COMPANION MODELLING FOR RAZOR CLAM *Solen regularis* CONSERVATION AT DON HOI LORD, SAMUT SONGKHRAM PROVINCE

Mr. Kobchai Worrapimphong

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Zoology
Department of Biology
Faculty of Science
Chulalongkorn University
Academic Year 2005
ISBN 974-53-2018-8

การสร้างแบบจำลองเพื่อนคู่เคียงเพื่อการอนุรักษ์หอยหลอด *Solen regularis* บริเวณดอนหอยหลอด จังหวัดสมุทรสงคราม

นายกอบชัย วรพิมพงษ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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By	Mr. Kobchai Worrapimphong
Field of Study	Zoology
Thesis Advisor	Associate Professor Nantana Gajaseni, Ph.D.
Thesis Co-advisor	Francois Bousquet, Ph.D.

Accepted by the Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

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กอบชัย วรพิมพงษ์: การสร้างแบบจำลองเพื่อนคู่เคียงเพื่อการอนุรักษ์หอยหลอด *Solen regularis* บริเวณดอนหอยหลอด จังหวัด สมุทรสงคราม (**COMPANION MODELLING FOR RAZOR CLAM *Solen regularis* CONSERVATION AT DON HOI LORD, SAMUT SONGKHRAM PROVINCE**) อ. ที่ปรึกษา: รศ.ดร.นันทนา คชเสนี, อ. ที่ปรึกษาร่วม: ดร. ฟรองซัว บูซเกะ.

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การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อศึกษาพลวัตรประชากรหอยหลอดในปัจจุบัน พฤติกรรมการหยอดหอยหลอดของชาวประมงพื้นบ้าน และนำไปสร้างแบบจำลองชนิดหลายตัวแทนเพื่อการอนุรักษ์หอยหลอด โดยใช้วิธีการสร้างแบบจำลองที่เป็นเหมือนเพื่อนคู่เคียง ซึ่งประกอบด้วย การจำลองแบบชนิดหลายตัวแทนบนคอมพิวเตอร์ และการเล่นบทบาทสมมติ ข้อมูลภาคสนามที่ได้จากการเก็บทุกเดือนเป็นระยะเวลาหนึ่งปี แบ่งเป็นสองส่วนคือ ข้อมูลประชากรหอยหลอดบนสันดอนทรายที่ใหญ่ที่สุด จากวิธีการสุ่มตัวอย่างตามแนวตัดขวางร่วมกับตารางสี่เหลี่ยมจับสัตว์แบบสุ่ม และการสอบถาม, สัมภาษณ์ชาวประมงพื้นบ้านเชิงลึกทุกเดือน ในประเด็นของการจับหอยหลอด อีกทั้งยังสัมภาษณ์นักท่องเที่ยวด้วยแบบสอบถาม จากนั้น นำข้อมูลภาคสนามทั้งสองส่วน ไปสร้างแบบจำลองชนิดหลายตัวแทน บนคอมพิวเตอร์ ภายใต้โปรแกรม คอร์แมส จากนั้น การเล่นบทบาทสมมติ 2 ครั้ง ได้ถูกจัดขึ้นในเดือนมีนาคม และ กรกฎาคม 2548 เพื่อการอภิปรายร่วมกัน จากผลการศึกษา ในส่วนของการศึกษาประชากรหอยหลอด พบว่า ความหนาแน่นเฉลี่ยตลอดการศึกษาเท่ากับ 5.71±2.49 ตัว/ตารางเมตร ความยาวเฉลี่ยของหอยหลอดตลอดการศึกษาเท่ากับ 4.55±0.90 เซนติเมตร และกลุ่มของความยาวหอยหลอดส่วนใหญ่ คือ กลุ่มที่มีความยาว 3-5 เซนติเมตร จากการเปรียบเทียบข้อมูลที่ผ่านมา พบว่าประชากรหอยหลอดเริ่มมีความหนาแน่นมากขึ้นและตัวใหญ่ขึ้นกว่าการศึกษาล่าสุด ซึ่งน่าจะเป็นผลมาจากการออกกฎระเบียบในการจับหอยหลอดของทางจังหวัดสมุทรสงคราม ในขณะที่ผลของการเล่นบทบาทสมมติทั้งสองครั้ง สามารถชักนำให้ชาวประมงพื้นบ้านและองค์กรการปกครองส่วนท้องถิ่นอภิปรายร่วมกันถึงแนวทางในการจัดการและอนุรักษ์หอยหลอดได้ 4 สถานการณ์สมมติ ในแต่ละครั้งของการเล่นบทบาทสมมติ นอกจากนั้น สถานการณ์สมมติที่ 2 (การปิดพื้นที่ห้ามจับ เพื่อการอนุรักษ์หอย 3 เดือน/บริเวณ) จากการเล่นบทบาทสมมติครั้งแรก และ สถานการณ์สมมติที่ 4 (ระบบการจัดสรรโควตาการหยอดหอยหลอด) ได้ถูกเลือกและยอมรับว่าสามารถนำไปใช้ในเหตุการณ์จริงได้ และได้นำสถานการณ์สมมตินี้ ไปใช้ในการศึกษาระยะยาวในแบบจำลองชนิดหลายตัวแทนที่สร้างขึ้น พบว่า ประชากรหอยหลอดมีการเปลี่ยนแปลงที่ดี เมื่อพิจารณาในด้านของความคงที่ในพลวัตรประชากร ซึ่งแนวทางในการจัดการทรัพยากรหอยหลอด จากทั้ง 2 สถานการณ์สมมตินี้ น่าจะเป็นแนวทางที่เหมาะสมในการอนุรักษ์หอยหลอดในระยะยาว

ภาควิชา.................ชีววิทยา................ลายมือชื่อนิสิต..

สาขาวิชา................สัตววิทยา............ ลายมือชื่ออาจารย์ที่ปรึกษา..

ปีการศึกษา..............2548.................. ลายมือชื่ออาจารย์ที่ปรึกษาร่วม......................................

4572210923: MAJOR ZOOLOGY
KEY WORD: COMPANION MODELLING/ MULTI-AGENT SYSTEMS/ ROLE-PLAYING GAME /RAZOR CLAM / DON HOI LORD

KOBCHAI WORRAPIMPHONG: COMPANION MODELLING FOR RAZOR CLAM *Solen regularis* CONSERVATION AT DON HOI LORD, SAMUT SONGKHARM PROVINCE. THESIS ADVISOR: ASSOC. PROF. NANTANA GAJASENI, Ph.D.THESIS CO-ADVISOR: FRANCOIS BOUSQUET, Ph.D.
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This study aimed to access the current razor clam population dynamics of Don Hoi Lord, to identify fisherman behavior and interactions, and to construct a multi-agent simulation model for collective discussion of razor clam management and conservation. Companion modelling approach, specifically Multi-agent system model (MAS) and Role-playing game (RPG) was used in this study. Monthly filed data collection was conducted for one year. Line transects and quadrat sampling method were used for collecting razor clam population data on the biggest sand dune in Don Hoi Lord. In addition, socio-economic surveys of local fisherman were conducted monthly to understand their harvesting behavior. A Multi-agent simulation model was constructed under Cormas platform based on both of razor clam population data and local fisherman harvesting behavioral patterns. Then, two rounds of RPG were organized in March and July 2005, to initiate collective discussion among stakeholders. Mean razor clam density was 5.71±2.49 individual/m^2, mean razor clam length was 4.55±0.90 cm and dominant size class was 3-5 cm. At the moment, razor clam population has started to recover from the past exploitation caused by razor clam harvesting policy of provincial government. Besides, both rounds of RPG were an efficient tool to initiate collective learning and discussion among stakeholders. In each round, 4 scenarios were played. Scenario II (closed zone rotation for 3 month/each) in first RPG and scenario IV (quota system) in second RPG have been agreed upon by stakeholders and possibly implemented in the future. The result of the multi-agent simulation model based on both agreed scenarios indicated that the razor clam population has responded positively due to consistent dynamics of razor clam population. Finally, a policy based on both agreed scenarios should be an appropriate management for razor clam conservation.

Department..............Biology............... Student's signature..

Field of study............Zoology.............Advisor's signature..

Academic year..........2005.....................Co-advisor's signature..

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I would like to express my gratitude to my advisor, Associate Professor Dr. Nantana Gajaseni, who opens my mind in ecological system approach and let me enter in ecological modelling world, with her advice, comment and suggestion in this thesis. Without her kindness, this study could not be accomplished. I am very grateful to my co-advisor Dr. François Bouequet who gave me a chance in Multi-agent systems and the best help in model construction and role-playing game. I would like to especially thanks to Dr. Christhope Le Page for great suggestion in Role-playing game. I am deeply thanks to Dr. Guy and Dr. Ingon Trebuil for their kindly explanation of Multi-agent systems. I also thanks Dr. Art-Ong Pradatsundarasar who has been a great consultant in razor clam population.

