		Sig. (2-tailed)	.822	.000	.
		N	168	168	168
	Water temperature in each station	Correlation Coefficient	.216**	.123*	-.075
		Sig. (2-tailed)	.000	.020	.154
		N	168	168	168
	Salinity in each station	Correlation Coefficient	.032	.207**	.469**
		Sig. (2-tailed)	.590	.000	.000
		N	168	168	168
Spearman's rho	Density of razor clam/sq. m. in each station	Correlation Coefficient	1.000	.158*	-.018
		Sig. (2-tailed)	.	.040	.818
		N	168	168	168
	pH in each station	Correlation Coefficient	.158*	1.000	.426**
		Sig. (2-tailed)	.040	.	.000
		N	168	168	168
	Dissolve oxygen in each station (mg/l)	Correlation Coefficient	-.018	.426**	1.000
		Sig. (2-tailed)	.818	.000	.
		N	168	168	168
	Water temperature in each station	Correlation Coefficient	.297**	.195*	-.132
		Sig. (2-tailed)	.000	.011	.089
		N	168	168	168
	Salinity in each station	Correlation Coefficient	.040	.278**	.661**
		Sig. (2-tailed)	.608	.000	.000
		N	168	168	168

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Nonparametric correlations test between razor clam density and %OM

Correlations

			Density of razor clam/sq. m. in each station	%OM in each station
Kendall's tau_b	Density of razor clam/sq. m. in each station	Correlation Coefficient	1.000	-.515**
		Sig. (2-tailed)	.	.000
		N	168	168
	%OM in each station	Correlation Coefficient	-.515**	1.000
		Sig. (2-tailed)	.000	.
		N	168	168
Spearman's rho	Density of razor clam/sq. m. in each station	Correlation Coefficient	1.000	-.662**
		Sig. (2-tailed)	.	.000
		N	168	168
	%OM in each station	Correlation Coefficient	-.662**	1.000
		Sig. (2-tailed)	.000	.
		N	168	168

**. Correlation is significant at the 0.01 level (2-tailed).

Nonparametric correlations test between razor clam density and soil compositions

Correlations

			Density of razor clam/sq. m. in each station	Percentage of sand in each station
Kendall's tau_b	Density of razor clam/sq. m. in each station	Correlation Coefficient	1.000	.445**
		Sig. (2-tailed)	.	.000
		N	168	168
	Percentage of sand in each station	Correlation Coefficient	.445**	1.000
		Sig. (2-tailed)	.000	.
		N	168	168
	Percentage of silt in each station	Correlation Coefficient	-.366**	-.782**
		Sig. (2-tailed)	.000	.000
		N	168	168
	Percentage of clay ineachstation	Correlation Coefficient	-.456**	-.708**
		Sig. (2-tailed)	.000	.000
		N	168	168
Spearman's rho	Density of razor clam/sq. m. in each station	Correlation Coefficient	1.000	.572**
		Sig. (2-tailed)	.	.000
		N	168	168
	Percentage of sand in each station	Correlation Coefficient	.572**	1.000
		Sig. (2-tailed)	.000	.
		N	168	168
	Percentage of silt in each station	Correlation Coefficient	-.474**	-.922**
		Sig. (2-tailed)	.000	.000
		N	168	168
	Percentage of clay ineachstation	Correlation Coefficient	-.580**	-.865**
		Sig. (2-tailed)	.000	.000
		N	168	168

**. Correlation is significant at the 0.01 level (2-tailed).

Mean razor clam density in each soil type

Kruskal-Wallis Test

Ranks

	Type of Soil	N	Mean Rank
Density of razor clam/sq. m. in each station	Fine sand	84	107.39
	Loamy fine sansand	46	70.97
	Fine sandy loam	38	50.28
	Total	168	

Test Statistics[a,b]

	Density of razor clam/sq. m. in each station
Chi-Square	49.523
df	2
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Type of Soil

Nonparametric correlations test between razor clam density and particulate sediment, POC

Correlations

			Density of razor clam/sq. m. in each station	POC in each station (µg/l)	Particulate sediment in each station (mg/l)
Kendall's tau_b	Density of razor clam/sq. m. in each station	Correlation Coefficient	1.000	-.097	-.183**
		Sig. (2-tailed)	.	.093	.002
		N	168	168	168
	POC in each station (µg/l)	Correlation Coefficient	-.097	1.000	.334**
		Sig. (2-tailed)	.093	.	.000
		N	168	168	168
	Particulate sediment in each station (mg/l)	Correlation Coefficient	-.183**	.334**	1.000
		Sig. (2-tailed)	.002	.000	.
		N	168	168	168
Spearman's rho	Density of razor clam/sq. m. in each station	Correlation Coefficient	1.000	-.125	-.246**
		Sig. (2-tailed)	.	.107	.001
		N	168	168	168
	POC in each station (µg/l)	Correlation Coefficient	-.125	1.000	.486**
		Sig. (2-tailed)	.107	.	.000
		N	168	168	168
	Particulate sediment in each station (mg/l)	Correlation Coefficient	-.246**	.486**	1.000
		Sig. (2-tailed)	.001	.000	.
		N	168	168	168

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix D: Three cluster analysis for the factors correlated with razor clam density

Specific 3 clusters analysis for water pH

Jun 08 (Trip 1)

Cluster Membership

Case Number	NameSta	Cluster	Distance
1	A1	3	.077
2	A2	2	.005
3	B1	3	.061
4	B2	2	.005
5	B3	2	.010
6	C1	3	.000
7	C2	1	.020
8	C3	1	.102
9	C4	1	.072
10	D1	3	.000
11	D2	3	.015
12	D3	1	.082
13	D4	1	.036
14	D5	1	.036

Jul 08 (Trip 2)

Cluster Membership

Case Number	NameSta	Cluster	Distance
15	A1	2	.035
16	A2	2	.026
17	B1	2	.026
18	B2	2	.026
19	B3	2	.026
20	C1	2	.026
21	C2	2	.026
22	C3	2	.051
23	C4	2	.066
24	D1	3	.051
25	D2	3	.010
26	D3	1	.000
27	D4	3	.041
28	D5	2	.005

Aug 08 (Trip 3)

Cluster Membership

Case Number	NameSta	Cluster	Distance
29	A1	1	.036
30	A2	2	.008
31	B1	3	.000
32	B2	2	.023
33	B3	2	.008
34	C1	3	.046
35	C2	2	.023
36	C3	2	.023
37	C4	1	.026
38	D1	2	.069
39	D2	3	.046
40	D3	2	.023
41	D4	2	.008
42	D5	1	.010

Sep 08 (Trip 4)

Cluster Membership

Case Number	NameSta	Cluster	Distance
43	A1	3	.061
44	A2	3	.231
45	B1	3	.584
46	B2	2	.486
47	B3	2	.221
48	C1	2	.329
49	C2	2	.298
50	C3	2	.083
51	C4	2	.071
52	D1	3	.323
53	D2	2	.640
54	D3	2	.267
55	D4	1	.000
56	D5	3	.031

Oct 08 (Trip 5)

Cluster Membership

Case Number	NameSta	Cluster	Distance
57	A1	3	.409
58	A2	2	.223
59	B1	3	.578
60	B2	3	.409
61	B3	3	.344
62	C1	1	.503
63	C2	3	.513
64	C3	3	.621
65	C4	2	.223
66	D1	1	.342
67	D2	1	.111
68	D3	1	.050
69	D4	3	.221
70	D5	3	.302

Nov 08 (Trip 6)

Cluster Membership

Case Number	NameSta	Cluster	Distance
71	A1	1	.158
72	A2	1	.011
73	B1	1	.088
74	B2	1	.119
75	B3	1	.134
76	C1	3	.238
77	C2	3	.177
78	C3	1	.042
79	C4	3	.161
80	D1	3	.100
81	D2	2	.000
82	D3	3	.177
83	D4	1	.235
84	D5	3	.177

Dec 08 (Trip 7)

Cluster Membership

Case Number	NameSta	Cluster	Distance
85	A1	3	.015
86	A2	3	.046
87	B1	3	.031
88	B2	1	.052
89	B3	1	.052
90	C1	1	.040
91	C2	1	.083
92	C3	2	.072
93	C4	1	.067
94	D1	1	.086
95	D2	2	.005
96	D3	1	.086
97	D4	2	.067
98	D5	1	.040