I gratefully acknowledge to the head of department of biology and the chair of the committee Dr. Siriwat Wongsiri, financial support by department of biology, Chulalongkorn university graduate school and especially grant and financial support from The Biodiversity Research and Training Program (BRT) for studied at Don Hoi Lord, Samut Songkhram province.

Gratefully thank Mr. Pranomsak Pomburom, Mr. Warong Naiwinit and Mr. Paolo Campo for giving me more understanding on Multi-agent systems and Role-playing game

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I would like to express all of my heart-feeling gratefulness to my mom, uncle, aunt and brother who gave me education that is the best wealth in my life and always embrace and encourage me to withstand and to conquer with such love and care.

Finally, I would like to dedicate this thesis to my late father who always said to me in my mind "Don't give up".

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ABBREVIATIONS

MAS	=	Multi-agent systems
LWR	=	Length and weight relationship
RPG	=	Role-playing game
PKMC	=	Prince Chumporn Khedudomsak Memoria
TAO	=	Tambon Administrative Organization

CHAPTER I

INTRODUCTION

1.1 OVERVIEW OF THE STUDY

"sustainable development must ensure that it meet the needs of the present without compromising the ability of future generations to meet their need.....sustainable development requires meeting the basic need of all and extending to all the opportunity to fulfill their aspiration"

(The World Commission on Environment and Development [WCED], 1987)

Since the first descriptive definition of sustainable development was first introduced during "The Brundtland Report" in 1987, there has been widespread recognition of the importance of sustainable development. There are many consequences of development affecting to ecosystems for example air pollution, water pollution and over exploitation of natural resources. Moreover, the exponential growth of human population in the present day results in increase in demand of resources. Thus the challenge for scientists and policy makersw is "How to manage our resources?" to meet the goal of sustainable development.

A wetland is a complex ecosystem, which comprise of many sub communities for many living organisms. Generally a wetland can store a rainfall, regulate ground water level, prevent a seawater intrusion and provide nursing ground for aquatic life as well as produce food supply for human. With specific characteristics and importance of wetland, Ramsar Convention was established in 1971 for wetland conservation at international level. Nowadays, 1,328 wetlands are registered as a Ramsar site, 10 Ramsar sites are located in Thailand especially connected to coastal zone. Many wetlands in Thailand have been degraded by the effect of unsustainable development.

Don Hoi Lord was registered as an international wetland or Ramsar site in 2001 that also has an effect from development. Razor clam or *Solen regularis* is well known as Hoi Lord. The wetland derives its name from razor clam and high abundance of razor clam population. Moreover, razor clam has been a source of income for local fishermen income who harvest razor clam on the sand dune during the low tide.

Presently, the number of razor clam is decreasing due to harvesting pressure by local fishermen, who respond to high market demand. Many studies have been conducted on razor clam, such as life history, environmental condition of Don Hoi Lord and social awareness for Razor clam. The objectives of all studies emphasized conservation but most of the studies were conducted with reductionistic approaches, without considering the integration for better problem solving or management.

Modelling has become an important tool in the study of ecological system as well as natural resource management. Models provide an opportunity to explore ideas regarding ecological systems that it may not be possible to field-test for logistical, political, or financial reason. Numerous scientists now believe that the study of ecosystem requires a multi-disciplinary approach or holistic approach in order not to neglect the social interaction from natural resource management. (Jackson et al., 2000).

Multi-Agent Systems (MAS), also called agent-based modeling has been used by researchers in ecology or economics, as well as tools for ecosystem management (Bousquet and Le page, 2004). Moreover, MAS can integrate socio-economic, ecological and spatial dynamics into a single model. It provides a better understanding of how the properties of human-construct landscape at a macroscopic level can arise from the interaction of system components at a microscopic level (Ferber, 1995).

In this study, Multi-agent simulation was created to investigate interaction between a razor clam population and local fisherman harvesting behavior. Components of the model were comprised of razor clam population data from field collection, local fisherman behavior data, and other stakeholder data (trader and tourist) from interview. Different scenarios were tested in the simulation to assess situation of razor clam population and local fisherman behavior, and determine appropriate management strategy from the simulation. After simulation session, the Role-Playing Game (RPG) session was organized by inviting some local fishermen at Don Hoi Lord who normally harvest razor clam as well as other stakeholders to participate. The RPG would be able to conduct opportunity of discussion among local fisherman as well as the modeler can extract information to cooperate with simulation model. Finally, the perception among fishermen could propose for suitable razor clam management strategy.

1.2 OBJECTIVES OF THIS STUDY

To achieve goal of sustainable management, holistic approach study should be used in a study of ecosystem management. As Jackson et al. (2000) suggested not neglect the behavior of the social group which involve in natural resource management, the purpose of this study was to build an ecological model for razor clam conservation and facilitated conservation ideas to stakeholders who involved at Don Hoi Lord.

Thus, the objectives of this study were:

- To assess existing condition of population dynamics of razor clam at Don Hoi Lord.
- To identify behavior and interactions of local fishermen who harvest razor clam.
- To construct a multi-agent simulation model to explore the interaction between human activities and razor clam population.
- To propose and discuss collectively a strategy for razor clam conservation.

1.3 HYPOTHESIS OF THE STUDY

As a purpose of this study, an ecological model will be built and explored razor clam populations under different scenarios. In addition, exploring razor clam population through the model should reflect behaviors of fisherman, which would be discussed later with local fishermen for razor clam management and conservation purposes. Therefore, hypothesis of this study was:

"The population of razor clam will respond to different patterns of human activities."

1.4 SCOPE OF STUDY

Based on MAS as a tool for ecosystem management, the razor clam population at Don Hoi Lord, Samut Songkhram province, Central of Thailand was studied (Figure. 1). Razor clam is well-known a common property, such that everybody can harvest it. To date, the population of razor clam is decreased therefore, an appropriate management is needed for conservation.

There are five sand dunes at Don Hoi Lord, the largest one was selected as a study site. This sand dune is closed to local communities and there are high harvesting rate from fisherman and indirect effect of tourism. This study was designed for monthly data collection for one year including ecological data of razor clam population and socio-economic data from interview. Cormas (common-pool resources and multi-agent systems) platform was used in this study to build an ecological model to explore razor clam population. Finally, RPG was used in a discussion session to share experience on razor clam conservation and model calibration with local fisherman at Don Hoi Lord.

Source: http://www.gisthai.org/map-galery/thai_atlas/images/forest43/forest43.html

Figure 1.1 Samut Songkhram province, Central of Thailand (in the red circle)

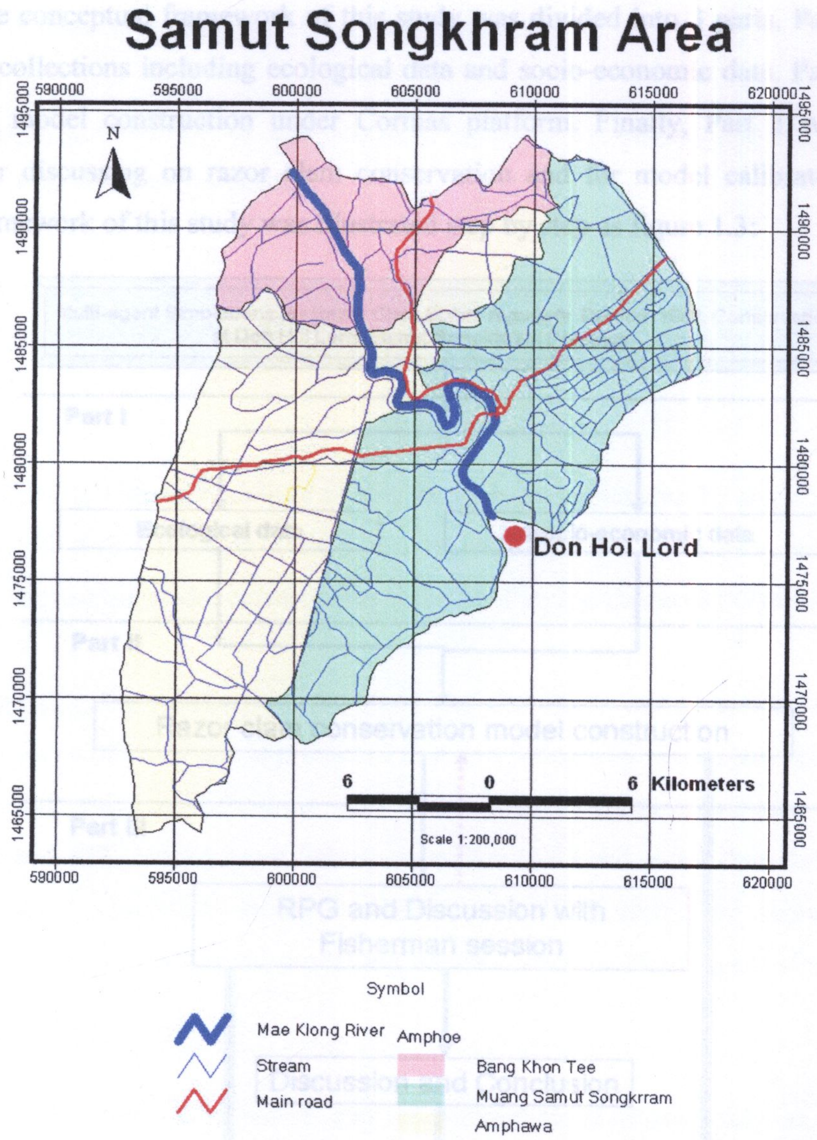


Figure 1.2 Location of Don Hoi Lord (red spot) in Samut Songkhram province

1.5 CONCEPTUAL FRAMEWORK OF THE STUDY

The conceptual framework of this study was divided into 3 parts. Part 1 was field data collections including ecological data and socio-economic data. Part 2 was ecological model construction under Cormas platform. Finally, Part 3 was RPG session for discussing on razor clam conservation and for model calibration. The overall framework of this study was illustrated step by step as figure 1.3:

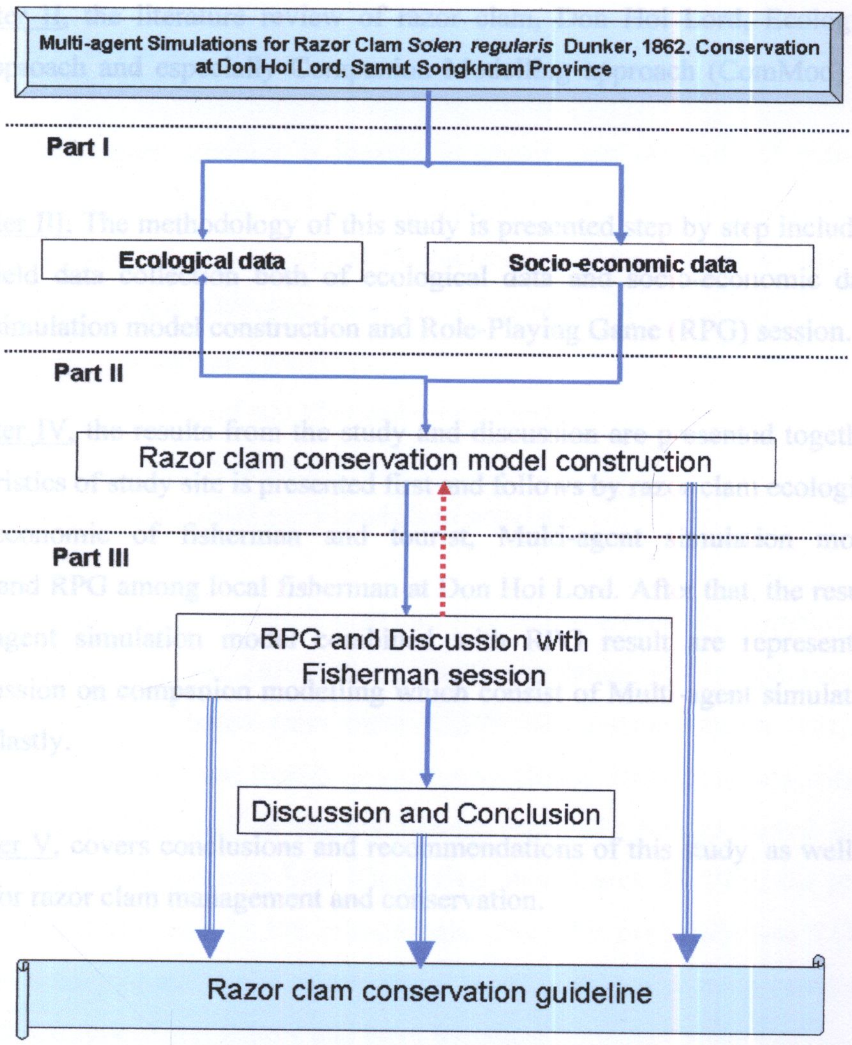


Figure 1.3 Conceptual frame work of this study

1.6 THESIS OUTLINE

In this thesis is composed of five chapters as follows:

Chapter I, overview of this study, objectives, hypothesis and conceptual framework of the study are presented.

Chapter II, the literature review of razor clam, Don Hoi Lord, Ecological modelling approach and especially Companion Modelling approach (ComMod) are presented.

Chapter III, The methodology of this study is presented step by step including study site, field data collection both of ecological data and socio-economic data, Multi-agent simulation model construction and Role-Playing Game (RPG) session.

Chapter IV, the results from the study and discussion are presented together. The characteristics of study site is presented first and follows by razor clam ecological data, socio-economic of fisherman and tourist, Multi-agent simulation model construction and RPG among local fisherman at Don Hoi Lord. After that, the results from Multi-agent simulation model combined with RPG result are represented. Finally, discussion on companion modelling which consist of Multi-agent simulation and RPG are lastly.

Chapter V, covers conclusions and recommendations of this study, as well as future study for razor clam management and conservation.

CHAPTER II

LITERATURE REVIEWS

2.1 SAMUT SONG KHRAM PROVINCE AND DON HOI LORD

2.1.1 Samut Songkhram province

Samut Songkhram province is located in central part of Thailand between latitude 13-14° N and longitude 99-103° E and approximately 74 kilometers from Bangkok. It covers area of 416.707 square kilometers or 260,441.87 rai (Ministry of Interior. 2004) and connects with other province as follows:

North	Ratchaburi province
South	Thai Gulf and Phetchaburi province
East	Samut Sakhon province
West	Ratchaburi and Phetchaburi province

The administration of Samut Songkhram province consists of 3 amphurs, 36 districts, 5 municipalities and 283 villages. Total population is 195,108 persons (51,077 households) contributed from male 93,979 persons and female 101,129 persons (National Economic and Social Development Board, 2005). The majority of Samut Songkhram people hlive in amphur Muang especially Muang Samut Song Khram municipality it closed with Mae Klong river mouth area. In 2003, the gross provincial product (GPP) was 11,158 million baht. The GPP per capita was 57,871 baht (National economic and social development board, 2005). The main careers of people (≈80%) are agriculture, fishery and labor in industry.

Samut Songkhram is generally flat plains with no mountain. There is one main river named Mae Klong River, which run across the province 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 in amphor Muang Samut Songkhram (Thaviongse Sriburi and Nantana Gajaseni, 1996).

Geographical, 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.

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 approximately 4 km from shore line into the sea (Thaviongse Sriburi and Nantana Gajaseni, 1996).

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 (MLS), 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.

Land use in Samut Songkhram include fruit orchard (lichee, coconut, pomelo etc.), salt farm, paddy rice, fishery and aquaculture farming. The fishery activities in Samut Songkhram province include fresh water, brackish and marine fishery. In brackish area, there are many types of aquaculture such as shrimp, mud crab, cockle, green mussel and perch fish. In the past, mangrove area was destroyed for aquaculture particularly shrimp aquaculture, causing mangrove area conversion and wastewater discharged to Mae Klong estuary. Now a day, many area of shrimp aquaculture are abandon because the shrimp farmer could not get enough economic benefic.

2.1.2 Don Hoi Lord

Don Hoi Lord (Figure 2.1) is the 1099th Ramsar site located in Mae Klong estuary (13°21’N 099°59’E) in Thailand includes both terrestrial areas and water body of Ban Jakreng, Lam Yai, and Klong Cone district, Muang amphur, Samut Songkhram province covering area of 87,500 ha (Ramsar, 2003).

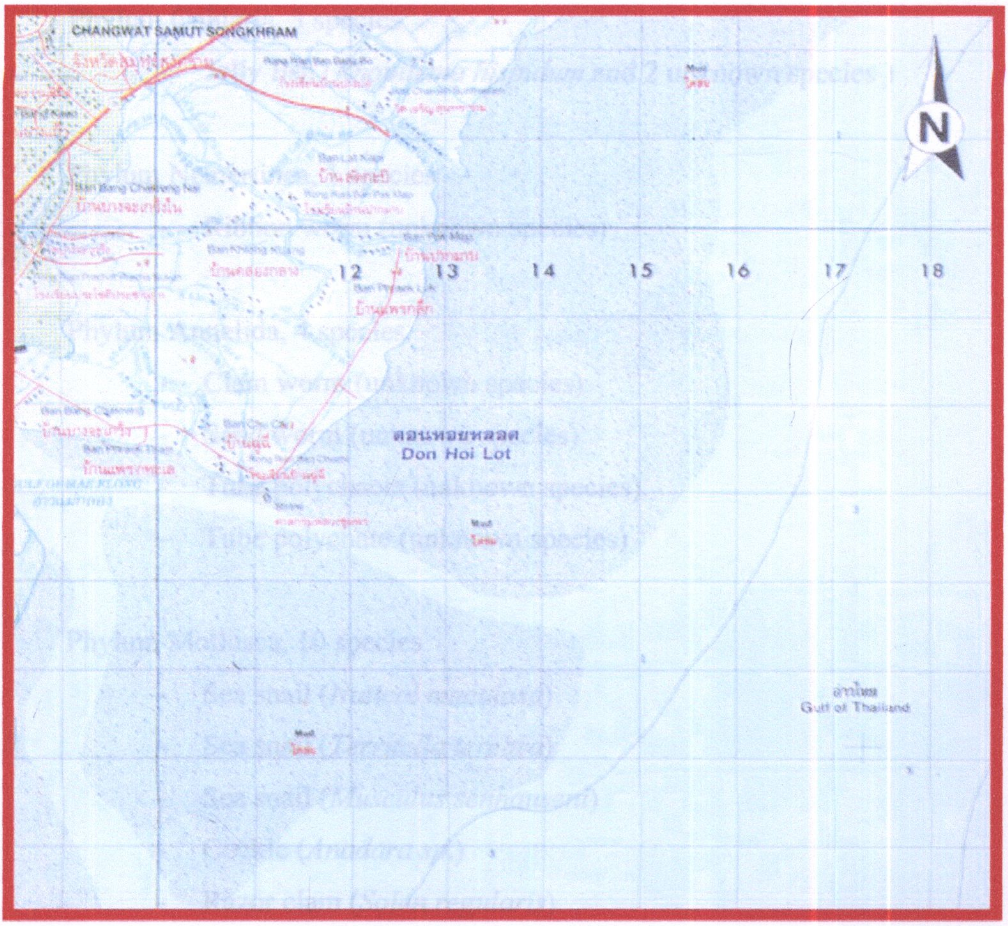


Figure 2.1 Area of Don Hoi Lord, Samut Songkhram province

Don Hoi Lord is a coastal wetland formed by accumulation of sediments and rich in nutrients. It has rare and unique characteristics of natural wetland in Thailand. In addition, the mudflat in wetland is razor calm (*Solen regularis*) habitat.The name of this wetland has been derived from razor clam and it important to local communities economically around Don Hoi Lord.

Don Hoi Lord has high biodiversity Thaviongse Sriburi and Nantana Gajaseni (1996) were found macrofauna including epifauna and infauna of 39 species belonging to 7 phyla of invertebrate and vertebrate following:

Phylum Cnidaria, 3 species

- Jelly fish (*Rhopilema hispidum* and 2 unknown species)

Phylum Nemertinea, 1 species

- Ribbon worm (unknown species)

Phylum Annelida, 4 species

- Clam worm (unknown species)
- Sand worm (unknown species)
- Tube polychaete (unknown species)
- Tube polychate (unknown species)

Phylum Mollusca, 10 species

- Sea snail (*Natical maculosa*)
- Sea snail (*Territella terebra*)
- Sea snail (*Musculus senhauseni*)
- Cockle (*Anadara sp.*)
- Razor clam (*Solen regularis*)
- Rock clam (*Solen vitreus*)
- Bean clam (*Donax faba*)
- Ridge venus clam (*Terpes tergidus*)
- Bivalve (unknown species)

- Bivalve (unknown species)

Phylum Brachiopoda, 1 species

- Tongue shell (*Lingula unguis*)

Phylum Arthropoda, 16 species

- Giant king crab (*Tachypleus gigas*)
- Hermit crab (*Clibanarius infraspinatus*)
- Hermit crab (*Clibanarius longitarsus*)
- Giant tiger prawn (*Penaeus monodon*)
- Banana prawn (*Penaeus merguiensis*)
- Jinga shrimp (*Metapenaeus sp.*)
- Dwarf prawn (*Macrobrachium equiensis*)
- Mantis shrimp (*Cloridopsis scorpio*)
- Mantis shrimp (*Cloridopsis maculata*)
- Pebble crab (*Leucosia haswelli*)
- Eyed swimming crab (*Macropthalmus abbreviatus*)
- Portunid crab (*Charybdis affinis*)
- Blue crab (*Portunus pelegicus*)
- Rock barnacle (*Balanus sp.*)
- Goose neck barnacle (*Lepas sp.*)

Phylum Vertebrata, 4 species

- Conger ell (*Congresox talabon*)
- Flatfish (*Cynoglossus sp.*)
- Goby (*Cryptocentrus sp.*)
- Unknown fish (Unknown species)

Moreover, there are at least 18 species of bird around Don Hoi Lord following:

- Common sandpiper (*Actitis hypoleucos*)
- Edible-nest swiftlet (*Aerodramus fuciphagus*)

- Grey heron (*Ardea cinerea*)
- Javan pond-heron (*Ardeola speciosa*)
- Chinese pond-heron (*Ardeola bacchus*)
- Little heron (*Butorides striatus*)
- Kentish plover (*Charadrius alexandrinus*)
- Little ringed plover (*Charadrius dubius*)
- Whiskered tern (*Chlidonias hybridus*)
- Collared kingfisher (*Halcyon chloris*)
- Brahminy kite (*Haliastur indus*)
- Black-winged stilt (*Himantopus himantopus*)
- Brown-headed gull (*Larus brunnicephalus*)
- Whimbrel (*Numenius phaeopus*)
- Pacific golden plover (*Pluvialis fulva*)
- Wood sandpiper (*Tringa glareola*)
- Marsh sandpiper (*Tringa stagnatilis*)
- Common Redshank (*Tringa totanus*)

Don Hoi Lord is one of the most famous tourist destinations due to distinction of razor clam called "Hoi Lord" in local name, which can be harvested mostly from this sand dune. This bring plenty of tourism to visit there and made more demand of razor clam as delicacy for visitors.

Nowadays, Don Hoi Lord is facing problems because of unsustainable development in term of land development, infrastructure construction. The problems maybe described as follows:

- Changing of environment around Mae Klong river mouth by much more pilling up of sediment.
- Changing of mangrove along coastal zone to aquaculture and decreasing nursing ground and productivity in estuary ecosystem.
- Increasing pollution due to garbage and waste from restaurant and tourism.
- Over harvesting of razor clam regarding high market demand.

2.2 RAZOR CLAM

2.2.1 General characteristics of razor clam

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

Phylum Mollusca

Class Bivalvia

Order Eulamellibranchia

Family Solenidae

Genus Solen

Species *Solen regularis* Dunker,1862

Razor clam is a bivalve and sex-separate. It has cylinder shape and thin shell hold by hinge teeth. There are 2 openings which anterior opening has two siphons for filter feeding purpose and posterior opening has foot for vertical movement. Adult size of razor clam is ranged from 0.5 cm. to 8.0 cm and lives in sandy soil approximately 1-30 cm. in depth (Department of fishery, 1995).

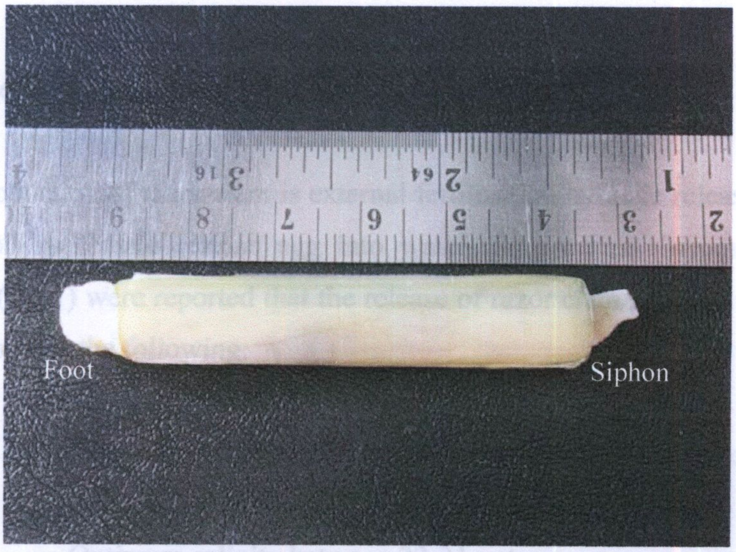


Figure 2.2 Razor clam (*Solen regularis* Dunker, 1862.)

2.2.2 Distribution of razor clam

Distribution of razor clam normally covers estuary area near river mouth especially in Asia pacific from Japan, Korea, China to Thailand. In Thailand, it is found both at Andaman sea of Phuket and Gulf of Thailand, Songkhla, Prachuap Khiri Khan, Phetchaburi, Samut Songkhram and Samut Prakarn province especially Samut Songkhram province. Don Hoi Lord is located in Samut Songkhram, where it is the largest area of razor clam production in Thailand.