Jan 09 (Trip 8)

Cluster Membership

Case Number	NameSta	Cluster	Distance
99	A1	1	.005
100	A2	1	.041
101	B1	2	.004
102	B2	2	.035
103	B3	1	.036
104	C1	3	.008
105	C2	2	.035
106	C3	2	.020
107	C4	2	.042
108	D1	3	.038
109	D2	3	.008
110	D3	3	.023
111	D4	2	.011
112	D5	2	.042

Feb 09 (Trip 9)

Cluster Membership

Case Number	NameSta	Cluster	Distance
113	A1	1	.061
114	A2	1	.015
115	B1	1	.015
116	B2	3	.013
117	B3	1	2.220E-16
118	C1	3	.033
119	C2	1	2.220E-16
120	C3	1	.031
121	C4	3	.003
122	D1	1	2.220E-16
123	D2	3	.003
124	D3	3	.003
125	D4	3	.028
126	D5	2	.000

Mar 09 (Trip 10)

Cluster Membership

Case Number	NameSta	Cluster	Distance
127	A1	2	.008
128	A2	2	.023
129	B1	2	.008
130	B2	3	.020
131	B3	3	.010
132	C1	2	.008
133	C2	3	.020
134	C3	3	.010
135	C4	3	.005
136	D1	1	.000
137	D2	3	.010
138	D3	3	.010
139	D4	3	.010
140	D5	3	.005

Apr 09 (Trip 11)

Cluster Membership

Case Number	NameSta	Cluster	Distance
141	A1	1	.115
142	A2	2	.120
143	B1	2	.120
144	B2	2	.018
145	B3	1	.008
146	C1	2	.095
147	C2	3	.203
148	C3	2	.126
149	C4	3	.012
150	D1	1	.069
151	D2	3	.228
152	D3	3	.157
153	D4	3	.120
154	D5	1	.038

May 09 (Trip 12)

Cluster Membership

Case Number	NameSta	Cluster	Distance
155	A1	1	.000
156	A2	2	.109
157	B1	2	.017
158	B2	2	.244
159	B3	2	.309
160	C1	3	.019
161	C2	3	.104
162	C3	2	.125
163	C4	2	.167
164	D1	2	.075
165	D2	3	.004
166	D3	2	.121
167	D4	3	.081
168	D5	2	.048

<u>Specific 3 clusters for water temp</u>

Jun 08 (Trip 1)

Cluster Membership

Case Number	NameSta	Cluster	Distance
1	A1	1	.045
2	A2	3	.040
3	B1	1	.045
4	B2	3	.027
5	B3	3	.027
6	C1	1	.045
7	C2	3	.040
8	C3	3	.027
9	C4	2	.000
10	D1	1	.022
11	D2	1	.022
12	D3	1	.089
13	D4	2	.000
14	D5	2	.000

Jul 08 (Trip 2)

Cluster Membership

Case Number	NameSta	Cluster	Distance
15	A1	1	.033
16	A2	1	.033
17	B1	1	.033
18	B2	3	.033
19	B3	3	.033
20	C1	1	.033
21	C2	2	.050
22	C3	2	.017
23	C4	3	.033
24	D1	3	.033
25	D2	3	.033
26	D3	3	.033
27	D4	2	.017
28	D5	2	.017

Aug 08 (Trip 3)

Cluster Membership

Case Number	NameSta	Cluster	Distance
29	A1	1	.277
30	A2	1	.010
31	B1	1	.010
32	B2	1	.124
33	B3	1	.124
34	C1	1	.010
35	C2	3	.134
36	C3	3	.067
37	C4	3	.134
38	D1	1	.057
39	D2	3	.134
40	D3	3	.201
41	D4	2	.000
42	D5	3	.000

Sep 08 (Trip 4)

Cluster Membership

Case Number	NameSta	Cluster	Distance
43	A1	1	.000
44	A2	2	.020
45	B1	2	.020
46	B2	2	.020
47	B3	1	.000
48	C1	1	.000
49	C2	2	.020
50	C3	2	.020
51	C4	2	.020
52	D1	3	.000
53	D2	2	.047
54	D3	2	.047
55	D4	2	.020
56	D5	2	.047

Oct 08 (Trip 5)

Cluster Membership

Case Number	NameSta	Cluster	Distance
57	A1	1	.096
58	A2	2	.033
59	B1	2	.100
60	B2	2	.033
61	B3	2	.100
62	C1	1	.096
63	C2	2	.100
64	C3	2	.033
65	C4	1	.029
66	D1	1	.105
67	D2	3	.000
68	D3	1	.105
69	D4	1	.029
70	D5	1	.038

Nov 08 (Trip 6)

Cluster Membership

Case Number	NameSta	Cluster	Distance
71	A1	2	.022
72	A2	2	.045
73	B1	3	.017
74	B2	3	.017
75	B3	2	.022
76	C1	1	.000
77	C2	3	.050
78	C3	2	.045
79	C4	2	.022
80	D1	2	.045
81	D2	2	.022
82	D3	2	.022
83	D4	2	.022
84	D5	3	.017

Dec 08 (Trip 7)

Cluster Membership

Case Number	NameSta	Cluster	Distance
85	A1	1	2.220E-16
86	A2	2	.000
87	B1	1	2.220E-16
88	B2	1	2.220E-16
89	B3	3	.000
90	C1	1	2.220E-16
91	C2	1	2.220E-16
92	C3	1	2.220E-16
93	C4	1	2.220E-16
94	D1	1	2.220E-16
95	D2	1	2.220E-16
96	D3	1	2.220E-16
97	D4	1	2.220E-16
98	D5	3	.000

Jan 09 (Trip 8)

Cluster Membership

Case Number	NameSta	Cluster	Distance
99	A1	1	.045
100	A2	2	.022
101	B1	3	.142
102	B2	3	.125
103	B3	3	.125
104	C1	3	.008
105	C2	3	.075
106	C3	3	.075
107	C4	2	.045
108	D1	1	.089
109	D2	1	.045
110	D3	3	.008
111	D4	3	.059
112	D5	2	.022

Feb 09 (Trip 9)

Cluster Membership

Case Number	NameSta	Cluster	Distance
113	A1	1	.000
114	A2	2	.022
115	B1	1	.000
116	B2	3	.000
117	B3	3	.000
118	C1	3	.000
119	C2	1	.000
120	C3	3	.000
121	C4	2	.045
122	D1	1	.000
123	D2	3	.000
124	D3	3	.000
125	D4	3	.000
126	D5	2	.022

Mar 09 (Trip 10)

Cluster Membership

Case Number	NameSta	Cluster	Distance
127	A1	1	.022
128	A2	2	.033
129	B1	1	.045
130	B2	2	.033
131	B3	2	.033
132	C1	1	.022
133	C2	2	.033
134	C3	3	.019
135	C4	3	.048
136	D1	3	.019
137	D2	3	.019
138	D3	3	.019
139	D4	3	.019
140	D5	3	.048

Apr 09 (Trip 11)

Cluster Membership

Case Number	NameSta	Cluster	Distance
141	A1	1	.000
142	A2	2	.075
143	B1	3	.067
144	B2	2	.075
145	B3	3	9.992E-16
146	C1	3	.067
147	C2	3	.067
148	C3	2	.059
149	C4	2	.008
150	D1	2	.125
151	D2	2	.008
152	D3	2	.008
153	D4	2	.008
154	D5	3	.067

May 09 (Trip 12)

Cluster Membership

Case Number	NameSta	Cluster	Distance
155	A1	3	.045
156	A2	2	.104
157	B1	2	.037
158	B2	2	.037
159	B3	2	.037
160	C1	3	.089
161	C2	1	.033
162	C3	2	.104
163	C4	1	.033
164	D1	3	.045
165	D2	2	.097
166	D3	2	.097
167	D4	2	.097
168	D5	2	.030

Specific 3 clusters analysis for soil organic matter

Jun 08 (Trip 1)

Cluster Membership

Case Number	NameSta	Cluster	Distance
1	A1	3	.356
2	A2	3	.326
3	B1	3	.023
4	B2	2	.163
5	B3	2	.027
6	C1	3	.053
7	C2	2	.200
8	C3	2	.103
9	C4	2	.238
10	D1	1	.038
11	D2	1	.038
12	D3	3	.061
13	D4	2	.027
14	D5	2	.444