2.2.3 Razor clam feeding behavior

Naturally, razor clam is semi-permanent mud burrower, using foot to dig and bury in the fine sandy soil in vertical direction in their hole. During high tide, razor calm moves up to surface of substrate and protrude siphons into water for pumping water and filtering food from water. Its foods are phytoplankton, zooplankton, organic matters and pieces of decomposed plant or animal. Moreover, when razor clam is attached by enemy or risky sign, razor clam will throw off siphon and move to deeper level in substrate.

2.2.4 Razor clam reproduction

Reproduction of razor clam is external fertilization by male release sperm into water as well as female release egg into water. Sunan Tuaycharoean and Panit Voraingtara (1991) were reported that the release of razor clam gametes is influenced by many factors as the following:

- Stage of gamete development
- Optimum water temperature between 22-39 °C and optimum soil temperature between 21-38 °C
- Optimum salinity between 22-31 ppt

Breeding season of razor clam is twice a year, with the first period starting from June to October and the second period from November to April (Art-Ong Pradatsundarasar et al., 1989). However, breeding season depends on environment condition and might be different from year to year.

2.2.5 Razor clam harvesting methods

Traditionally, there are 5 methods developed by local fishermen knowledge to catch razor clam during low tide when sand dune is 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.

Method II Applying lime; local fishermen apply lime on the wet ground where razor clams live around 1 sq.m. 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 sq.m. 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 labour and the production is not as high as the other methods.

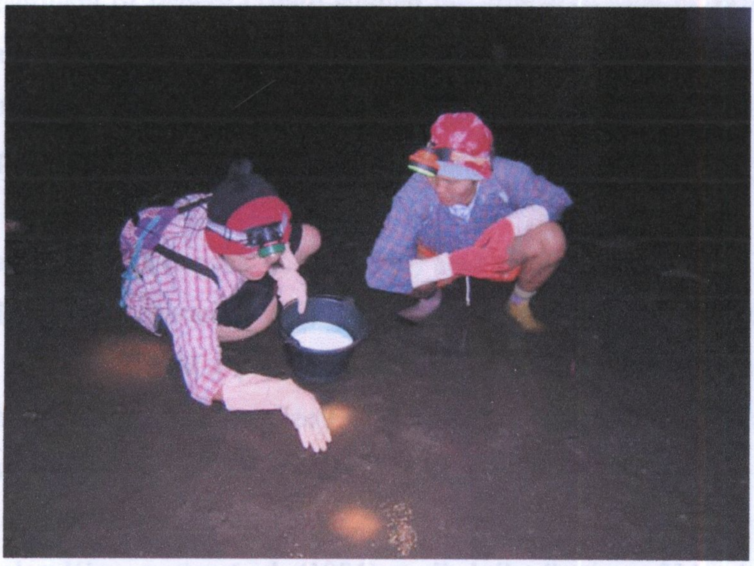


Figure 2.3 Dipping lime method which is widely used and legalized in razor clam harvesting

Nowadays, local government has allowed local fishermen to uses method I and V to catch razor clam. While method II, III and IV are prohibited because these cause damage to small razor clam and other animals. But some fisherman still try to use those methods due to no serious enforcement.

2.3 OVERVIEWS OF RESEARCH ON RAZOR CLAM AND DON HOI LORD

Art-Ong 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 10.20 individual/m^2 .

Department of fishery (1990) studied the effects of lime on razor clam death rate and reported that the increasing death rate was found with razor clam was exposed to lime or used to have some previous lime exposure. It indicated the relationship of lime exposure and razor clam death rate.

Chanintorn Srithongsuk et. al. (1990) also 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.

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

Somprasong Kanthom and Somchart Sukawong (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.

Sunan Tuaycharoean and Panit 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.

Kanoksak Jinphuhuad (1994) studied pH of seawater for razor clam and reported that the suitable pH of seawater for razor clam was 6.9-8.5. In addition, if pH of seawater was higher than 9.1, razor clam would die suddenly. On the other hands, if pH of sea water is lower than 6.5, the ability of razor clam feeding would decrease and die from starvation.

Thaviongse Sriburi and Nantana 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, 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 ordinary method and cause decreasing population.

. Rangsimant 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 individual/m^2 in 1994 to 4.1 individual/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.

Natsucha 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.

Weerasak 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.

Wanpen Sriprathumwong, Ritthikorn Sornkaew and Nopadol 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.).

Nathakan Suwanna (2003) studied the ability of community to manage local resources: a case study of Don Hoi Lord, Samut Songkhram province and reported that the social, economic and politic developments affected on the decrease of razor clam population because of increasing razor clam demand. The high market demand made local fisherman search for another method to catch more razor clam than old method, without realizing its effect on the environment. When the government established the regulation to control razor clam harvesting, there is a lot of cooperation in Don Hoi Lord conservation. The protected area for razor clam has been established and local fishermen also participate in conservation activities. The activities for conservation in community also reduced inappropriate harvesting method in local fishermen and set up conservation group.

2.4 ECOLOGICAL MODELLING

Few decades ago, there is one science has been developing from many scientific disciplinary (eg. Ecology, Mathematic, Computer science, etc.) that integrated in terms of subsystem into main system. That calls "Modelling approach" which has main objectives are:

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

Combining ecological knowledge with modelling approach has give rise to "Ecological modelling". It is an effective tool to study ecosystem and ecosystem management (Jackson et al., 2000). The approach focuses on modelling subsystem of an ecosystem as well as ecological relationships within and between the subsystems.

The process of modelling uses subsystem data that considers the main system from past until present. Correction of the model and result depend on quality of data from each subsystem that contribute to the model.

There are 3 main processes to build an ecological modelling:

1. Model construction: the model will be construct from conceptual model combining with quantitative model (or mathematical model)

2. Model calibration: this process tests the model by performing simulation runs for accuracy, consistency of model in several time steps.
3. Validation: this process compares the results of model by runing simulation under various scenarios with the real world or system study.