Jul 08 (Trip 2)

Cluster Membership

Case Number	NameSta	Cluster	Distance
15	A1	1	.095
16	A2	2	.287
17	B1	3	1.405E-16
18	B2	2	.135
19	B3	2	.060
20	C1	1	.171
21	C2	2	.211
22	C3	3	.265
23	C4	2	.054
24	D1	3	.265
25	D2	1	.360
26	D3	1	.284
27	D4	2	.282
28	D5	2	.358

Aug 08 (Trip 3)

Cluster Membership

Case Number	NameSta	Cluster	Distance
29	A1	3	.046
30	A2	2	.204
31	B1	3	.311
32	B2	2	.090
33	B3	2	.137
34	C1	3	.182
35	C2	2	.062
36	C3	2	.090
37	C4	2	.052
38	D1	3	.144
39	D2	1	.000
40	D3	3	.030
41	D4	2	.251
42	D5	2	.014

Sep 08 (Trip 4)

Cluster Membership

Case Number	NameSta	Cluster	Distance
43	A1	3	.121
44	A2	2	.147
45	B1	3	.447
46	B2	2	.005
47	B3	2	.081
48	C1	3	.159
49	C2	2	.147
50	C3	2	.261
51	C4	2	.109
52	D1	3	.030
53	D2	1	.000
54	D3	3	.197
55	D4	2	.194
56	D5	2	.384

Oct 08 (Trip 5)

Cluster Membership

Case Number	NameSta	Cluster	Distance
57	A1	1	.000
58	A2	2	.068
59	B1	3	.303
60	B2	3	.152
61	B3	2	.258
62	C1	3	.114
63	C2	2	.690
64	C3	3	.152
65	C4	3	.265
66	D1	2	.372
67	D2	3	.114
68	D3	3	.303
69	D4	3	.038
70	D5	2	.008

Nov 08 (Trip 6)

Cluster Membership

Case Number	NameSta	Cluster	Distance
71	A1	1	.291
72	A2	2	.271
73	B1	3	.114
74	B2	2	.108
75	B3	2	.108
76	C1	3	.265
77	C2	2	.157
78	C3	3	.228
79	C4	2	.043
80	D1	1	.506
81	D2	1	.215
82	D3	3	.152
83	D4	2	.146
84	D5	2	.108

Dec 08 (Trip 7)

Cluster Membership

Case Number	NameSta	Cluster	Distance
85	A1	2	.016
86	A2	2	.287
87	B1	2	.168
88	B2	1	.000
89	B3	2	.932
90	C1	3	.600
91	C2	2	.206
92	C3	3	.006
93	C4	3	.006
94	D1	2	.022
95	D2	3	.411
96	D3	2	.850
97	D4	3	.259
98	D5	3	1.258

Jan 09 (Trip 8)

Cluster Membership

Case Number	NameSta	Cluster	Distance
99	A1	1	.028
100	A2	2	.185
101	B1	3	.114
102	B2	2	.194
103	B3	2	.005
104	C1	1	.066
105	C2	2	.299
106	C3	2	.071
107	C4	2	.412
108	D1	1	.028
109	D2	1	.123
110	D3	3	.114
111	D4	2	.308
112	D5	2	.460

Feb 09 (Trip 9)

Cluster Membership

Case Number	NameSta	Cluster	Distance
113	A1	1	.281
114	A2	2	.238
115	B1	3	.038
116	B2	2	.238
117	B3	2	.352
118	C1	1	.470
119	C2	3	.038
120	C3	2	.049
121	C4	2	.011
122	D1	1	.015
123	D2	1	.781
124	D3	1	.015
125	D4	2	.217
126	D5	2	.672

Mar 09 (Trip 10)

Cluster Membership

Case Number	NameSta	Cluster	Distance
127	A1	1	.303
128	A2	2	.076
129	B1	3	.114
130	B2	2	.341
131	B3	2	.038
132	C1	1	.190
133	C2	3	.303
134	C3	2	.038
135	C4	3	.114
136	D1	1	.038
137	D2	1	.531
138	D3	3	.303
139	D4	2	.152
140	D5	2	.341

Apr 09 (Trip 11)

Cluster Membership

Case Number	NameSta	Cluster	Distance
141	A1	3	.373
142	A2	2	.293
143	B1	3	.651
144	B2	2	.027
145	B3	2	.027
146	C1	3	.107
147	C2	3	.070
148	C3	2	.065
149	C4	2	.065
150	D1	3	.259
151	D2	1	.000
152	D3	3	.158
153	D4	2	.087
154	D5	2	.390

May 09 (Trip 12)

Cluster Membership

Case Number	NameSta	Cluster	Distance
155	A1	1	.190
156	A2	2	.043
157	B1	3	.256
158	B2	2	.005
159	B3	2	.222
160	C1	3	.104
161	C2	1	.190
162	C3	2	.081
163	C4	2	.108
164	D1	3	.028
165	D2	3	.389
166	D3	1	1.665E-16
167	D4	2	.005
168	D5	2	.195

Specific 3 clusters analysis for particulate sediment

Jun 08 (Trip 1)

Cluster Membership

Case Number	NameSta	Cluster	Distance
1	A1	2	.042
2	A2	2	.042
3	B1	3	.037
4	B2	3	.021
5	B3	3	.093
6	C1	3	.002
7	C2	3	.072
8	C3	3	.005
9	C4	3	.009
10	D1	3	.081
11	D2	3	.069
12	D3	1	.000
13	D4	3	.002
14	D5	3	.030

Jul 08 (Trip 2)

Cluster Membership

Case Number	NameSta	Cluster	Distance
15	A1	1	.001
16	A2	1	.015
17	B1	1	.027
18	B2	3	.098
19	B3	3	.045
20	C1	3	.024
21	C2	1	.083
22	C3	3	.013
23	C4	3	.064
24	D1	1	.022
25	D2	2	.000
26	D3	1	.057
27	D4	1	.212
28	D5	1	.036

Aug 08 (Trip 3)

Cluster Membership

Case Number	NameSta	Cluster	Distance
29	A1	3	.017
30	A2	2	.020
31	B1	3	.034
32	B2	1	.033
33	B3	1	.036
34	C1	2	.019
35	C2	1	.003
36	C3	2	.015
37	C4	3	.025
38	D1	2	.017
39	D2	2	.002
40	D3	3	.011
41	D4	3	.008
42	D5	3	.006

Sep 08 (Trip 4)

Cluster Membership

Case Number	NameSta	Cluster	Distance
43	A1	1	.029
44	A2	2	.041
45	B1	1	.005
46	B2	3	.038
47	B3	1	.027
48	C1	1	.021
49	C2	3	.006
50	C3	3	.057
51	C4	1	.054
52	D1	2	.045
53	D2	1	.025
54	D3	1	.058
55	D4	3	.024
56	D5	2	.004

Oct 08 (Trip 5)

Cluster Membership

Case Number	NameSta	Cluster	Distance
57	A1	2	.380
58	A2	2	.352
59	B1	2	.732
60	B2	1	.362
61	B3	1	.362
62	C1	3	.111
63	C2	3	.700
64	C3	3	.164
65	C4	3	.008
66	D1	3	.259
67	D2	3	.164
68	D3	3	.039
69	D4	3	.067
70	D5	3	.109

Nov 08 (Trip 6)

Cluster Membership

Case Number	NameSta	Cluster	Distance
71	A1	1	.000
72	A2	3	.002
73	B1	3	.135
74	B2	3	.019
75	B3	2	.031
76	C1	3	.153
77	C2	2	.140
78	C3	2	.014
79	C4	2	.055
80	D1	2	.139
81	D2	2	.040
82	D3	2	.093
83	D4	2	.003
84	D5	2	.059

Dec 08 (Trip 7)

Cluster Membership

Case Number	NameSta	Cluster	Distance
85	A1	1	.045
86	A2	1	.057
87	B1	1	.008
88	B2	1	.052
89	B3	1	.018
90	C1	3	.048
91	C2	3	.053
92	C3	1	.034
93	C4	3	.054
94	D1	3	.026
95	D2	3	.038
96	D3	2	.000
97	D4	1	.048
98	D5	3	.018

Jan 09 (Trip 8)

Cluster Membership

Case Number	NameSta	Cluster	Distance
99	A1	1	.002
100	A2	2	.021
101	B1	3	.029
102	B2	2	.001
103	B3	1	.000
104	C1	3	.020
105	C2	3	.017
106	C3	1	.002
107	C4	3	.022
108	D1	3	.003
109	D2	3	.011
110	D3	2	.039
111	D4	2	.007
112	D5	2	.010

Feb 09 (Trip 9)

Cluster Membership

Case Number	NameSta	Cluster	Distance
113	A1	1	.090
114	A2	2	.646
115	B1	1	.389
116	B2	3	.558
117	B3	2	.317
118	C1	2	.152
119	C2	3	.437
120	C3	2	.329
121	C4	1	.605
122	D1	3	.121
123	D2	2	.580
124	D3	2	.428
125	D4	1	.132
126	D5	1	.438

Mar 09 (Trip 10)

Cluster Membership

Case Number	NameSta	Cluster	Distance
127	A1	2	.057
128	A2	2	.082
129	B1	3	.000
130	B2	2	.011
131	B3	2	.020
132	C1	2	.041
133	C2	2	.054
134	C3	1	.055
135	C4	2	.070
136	D1	2	.041
137	D2	1	.055
138	D3	2	.026
139	D4	2	.043
140	D5	2	.018

Apr 09 (Trip 11)

Cluster Membership

Case Number	NameSta	Cluster	Distance
141	A1	1	.016
142	A2	2	.017
143	B1	3	.006
144	B2	3	.020
145	B3	2	.015
146	C1	1	.016
147	C2	2	.023
148	C3	2	.015
149	C4	3	.012
150	D1	2	.005
151	D2	2	.009
152	D3	2	.010
153	D4	3	.026
154	D5	3	.011

May 09 (Trip 12)

Cluster Membership

Case Number	NameSta	Cluster	Distance
155	A1	1	.051
156	A2	2	.010
157	B1	1	.067
158	B2	1	.023
159	B3	2	.007
160	C1	1	.058
161	C2	3	.000
162	C3	2	.004
163	C4	2	.102
164	D1	1	.091
165	D2	1	.009
166	D3	2	.032
167	D4	2	.058
168	D5	2	.011

Appendix E: Fisherman interview details

The following are the answer from each fisherman:

1. Mr. Chalol (46 years ole) and Mrs. Nongyao (43 years old) Thanomchart

Q1. When did you start harvest razor clam?

Chalol: I started harvesting razor clam since I was a teenager around 30 year ago

Nongyao: Around when I was 14 years old

Q2: Are you going to harvest razor clam regularly since you start harvesting?

Chalol: Yes almost fifteen year ago I went to Middle East to be a crew of Korean fishing ship for 2 years and it not worth so I get back to razor clam again. While Nongyao has been continue since she started harvesting.

Q3: Which technique do you use to catch razor clam?

Chalol and Nongyao: We are using lime and adding some caustic soda because if I use lime only the clams usually not jump out from their hole when I put lime to its hole. Everyone use the same with us. But I hear from former head of village that they will prohibit caustic soda. For us it OK because comparing with other guy from another village we use it not so much as other.

Q4: How long did you harvest razor clam? (in average)

Chalol and Nongyao: It to difficult to tell exactly time or how long. It around 4 hrs/day.

10 days per moon phase let say 20 days per month. Around 10 months per year because there are another fishing activity along the year.

Q5: What are your reasons to spend more or less time than average when you harvest razor clam?

Chalol and Nongyao: Many reasons, weather is hot or not, cold or warmth? Raining or not? Etc.

Q6: How much razor clam can you harvest in each day? (average)

Chalol and Nongyao: Right now is around 3-4 kg/day. The maximum was over 20-30 kg. per day around 20 years ago. That time we used spread lime solution method the price of lime is worth to invest but nowadays is not worth anymore. The minimum is 0-0.5 kg. The last time that we harvest less like that is last year.

Q7: Do you keep record your harvest? If yes get data?

Chalol and Nongyao: No. we just observe another fisherman when they harvest or asking them. Sometime we go somewhere else to test weather razor clam abundance.

Q8: Where did you go to harvest?

Chalol and Nongyao: Last week we went to Don Nork and this week we still harvest the same place but last month we went to Sam Kha.

Q9: What did you do with harvested clam?

Chalol and Nongyao: We usually sell the clam to the same trader but sometime if our niece asking to buy the clam from us we will sell to her.

Q10: How much can you earn from razor clam in each day (average)?

Chalol and Nongyao: It not difference because the razor clam price. Let assume around 400-500 baht from both of us during day low tide while night low tide we can earn around 400 baht per night. Sometime in night low tide period our fried hire us to help them in crab fishery it can earn the same amount with razor clam but it more easier because we work at day and sleep at night or we do both as a labor and clam harvesting if clam price is good,

Q11: In the recent, did you change the way you decide to go harvesting razor clam?

Chalol and Nongyao: How long of recent you mean? We just come back to razor clam not over 3 months before we talk each other. Last year (2008) we stopped harvest razor clam for several months. We went to sandbar and looking for another species such as tiger moon shell but razor clam.

Q12: Could you specific harvesting location in each month in year round?

Chalol and Nongyao: No, as we said before we never know exactly the place before we reach sandbar. If harvesting yield is good for today tomorrow we will go the same place or near the same place. However, if it not good we go to another place and test it or looking and asking our friend where we should go.

Q13: Regarding the way of your harvesting, how do you feel about razor clam at Don Hoi Lord since you started harvest until now?

Chalol and Nongyao: Decreasing all the time. In the past 15-20 kg was easy for us. Currently, it impossible to harvest reach the same yield as the past. We have to do another job such as to be a labor in crab fishery or harvest another species on the sandbar or go to fish in the sea. However, razor clam is our first priority to be a job because comparing with another job razor clam harvesting is more comfortable than another.

Q14: What will you suggest to solve the razor clam reduction?

Chalol and Nongyao: We don't know how to sole the problem. Stop using caustic soda it might be good but everybody must stop using. Closing some zone as you said 3-4 years ago that would be good.

Q15: How many fishermen who harvest razor clam do you know?

Chalol and Nongyao: Around 10-15 people. 10 people they live in this village you can ask from former head of village. Five people live in another village for example Mun, Noiy, Kong, Jeab they live in Wat Sattha area and Ruang live in Wat Bangjakreng.

Q16: Do you usually see other fisherman when you are harvesting?

Chalol and Nongyao: Yes, we usually see them during harvesting. Sometime we go to harvest together not closed but we can chitchat each other it making us not feel lonely.

Q17: How much fisherman do they harvest razor clam in average?

Chalol and Nongyao: Nowadays is around 10 -20 is not so much as the past. We remember in the past around 15-20 year ago it almost 200 fishermen on the sandbar.

Q18: How much percentage do you know them?

Chalol and Nongyao: 60-80%

Q19: How do you feel about the number of fisherman who harvests razor clam?

Chalol and Nongyao: It less number of fisherman. We understand because there are less razor clam if someone come to harvest and they not satisfy they stop harvest razor clam and go to another job.

Q20: Have you heard about the companion modeling workshops organized 5 years ago?

Chalol and Nongyao: Yes, we were participated the workshop. We think about benefit of what we discuss but no one follow it. I know Jo (former head of village) tried to tell Governor. In addition, former head of village usually comes to talk with me (Chalol) when he need some criticize from razor clam harvester. TAO attended the workshop 5 years ago but we did not see any actions from TAO.

Q21: In your opinion, should management rules of razor clam fishery be introduced?

Chalol and Nongyao: Difficult to say about should or should not. But if everyone agree on the regulation we will follow them.

2 Mrs. Rungruang Arthaya (38 years old)

Q1. When did you start harvest razor clam?

Rungruang: I started harvest razor clam since I was a kid around 7 years old. I went to the sandbar with my relative or my parent but I could harvest razor clam as a job when I was around 17 years old.

Q2: Are you going to harvest razor clam regularly since you start harvesting?

Rungruang: Yes, I has been continued harvest clam since that time. However, it not year long to harvest razor clam because sometime I stop harvesting if it not worth to harvest.