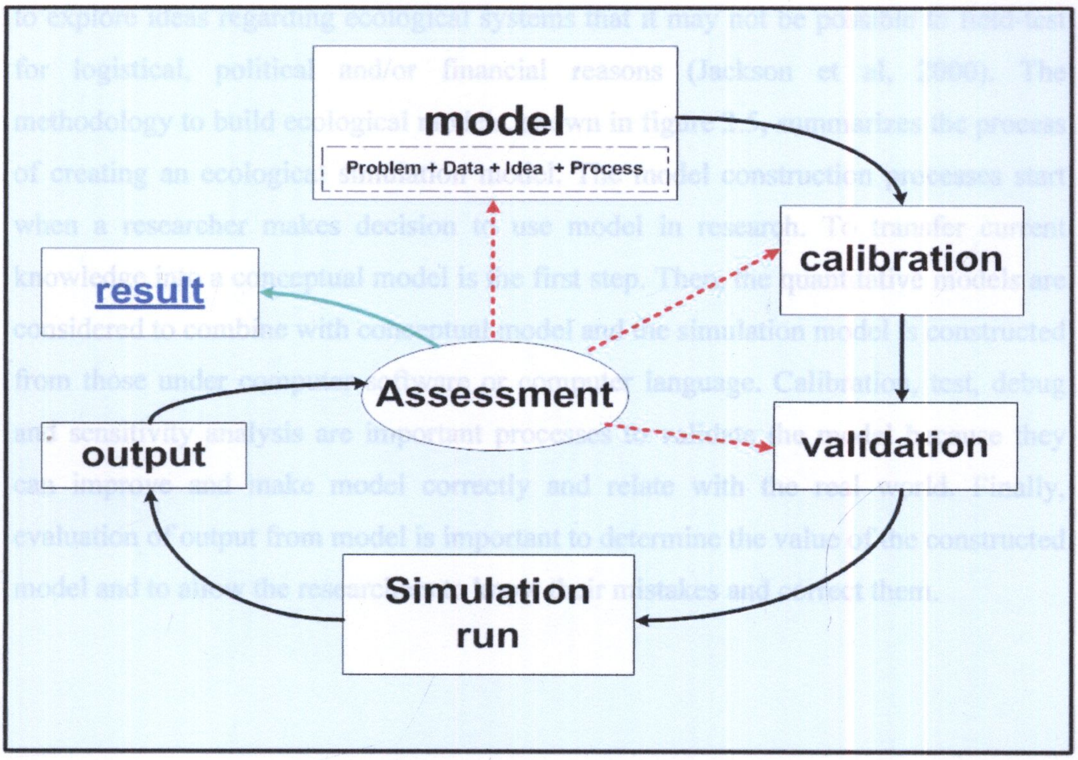


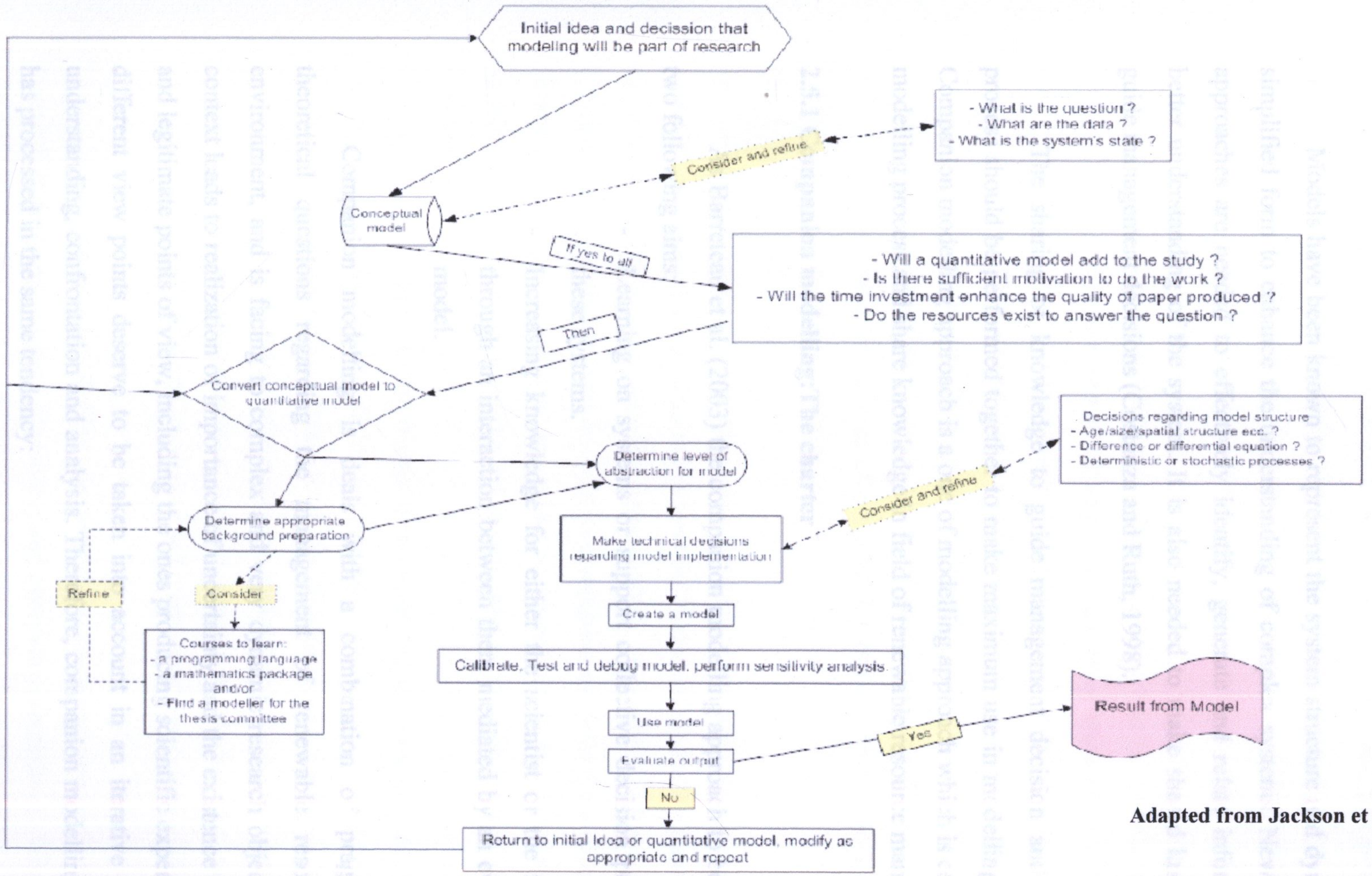
Figure 2.4 Overview of modelling approach

However, modelling approach is a computer-based tool, especially with simulation runs on computer program. The computer hardware and software make modelling approach more applicable to various fields of study for instance, economic, marketing, engineering and science.

Nowadays, there are many environmental problems that have been occurring in the world. Modelling approach is an effective tool to explore and find solutions for the present problems or some problems which may happen in the future.

2.4.1 Methodology to build an ecological model

Modelling approach is a tool to study system dynamic and/or relationships in the system. Fast computers and graphical software package have removed much of the drudgery of creating model with a programming language and opened new avenues of model construction, use and even misuse. In addition, models provide an opportunity to explore ideas regarding ecological systems that it may not be possible to field-test for logistical, political and/or financial reasons (Jackson et al, 2000). The methodology to build ecological models, shown in figure 2.5, summarizes the process of creating an ecological simulation model. The model construction processes start when a researcher makes decision to use model in research. To transfer current knowledge into a conceptual model is the first step. Then, the quantitative models are considered to combine with conceptual model and the simulation model is constructed from those under computer software or computer language. Calibration, test, debug and sensitivity analysis are important processes to validate the model because they can improve and make model correctly and relate with the real world. Finally, evaluation of output from model is important to determine the value of the constructed model and to allow the researchers to know their mistakes and correct them.



Adapted from Jackson et al., 2000

Figure 2.5 Methodology to build an ecological model

2.5 COMPANION MODELLING

Models have been known to represent the system structure and dynamics in a simplified form to enhance the understanding of complex systems. New modelling approaches are needed to effectively identify, generate and relate information for better understanding of the system. It is also needed to make shared knowledge to guide management decisions (Costanza and Ruth, 1998).

The sharing of knowledge to guide management decision and modelling process should be performed together to make maximum use in modelling approach. Companion modelling approach is a one of modelling approach which is composed of modelling process and share knowledge in field of renewable resource management.

2.5.1 Companion modelling:The charter

As Barreteau et al. (2003) the companion modelling approach to be used with two following aims:

- Learning on systems or support collective decision processes in these systems.
- Increasing knowledge for either the scientist or the field actor, through an interaction between them mediated by an evolutionary model.

Companion modelling is deals with a combination of pragmatic and theoretical questions regarding the management of renewable resources and environment, and is facing to complex and very dynamic research objects. Such a context leads to realization of importance of uncertainty and the existence of multiple and legitimate points of view, including the ones producing scientific expertise. These different view points deserve to be taken into account in an iterative process of understanding, confrontation and analysis. Therefore, companion modelling approach has processed in the same tendency:

- The fate of all the assumptions backing the modelling work is to be discarded after each interaction with the field, that is to say to be voluntarily and directly subject to refutation.
- Having no a priori implicit experimental hypothesis is an objective implying the adoption of procedures to unveil such implicit hypotheses.
- The impact in the field has to be taken into consideration as soon as the first step of the approach, in term of research objective, quality of approach, quantified monitoring and evaluation indicators.
- 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.

Tools in companion modelling can accompany the collective decision-making dynamics and make stakeholders understand the system of study. For example Multi-agent systems (MAS), Role-playing game (RPG), Geographic information system (GIS), economic tools, etc. can be tools in companion modelling approach. The tool selection to using in companion modelling is depending on the situation in various systems. Thus, the production of knowledge or point of view on a given system could lead to:

- improved knowledge of actors and/or decision-makers
- facilitated dialogue among stakeholders (including experts) providing a frame work for discussion and sharing of information, an exchange of viewpoints, knowledge and beliefs among them.
- negotiated support system aiming at closing the gap between diverging point of view and conflicting situation in system study.

From concepts of modelling and companion modelling approach, stakeholders learn collectively by creating, modifying and observing simulations. When carrying out simulations, one acts on the decision-making process by creating or modifying representations. Companion modelling leads stakeholders to share representation and simulations, taking into account possible decisions and actions related to their environments which are under consideration (management rules, new infrastructure etc.) Meanwhile, companion modelling does not include the other possible steps of the mediation process dealing with a more quantified expertise (size of a new infrastructure, estimated production etc.). Companion modelling intervenes upstream of the technical decision to support the reflexion of concerned actors, in order to produce a share representation of the problematic and to identify possible ways toward a process of collective management of the problem.

With regard to the two aims in companion modelling approach above, the first type of usage looks for its scientific legitimacy in the production and relevance of knowledge, while the latter aims to improve the quality of collective decision-making processes. In both aims, there is production of knowledge through the interaction among researchers and local stakeholders. But in the first situation, this production of knowledge (being for researchers, or for local actors through training activities) is the objective, while in the second aim is a necessary element of the method to achieve the main objective of supporting collective decision. However, there is nothing can guarantee that the tools and/or the models tested in a given situation will be useful, efficient and can adapted in another situation because the dynamics and the interaction in each system are different. That why the companion modelling approach has 2 aims and these concerning together, in addition the knowledge produced by each of two aims are useful to elucidate the secondary effects created by one of them.