Q3: Which technique do you use to catch razor clam?

Rungruang: Lime and mixing with caustic soda. I just use the soda last year. I feel that if not use soda clam will not jump from its hole quickly. Everybody use so I have to use it as other.

Q4: How long did you harvest razor clam? (in average)

Rungruang: It not exactly the time I can tell you how long in each day. In each day it around 4-5 hours. One month I go to harvest around 20 days. And in a year it almost 10-11 months. Some year I could harvest all year long if razor clam is high abundance.

Q5: What are your reasons to spend more or less time than average when you harvest razor clam?

Rungruang: Plenty of causes which affect razor clam harvesting. Weather is one of major cause someday is raining, hot weather, cool weather. Someday there is strong wind that it connecting with level of low tide. In day low tide if the weather is hot too much I want to back home while night low tide if the weather is cool too much I want to back home also.

Q6: How much razor clam can you harvest in each day? (average)

Rungruang: Nowadays, it around 2-2.5 kg/day. Maximum harvesting is around 20 kg/day when I was around 20 years old. Minimum harvesting is less than 0.5 kg last year that day I was cooking razor clam from my harvesting because it not enough to sell it.

Q7: Do you keep record your harvest? If yes get data?

Rungruang: No, I don't know why I should record it.

Q8: Where did you go to harvest?

Rungruang: Last week I went to Lhang Don it not high abundance but it worth. Last month I went to Sam khar. It more high abundance everybody go there but few week past there are less abundance and it not worth to go there.

Q9: What did you do with harvested clam?

Rungruang: I sell to the same trader. Sometime my relative or my friend asking me to sell the clam to them I sell it and the trader understands me.

Q10: How much can you earn from razor clam in each day (average)?

Rungruang: Right now is around 250 baht/day. If you ask me in average, day low tide is 250-300 baht/day. Night low tide is around 250 baht. In actually is not exactly amount that I told you. For example Sam Khar last month the first group who found that place high abundance they can earn more than 500 baht/day but few weeks past I could earn less than 200 baht.

Q11: In the recent, did you change the way you decide to go harvesting razor clam?

Rungruang: How much change?, last year there were less razor clam. I stopped harvest razor clam completely for around 8 months it not worth. I got another job such as help my husband to go to fish in the sea or to be labor in another fish business.

Q12: Could you specific harvesting location in each month in year?

Rungruang: No, I can not tell you because I never know where has high clam abundance until somebody go there and got a lot of clam.

Q13: Regarding the way of your harvesting, how do you feel about razor clam at Don Hoi Lord since you started harvest until now?

Rungruang: Decreasing since I started harvest razor clam. In the past I can harvest at least 10 kg/day (more than 15 years ago). I just get back to harvest razor clam several months ago. The density is worth for go to harvesting. However, if comparing from the past it decreasing 100% sure.

Q14: What will you suggest to solve the razor clam reduction?

Rungruang: I don't know. Don't allow caustic soda may be good. I use because everybody used. Several months ago there were rumor about closing sandbar (prohibited harvesting). If it closed we will look for another job.

Q15: How many fishermen who harvests razor clam do you know?

Rungruang: Not to much. Around 15-20 people. Most of them located in this village. I know only their nick name. You can ask former head of village for their name. Not over 5 people live in another village such as Wat Suttha.

Q16: Do you usually see other fisherman when you are harvesting ?

Rungruang: Yes, I usually see them. We usually talk each other if we harvest closed other.

Q17: How much fisherman do they harvest razor clam in average?

Rungruang: 40-50 people maximum. It less than the past it over 100 people from everywhere near Don Hoi Lord. For average is around 20-25 people. The abundance just came back. Most of fisherman stop harvesting last year.

Q18: How much percentage do you know them?
Rungruang: around 70%

Q19: How do you feel about the number of fisherman who harvests razor clam?
Rungruang: Adequate number. There are fewer clams than before. Thus, the number of fisherman decreased also.

Q20: Have you heard about the companion modeling workshops organized 5 years ago?
Rungruang: Yes, Jo told me. We talking about it after workshop and Jo keep talking to me and other about the progressing after workshop finished for few months. The last information I knew the governor keen to do something. Then, this story is silence. Jo told me he was moved to another province. At that time, there are some arguments among fisherman. Most of them look agreed but no action was implied and we still do the same way as we do.

Q21: In your opinion, should management rules of razor clam fishery be introduced?
Rungruang: It should be introduce in my opinion. But I don't know which management rule will accepted by fishermen. Closing some part on sandbar is sound good most of them accepted if it implemented. Some say they (government level) will close all area on sandbar. It's impossible. One rule it recommended is forbidden caustic soda. I also used the soda because everybody uses it. If there is a regulation on this soda and government force it seriously with every fishermen. I will happy to stop using it.

3 Mr. Wirot Chaloklang (37 years old)

Q1. When did you start harvest razor clam?
Wirot: I could harvest razor clam since I was 12 years old. I helped my parent harvesting razor clam.

Q2: Are you going to harvest razor clam regularly since you start harvesting?

Wirot: Yes, almost. Sometime I go to another job when night low tide if it can earn equal or more than razor clam. Two years ago I started a small business to be a razor clam trader but I still harvesting by myself.

Q3: Which technique do you use to catch razor clam?

Wirot: Lime with a little portion of caustic soda. Fishermen from other village mix lime with the soda more proportion than me. When I was a kid and teenager dressing lime solution is popular everybody used this method. It easy and powerful.

Q4: How long did you harvest razor clam? (in average)

Wirot: Since 2 years before, I have been not go to harvest frequently because I have to run my business. Around 3 hrs/day, 10-15 days/month and 10 months/year.

However, if I don't have my business I'll go to harvest the same frequent like other such Chalol.

Q5: What are your reasons to spend more or less time than average when you harvest razor clam?

Wirot: Many reason, Weather, Is hot or not, how long of low tide period? It connecting together. For example, If high temperature and there is no wind. If I can harvest 2 kg (around 150 baht) and I feel very hot I decide to go home even is not high tide time.

Q6: How much razor clam can you harvest in each day?

Wirot: Currently I can harvest around 2 kg/day but I don't take time like other. I have to stop earlier to prepare buying clam from fishermen. Occasionally if there are much more harvested clam I have to stop harvesting because I must manage the clam that I already bought. I'm working with my wife. We don have too much labor like a big trader.

Q7: Do you keep record your harvest? If yes get data?

Wirot: No.

Q8: Where did you go to harvest?

Wirot: Last week I went to Lhang Don and Last month I went to Sam Kha. It long time to go to Sam Kha. I don't go there for 4-5 years. I knew from other that go to harvest there and there are high abundance of clam. For Lung Don I just tried it. Last year I could not harvest because there is no clam.

Q9: What did you do with harvested clam?

Wirot: I process the clam and sell to restaurant and tourist by myself. Before I have been a trader I sell my clam to the same trader.

Q10: How much can you earn from razor clam in each day (average)?

Wirot: around 800-1,000 baht/day from me and my wife. It from our business we harvest by ourselves and buy some clam from other. Process it and distribute it. For night low tide, we can earn around 700-900 baht. Someday in night low tide we can not find enough clams into business we have to keep it in freezer. There are big freezer providers a big trader rent their freezer to keep clam or other sea product. It cost around 5 baht/kg/month. We're not such a big trader. I got an order from restaurant and I try to find razor clam from harvesting and buying. Sometime I got surplus razor clam I have to reduce price for restaurant. From my 2 years experience in razor clam business, the demands of razor clam usually increase during weekend and it not difference between day and night low tide. Last year there is no razor clam from Don Hoi Lord because razor clam absented and fisherman didn't go to harvest razor clam it not worth. They go to another clam such as tiger moon shell, blood cockle etc. even us.

Q11: In the recent, did you change the way you decide to go harvesting razor clam?

Wirot: No, We still do the same way as we do. If razor clam is abundance enough we go harvest razor clam. If it not abundance enough we go to another sea products. As you know last year, there is very less abundance of razor clam. All of razor clam harvester turned to another job. While a big razor clam trader can find razor clam from Chumporn province, and some from Cambodia. I herd that razor clam from outside Don Hoi Lord are not tasty but tourist don't know when It on the disk and ready to eat.

Q12: Could you specific harvesting location in each month in year round ?