2.5.2 Multi-agent systems modelling and role-playing game

Recently, several researchers started to use multi-agent systems, also called agent-based modelling (ABM), in different fields. Researchers in ecology or economics use this methodology and associated tools for ecosystem management. If a history of multi-agent systems were to be written over the coming year, those authors would certainly situate the birth of this approach and its formative years in the rich breeding ground of the interdisciplinary movement. Originally, multi-agent systems came from the field of artificial intelligence (AI). At first, this field was called distributed artificial intelligence (DAI); instead of reproducing the knowledge and reasoning of several heterogeneous agents that need to coordinate to jointly solve planning problems. (Bousquet and Le page, 2004)

Multi-agent systems are an assembly of agents with specific goals capable of perceiving, communicating, interacting and acting in an environment with other agents (Ferber, 1999). On the other hand, Le Page et al. (2000) propose that multi-agent systems are made of collection of agents, an agent being a computerized autonomous entity that is able to act locally in response to stimuli from the environment or communication with other agents (figure 2.6).

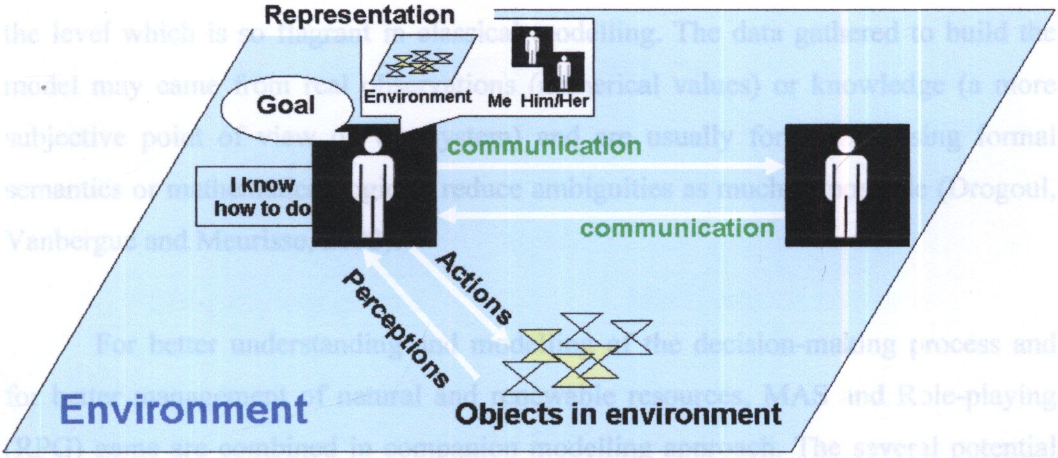


Figure 2.6 Multi-agent systems general organization and principles.
(adapted from Ferber, 1999)

Agents have:

- internal data representations (memory or stage)
- means for modifying their internal data representations (perception)
- 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 (exchange of messages) or via transactions (e.g., financial). (Le Page et al., 2000)

MAS provides simulation methods rich in potentials capable of modelling interactive processes between social and ecological dynamics (Bousquet et al., 1999). Following to Ferber (1999), the main qualities of multi-agent modelling are its capacity for integration and its flexibility. It is in fact possible to integrate within the same model quantitative variables, differential equations and behaviors based on symbolic rule. It is also very easy to integrate modifications, each enhancement of the model being brought about by adding behavioral rules which operate at the individual level. In addition, multi-agent systems make it possible to model complex situations whose overall structure emerge from interactions between individuals, that is, to cause structures on the macro level to emerge from models on the micro level, thus breaking the level which is so flagrant in classical modelling. The data gathered to build the model may came from real observations (numerical values) or knowledge (a more subjective point of view on the system) and are usually formalized using formal semantics or mathematical logic to reduce ambiguities as much as possible (Drogoul, Vanbergue and Meurisse, 2002).

For better understanding and modelling of the decision-making process and for better management of natural and renewable resources, MAS and Role-playing (RPG) game are combined in companion modelling approach. The several potential parallels between role game and MAS listed in Table 2.1

Table 2.1 Correspondences table between role-playing game and MAS (Gurang, 2004)

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

There are a few experiences with the coupled use of models and role games foe ecosystem management. Fish banks game, developed in 1993 (Meadows and Meadows, 1993 cited in Bousquet et al., 2002). It is a famous role game which is used for educational purposes. 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 harvest. 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.

Closely articulated with MAS models in the companion modelling approach, role-playing game are used to produce new knowledge, to help build MAS models, and to validate them (Figure 2.7). Depending on the circumstances, the linkage between two tools can very (Aquino et al., 2002 cited in Trebuil et al.,2002)

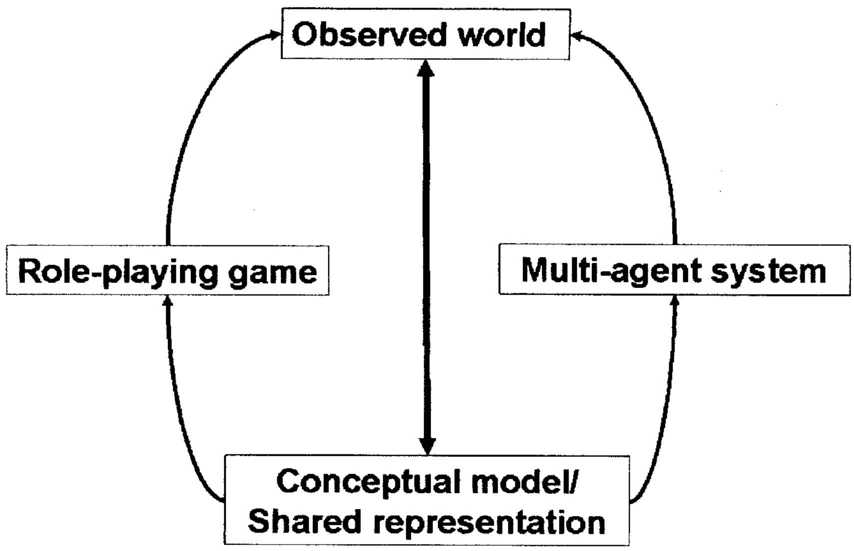


Figure 2.7 Linkages between the reality and interactive tools in the companion modelling approach (adapted from Trebuil et al., 2002)

The use of role-playing games derived from more complex models through simplifications facilitates the communication of the results of agent-based computer simulation to stakeholders. It helps empower them to use such powerful tools when looking for "solution" to concrete natural resource management (Trebuil et al., 2002).

Cormas (Common-pool Resources and Multi-agent Systems) has been develop since 1995. It provide facilities to build analyze agent-based models that represent ecosystems where various human activities compete for the use of natural resources (Le Page and Bommel, 2004). Cormas is based on the software VisualWorks which, in turn, is a programming environment based on Smalltalk language. Cincom, the American company that market VisualWorks, distributes the software freely (for education and research purposes) Cormas is also available to the scientific communities at http://cormas.cirad.fr/indexeng.htm . However, the goal of Cormas is not to make accurate predictions about the behavior of complex systems but to provide framework to help people develop new ways of thinking (Gurung, 2004).

There have been some researches on natural resource management using MAS and/or RPG as tools in study:

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.

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

Bousquet et al. (2001) studied simulation for hunting wild meat in a village in eastern Cameroon 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 companion modelling 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. This approach helped to identify acceptable rules for an improve regulation of collective uses of land resources.

Mathevet 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 develop to cover 55% of the region because of the increased of hunting marshes. For “Scenario alternation” whatever in order ABABAB or BABABA

Suphanchaimart et al. (2003) use MAS 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 (2004) used multi-agent systems and role-playing game 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.

CHAPTER III

MATERIALS AND METHODS

3.1 SECONDARY DATA COLLECTION

Relevant data of razor clam, ecology, Don Hoi Lord and Multi-agent systems and Role-playing game or Companion modelling (article, thesis, scientific papers, the past data of razor clam harvesting and map etc.) were gathered from government offices, libraries, online internet sources and others.

3.2 PRIMARY DATA COLLECTION

Primary data collections were carried out every month from March 2004 to February 2005. It is consisted of population of razor clam and human activities on razor clam habitat. Both sets of data were used in model construction.

3.2.1 Site selection

The largest sand dune in Don Hoi Lord was selected in this study. It covers an area of approximately 321 hectares. This sand dune is located closely to local communities and people can easily access it. Moreover, tourists who visit Don Hoi Lord usually come to visit this sand dune. This sand dune may have been affected by human activities and challenge in management.

Figure 3.1 The sand dune study site of this study

3.2.2 Razor clam population

Line transects and quadrat sampling method (Krebs, 1989) were used to data collection of razor clam population following:

- 4 line transects were laid in the sand dune during the low tide, covering all study area.
- Each line transect has stations to collect razor clam. The interval distance between stations is around 200-250 m. depending on physical characteristics of the sand dune. Every station was recorded position in GPS (Global Positioning System) and returned to the same position in each station through the field data collection.
- 3 sampling quadrats (size 1 m^2) were designed at each station to collect razor clam by following method:
    1) Using a bamboo stick dipped lime and dropped in to the razor clam hole.