Wirot: No. I can not tell you. Because we move follow razor clam abundance. If we know where is high abundance of razor clam? we move to there. Some month we change 3 locations to harvest razor clam. While some place such as Lamk we can harvest more than 2 months if it abundance.

Q13: Regarding the way of your harvesting, how do you feel about razor clam at Don Hoi Lord since you started harvest until now?

Wirot: Decreasing through the time. Last month how much razor clam could you catch during you field trip? (He asked researcher).

Q14: What will you suggest to solve the razor clam reduction?

Wirot: I see all of fishermen use caustic soda. I don't know it can make effect on razor clam reduction. One information board at the pier informs fisherman do not use caustic soda. Guarantee price might be a good way to control harvesting. Due to my business if too much harvested clam I have to reduce price following a big traders. If government helps us to guarantee razor clam price I think we can reduce amount of harvesting per fisherman. That is good to clam population.

Q15: How many fisherman who harvests razor clam do you know?

Wirot: Around 20 people. Most of them I know only nick name. In the village around 10 people and 10 people live another village such as Wat Sattha and Wat Bangjakreng.

Q16: Do you usually see other fisherman when you are harvesting?

Wirot: Yes, I usually see them. If I have an order from restaurant I'll go harvest and inform fisherman that I'm ready to buy clam from them.

Q17: How much fisherman do they harvest razor clam in average?

Wirot: Nowadays, around 30-35 people. It might be 40 in someday. We just continue harvest around 4 months before the clam is coming back to certain abundance again.

Q18: How much percentage do you know them?

Wirot: Let say 70-85% of fishermen who harvest razor clam. Even if I don't know the name but we can talk and asking something during we harvesting for example drinking water, lime etc.

Q19: How do you feel about the number of fisherman who harvests razor clam?

Wirot: Moderately, There are less razor clams why the razor clam harvester decreased following razor clam abundance. Some of them get a job in sea food factory, some to go fish in the sea etc., However, if razor clam back to high abundance again like the past I believe that number of clam harvester will come back again.

Q20: Have you heard about the companion modeling workshops organized 5 years ago?

Wirot: Yes, I was one of participants. At that time, I was not a trader. After the workshop finished we were still talking about it. Jo were working with government about that. I went to the meeting at Wat Sattha where you presented to the governor almost 4 years ago. However, everybody still do the same as they do because government did not do anything seriously to solve razor clam problem.

Q21: In your opinion, should management rules of razor clam fishery be introduced?

Wirot: Yes, we should do something. There is some rumor that the sandbar will closed and don't allow to harvest any species on sandbar. We ague on that because it too much for us. For razor clam is ok for me to forbidden for a while because last year during night low tide no one went to harvest. It can implicate that the sandbar was closed for razor clam harvesting and nature did it. I would suggest another option for razor clam management is to guarantee razor clam price to reduce harvesting. It might be work in my opinion.

4 Mr. Saryun (39 years old) and Mrs. Sutin (37 years old) Aim-Augsorn (Most of interview Sutin usually answers)

Q1. When did you start harvest razor clam?

Saryun and Sutin: I could harvest razor clam sine I was 13 years old and Saryun could harvest sine he was 17 years old. Saryun came from another village and got married with me.

Q2: Are you going to harvest razor clam regularly since you start harvesting?

Saryun and Sutin: Yes, after we got married we have been harvest razor clam as a career. Sometime we go to harvest another clam or to be a labor in another fishery such as blue crab.

Q3: Which technique do you use to catch razor clam?

Saryun and Sutin: Lime and sometime mixing with caustic soda. During we harvest if we feel clam come from its hole slowly then we put caustic soda into lime. At the beginning of our harvesting around 20 years ago we use lime solution if the clam very high abundance. If we use putting lime in clam's hole is not quick enough.

Q4: How long did you harvest razor clam?

Saryun and Sutin: If there are no problems with weather and low tide is normal we spend around 4 hours/day, 20-25 days/month. In a year we go to harvest razor clam around 10-11 years.

Q5: What are your reasons to spend more or less time than average when you harvest razor clam?

Saryun and Sutin: The reasons are connecting together. Weather is good?, How long is low tide? Is razor clam high abundance? Razor clam price high or not?. For example, if razor clam price low and razor clam is not high abundance but the weather is good we can harvest all the time of low tide we will spend more time than average. Another example, in night low tide razor clam price usually high if we can harvest 2-3 kg in 2 hrs but the weather is cool we just stop harvest even there are still more time to harvest because we can earn in satisfy money even if we can harvest more and more. From the last example, if the weather is not cool we will spend more time and we can harvest more than 3 kg.

Q6: How much razor clam can you harvest in each day?

Saryun and Sutin: The past month is around 2.5-3.0 Kg/person. The maximum harvesting it was 30 kg/day when I was around 20 years old. At that time, some body used lime solution method to harvest reach 80-90 kg/day (nearly 1 big rice bag). The worst year in my harvesting is last year. Two of us could harvest less than 1 kg.

Q7: Do you keep record your harvest?

Saryun and Sutin: Yes, I started record around 2004. I'm curious about how much I can harvest and earning exactly in each month.

Q8: Where did you go to harvest?

Saryun and Sutin: Last week I went to Don Nork and Last month I went to Sam Kha. We went to harvest with Mr. Chalol. I heard that there are some razor clams at Lang Don. I think if Don Nork not worth to harvest I will go to harvest at Lang Don.

Q9: What did you do with harvested clam?

Saryun and Sutin: We usually sell to the same trader.

Q10: How much can you earn from razor clam in each day (average)?

Saryun and Sutin: Right now it's around 200-300 baht/person depend on density of razor clam. If we got less than 200 baht/day we will start to look for another job. During night low tide it's less than day around 50 baht. However, someday in night low tide if we found high density area we may earn 500 baht/day because night low tide razor clam price is good.

Q11: In the recent, did you change the way you decide to go harvesting razor clam?

Saryun and Sutin: We don't know weather we changed. If there less razor clam I just go to another kind of clam such as tiger moon shell. Or sometime go to be a labor in our friend's fishery business.

Q12: you specific harvesting location in each month in year round if you continue harvesting?

Saryun and Sutin: Not really, we could not specify exactly. We have 2 options to select where I will go to harvest. First, we follow others or asking our friend. Second, we look in the record book where we went last year or 2 years before then go there and test razor clam density. It usually works with second option. However, we use second option when the current harvesting is not good.

Q13: Regarding the way of your harvesting, how do you feel about razor clam at Don Hoi Lord since you started harvest until now?

Saryun and Sutin: Absolutely decreasing, last year we stop harvesting for a while and this year we can started harvest razor clam again.

Q14: What will you suggest to solve the razor clam reduction?
Saryun and Sutin: Jo talk to us about management by limit size to harvest and don't allow caustic soda. We think that limit size to harvest is good for razor clam because it can reproduce before caught.

Q15: How many fishermen who harvest razor clam do you know?
Saryun and Sutin: Around 20 people, we know their nick name and village. Most of another fisherman we feel familiar with them even we don't know their name but we usually see each other for long time. We can talk each other even we don know name.

Q16: Do you usually see other fisherman when you are harvesting ?
Saryun and Sutin: Yes, we never harvest without people we know.

Q17: How much fisherman do they harvest razor clam in average?
Saryun and Sutin: Currently is around 20-35 people. If the fishing in the sea is not good or there is high abundance of clam we will see more fisherman harvest razor clam.

Q18: How much percentage do you know them?
Saryun and Sutin: It around 60-80% we know them during harvesting.

Q19: How do you feel about the number of fisherman who harvests razor clam?
Saryun and Sutin: It acceptable. Corresponding with amount of razor clam. Comparing with the past, 10 year ago it was around 100 people who harvest razor clam in each day. Some razor clam harvester heading to factory near Don Hoi Lord area it more consistent earning but we don't want to work like that. We prefer harvesting razor clam because is not energy, time invest too much. Every razor clam harvester thinks like this. For example, when less razor clam on sandbar we change to tiger moon shell, we have to walk across sand bar for long distance while razor clam we don't need to walk as tiger moon shell.

Q20: Have you heard about the companion modeling workshops organized 5 years ago?

Saryun and Sutin: Yes, we are one of participant. We talking each other for long time after your workshop finished. Unfortunately, no one follow the suggestion. It is not collective with government. They don't sincere with us to solve resource problem. We're ready to do but how can we do while another do the same thing.

Q21: In your opinion, should management rules of razor clam fishery be introduced?

Saryun and Sutin: It should introduce. Because razor clam is reducing in our opinion. However, we don't know everybody especially government will help us to force the management or not.

Appendix F: Statistical analysis of fisherman harvesting records

Linear regression between mean harvesting rate in each month and number of harvesting day in each month

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.746[a]	.556	.550	1.8697	.805

a. Predictors: (Constant), Number of razor clam catchig day in the month

b. Dependent Variable: Mean razor clam catching/day in the month

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	306.762	1	306.762	87.755	.000[a]
	Residual	244.697	70	3.496		
	Total	551.459	71			

a. Predictors: (Constant), Number of razor clam catchig day in the month

b. Dependent Variable: Mean razor clam catching/day in the month

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.621	.529		1.175	.244
	Number of razor clam catchig day in the month	.213	.023	.746	9.368	.000

a. Dependent Variable: Mean razor clam catching/day in the month

Linear regression between daily harvesting rate and tide level

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.233[a]	.054	.054	.48237	1.281

a. Predictors: (Constant), Catch

b. Dependent Variable: Level of lowest tide (from ThaChin)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20.879	1	20.879	89.733	.000[a]
	Residual	363.908	1564	.233		
	Total	384.787	1565			

a. Predictors: (Constant), Catch

b. Dependent Variable: Level of lowest tide (from ThaChin)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.484	.025		19.735	.000	.435	.532
	Catch	-.033	.004	-.233	-9.473	.000	-.040	-.026

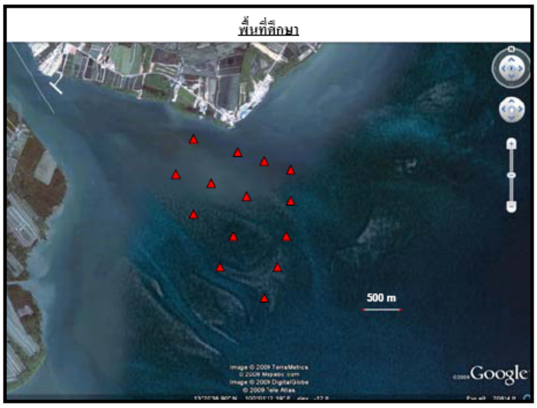
a. Dependent Variable: Level of lowest tide (from ThaChin)

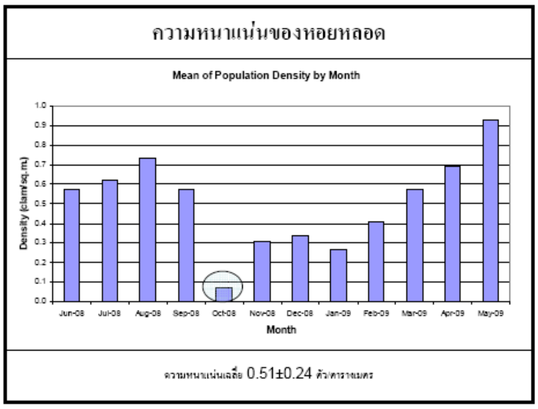
Appendix G: Poster and presentation in Participatory Simulation Workshop

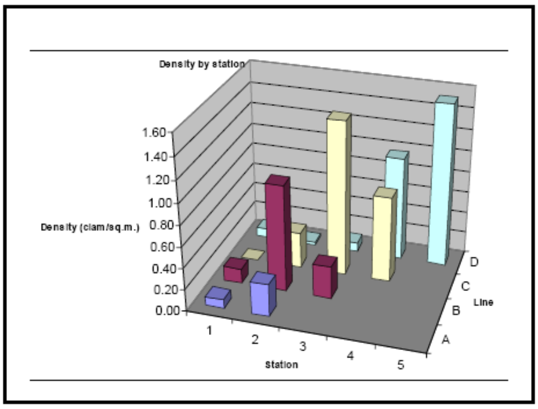
Poster

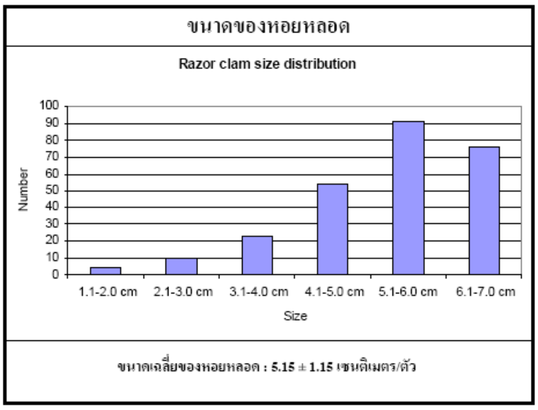
*Actual size in the workshop was A0 (84x119 cm)

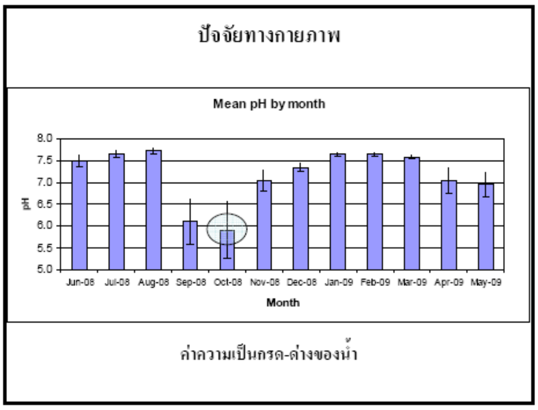
Presentation

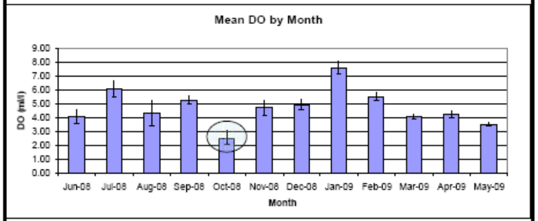






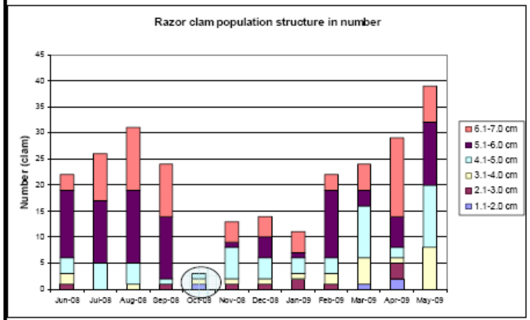






ค่าออกซิเจนละลายน้ำ

สัดส่วนของความยาวหอยหลอด



การลุกล้ำของหอยกะพง

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2		0.67	0.33	
3		1.33	1.00	
4			0.67	1.00
5				1.67

กรกฎาคม 2551

	Line A	Line B	Line C	Line D
1		1.33		
2	0.67	0.33	1.00	
3			1.00	1.00
4			0.33	1.00
5				2.00

สิงหาคม 2551

	Line A	Line B	Line C	Line D
1	0.67	0.33		0.33
2	1.33	1.00	1.00	0.33
3		1.00	0.67	
4			1.00	1.00
5				1.67

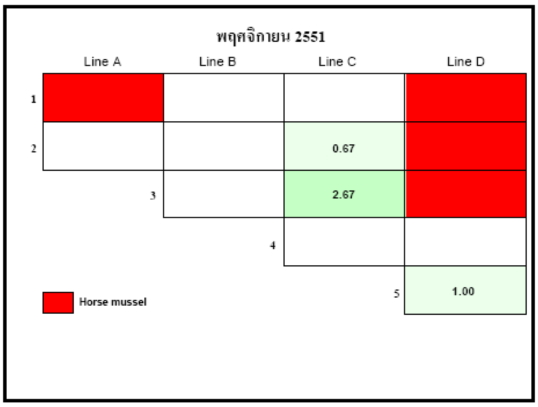
กันยายน 2551

	Line A	Line B	Line C	Line D
1				
2	0.33	1.00	0.33	
3			0.67	
4			0.67	1.33
5				3.67

ตุลาคม 2551

	Line A	Line B	Line C	Line D
1	0.33			
2	0.33			
3				
4				0.33
5				

Horse mussel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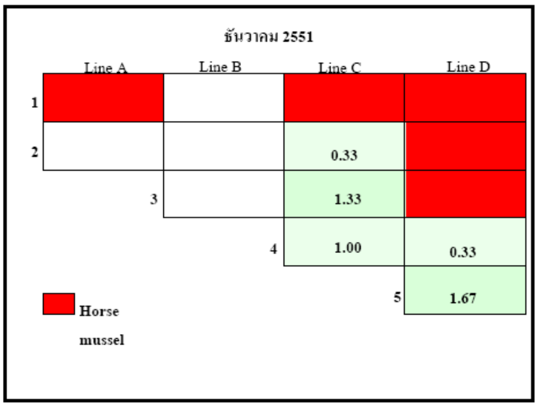
3
2.67
4
5
1.00
Horse mussel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Line C
Line D
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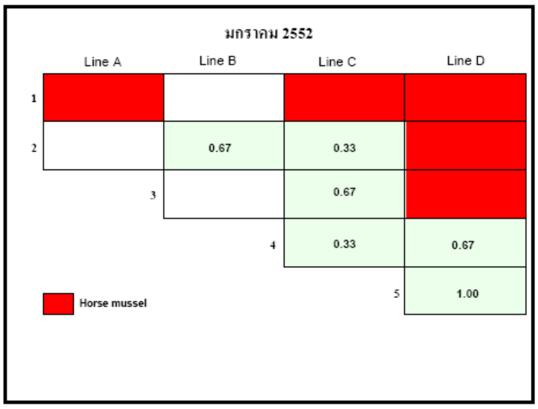
5
1.67
Horse mussel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Line C
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3
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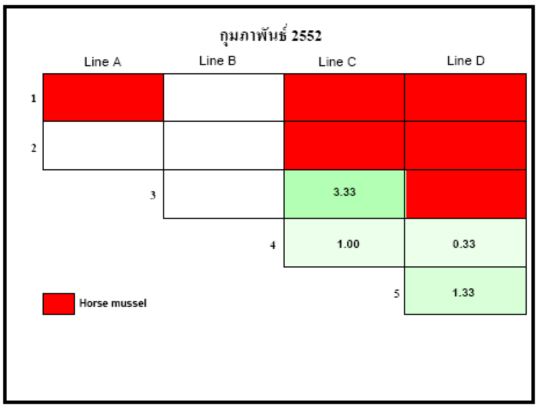
0.67
5
1.00
Horse mussel


กุมภาพันธ์ 2552
Line A
Line B
Line C
Line D
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2
3
3.33
4
1.00
0.33
5
1.33
Horse mussel


มีนาคม 2552
Line A
Line B
Line C
Line D
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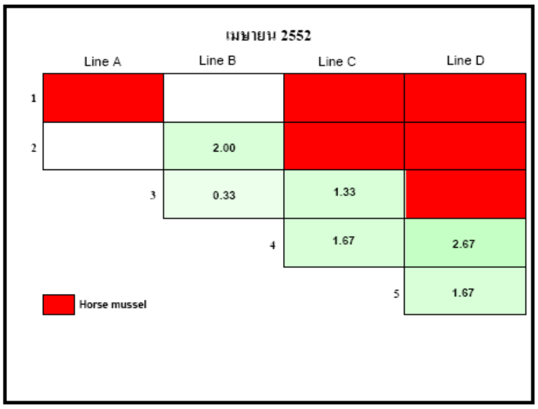
2
2.00
3
2.33
4
1.33
1.00
5
1.33
Horse mussel


เมษายน 2552
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Line B
Line C
Line D
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0.33
1.33
4
1.67
2.67
5
1.67
Horse mussel


พฤษภาคม 2552
Line A
Line B
Line C
Line D
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4
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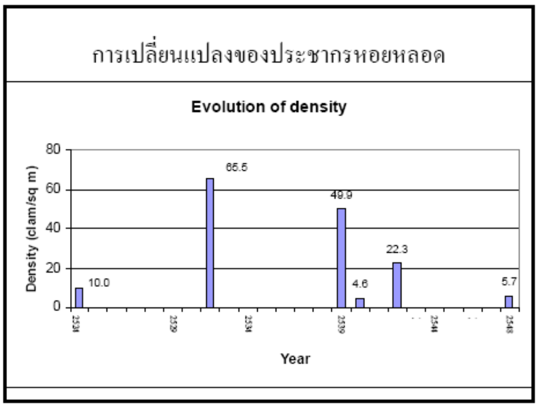
2.00
5
1.33
Horse mussel


การเปลี่ยนแปลงของประชากรหอยหลอด
Evolution of density
Density (clam/sq m)
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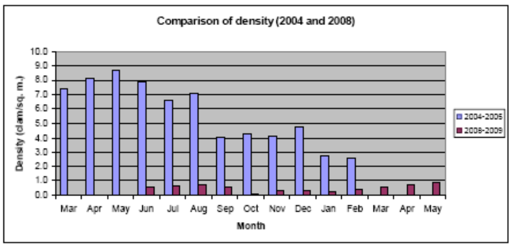
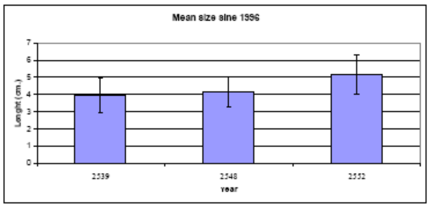
60
40
20
0
10.0
65.5
49.9
4.6
22.3
5.7
Year



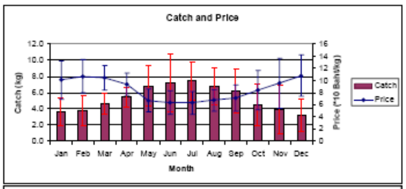
ปี 2548 : 5.71±2.49 ตัว/ตารางเมตร

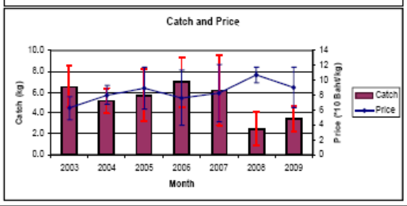
ปี 2552 : 0.51±0.24 ตัว/ตารางเมตร

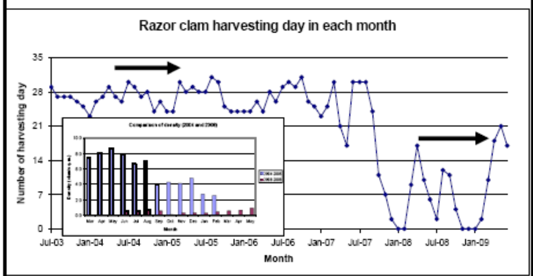
การเปลี่ยนแปลงความยาวของหอยหลอด



กลไกทางตลาด และพฤติกรรมการหยอดหอย







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พฤติกรรมการเดินหยอดหอย

- ได้ระยะทาง 1-2 กิโลเมตรต่อวัน ขึ้นอยู่กับจำนวนหอย
- ใช้เวลาประมาณ 3-4 ชั่วโมง
- ไม่ได้ใช้เวลาน้ำลงทั้งหมด

การนำเสนอแบบจำลอง

- เพื่อรับฟังความเห็นต่อแบบจำลองและร่วมกันพัฒนาแบบจำลอง
- รับข้อเสนอแนะเพิ่มเติม

BIOGRAPHY

The author who is responded for this thesis is Mr. Kobchai Worrapimphong. He was born on April 28th, 1980 at Singburi Province.

He graduated Bachelor of Science in Biology in 2001 from Chulalongkorn University, Bangkok, Thailand. Then, he graduated in Master of Science in Zoology in 2005. During his study in Master degree he got scholarship from The Biodiversity Research and Training Program (BRT) for his thesis in 2003.

After he graduated in 2005, he started his doctorate in the same year in Agricultural Technology Program, Faculty of Science, Chulalongkorn University. He receive scholarship from CIRAD, France and NSF (award number 0601320), USA for duty in research topic “Field experiments on Social and Commons Dilemmas” in 2005-2008. In addition, he got scholarship from The Biodiversity Research and Training Program (BRT) again for his doctorate dissertation in 2008-2009.