2) Using spade to dig sand around 30 cm deep from the surface, to collect all remaining razor clam.

Caught razor clam were separated into 2 groups, first from dropping lime and second one from digging sand.

- Count the number, measure length and weight of every individual in the quadrat

Figure 3.2 Quadrat size 1 m^2 which designed for razor clam collection

3.2.3 Human activities

Socio-economic data were collected monthly from human activities follows:

- To count a number of local fishermen who came to harvested razor clam in the study sand dune 4 days/month
- To survey and interview local fishermen who harvested razor clam as his/her career based on 3 main questions as follow:

1) How many razor clams can they catch in this month?

2) Where do they go to catch razor clam in this month?

3) How long do they catch razor clam in each day during this month?

4) How much can they sell razor clam to trader?

- To survey and interview trader to investigate market demand and mechanism of razor clam prize formation.
- To interview tourists with questionnaire.
- To count the number of tourists who come to visit sand dune 4 days/month

3.3 DATA ANALYSIS

Razor clam population data were analyses by program Excel 2003 and SPSS for Windows 11.5. The following data analyses were performed:

1) Density of razor clam (individual/m^2) by Excel
2) Mean weight of razor clam (g./individual) by Excel
3) Mean length of razor clam (cm./individual) by Excel
4) Relationship between weight and length of razor clam by Excel
5) Cluster analysis for separating razor clam density by SPSS for use spatial model construction

- Questionnaire data were analysed by program SPSS for Windows 11.5 to investigate general data and general behavior of tourist who visited Don Hoi Lord.

3.4 COMPANION MODELLING FOR DON HOI LORD

According to the concept of companion modelling, multi-agent systems and role-playing game were carried out in Don Hoi Lord. The main objective of Don Hoi Lord companion modelling was to share experience among researchers and stakeholders (local fishermen, trader and local government) and find the acceptable razor clam conservation method from stakeholder.

3.4.1 Principles

To apply principle of companion modelling to razor clam conservation at Don Hoi Lord, There are 2 main parts; first was the computer simulation model and second one was the role-playing game.

The linkage between computer simulation model and role-playing game aims at facilitating knowledge sharing. Therefore, the computer simulation model was built from secondary data combined with primary data from field study. The simulation model was consisted of 2 major sub-models. The first was the razor clam population model and the second sub-model was the local fisherman model. Both of the sub-models interacted through fishermen harvesting razor clam.

Role-playing can help researcher improve a simulation model by facilitating the sharing of knowledge from the simulation model to stakeholders (human) in the system and also from stakeholders to the model. Role-playing game can facilitate knowledge from computer simulation model to Don Hoi Lord local fishermen by letting them play in the game and discuss to find suitable conservation strategies. As a result, local fishermen know what researcher think and researchers know what fisherman think also.

To summarize, Don Hoi Lord companion modelling is shown in figure 3.3

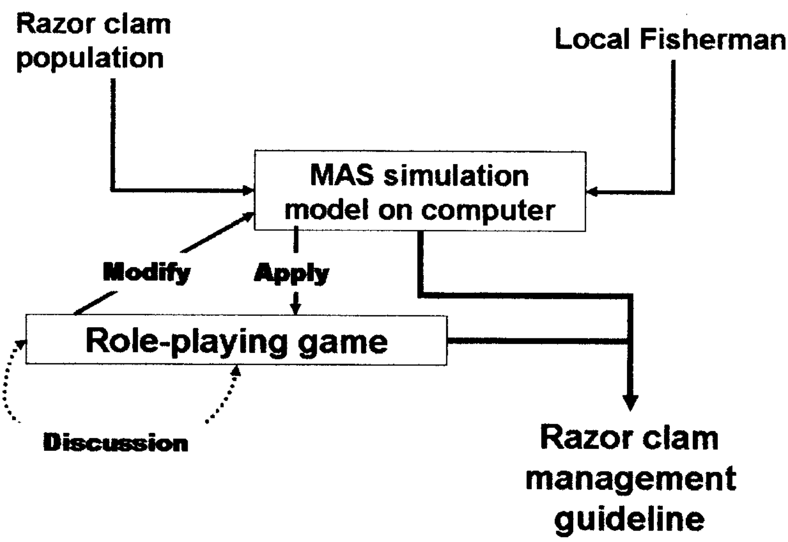


Figure 3.3 General principle of Don Hoi Lord companion modelling

3.4.2 Computer simulation model

The computer simulation model was constructed on Cormas simulation platform. This program is available at http://cormas.cirad.fr for free. However, any ecological modelling must start from a conceptual model so the consequences to construct the computer simulation model are:

- To create a conceptual model
- To apply the concept of MAS to the conceptual model by defining spatial entities (spatial), social entities (agent) and their interaction
- To create Unified Modelling Language (UML), a standard methodology to represent models (Le Page and Bommel, 2004). Furthermore, a sequential diagram is also created to represent activities in the model.
- To implement the model in Cormas platform with Smalltalk language. The Cormas platform is consisted of 3 modules (figure 3.4) following:
    1) Design specific entities
    2) Specify the sequence of task
    3) Define method of visualization

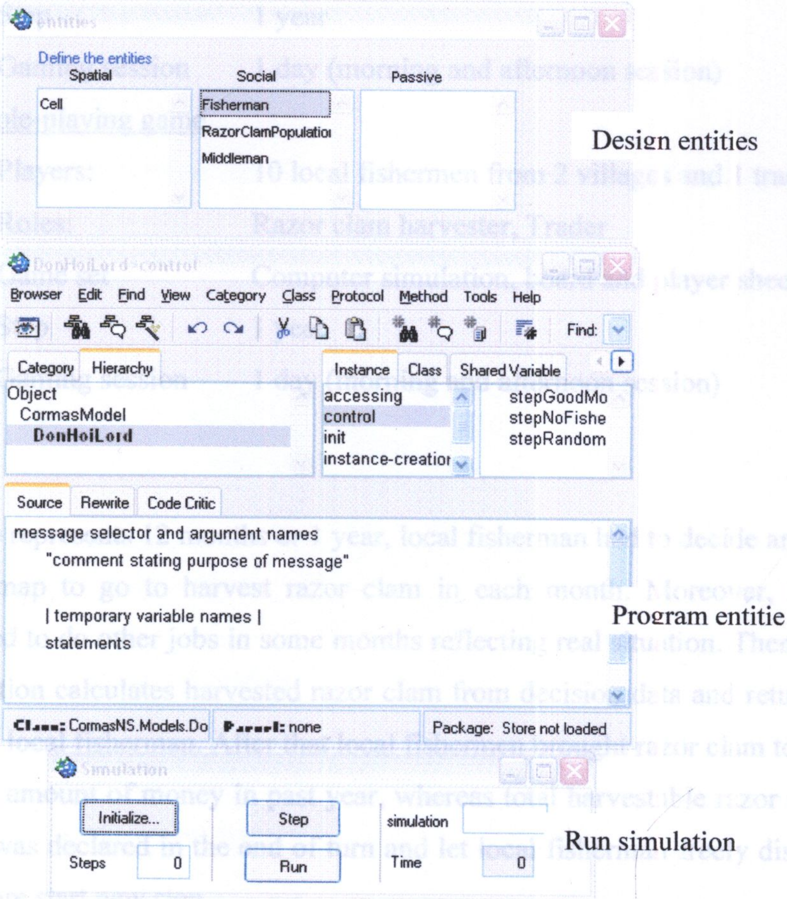


Figure 3.4 Three modules of Cormas platform

3.4.3 Role-playing game (RPG)

The RPG method was used to facilitate knowledge staring with local fishermen and to conduct collective discussion regarding razor clam conservation. Moreover, RPG enhanced researcher understanding of local fisherman behavior in razor clam harvesting. Two rounds of role-playing were conducted on 28 March 2005 and 14 July 2005 at the Chu Chi government clinic closed to Don Hoi Lord. The general features of the game included:

<u>First role-playing game</u>

- Players: 11 local fishermen
- Roles: Razor clam harvester, Trader by researcher
- Game set Computer simulation, board and player sheets

- Step 1 year
- Gaming session 1 day (morning and afternoon session)

Second role-playing game

- Players: 10 local fishermen from 2 villages and 1 trader
- Roles: Razor clam harvester, Trader
- Game set Computer simulation, board and player sheets
- Step 1 year
- Gaming session 1 day (morning and afternoon session)

Each step represents 12 months or 1 year, local fisherman had to decide area in Don Hoi Lord map to go to harvest razor clam in each month. Moreover, local fishermen decided to do other jobs in some months reflecting real situation. Then, the computer simulation calculates harvested razor clam from decision data and returned harvested data to local fisherman. After that local fishermen brought razor clam to sell to trader and got amount of money in past year, whereas total harvestable razor clam in the past year was declared in the end of turn and let local fisherman freely discuss among them before start new step.

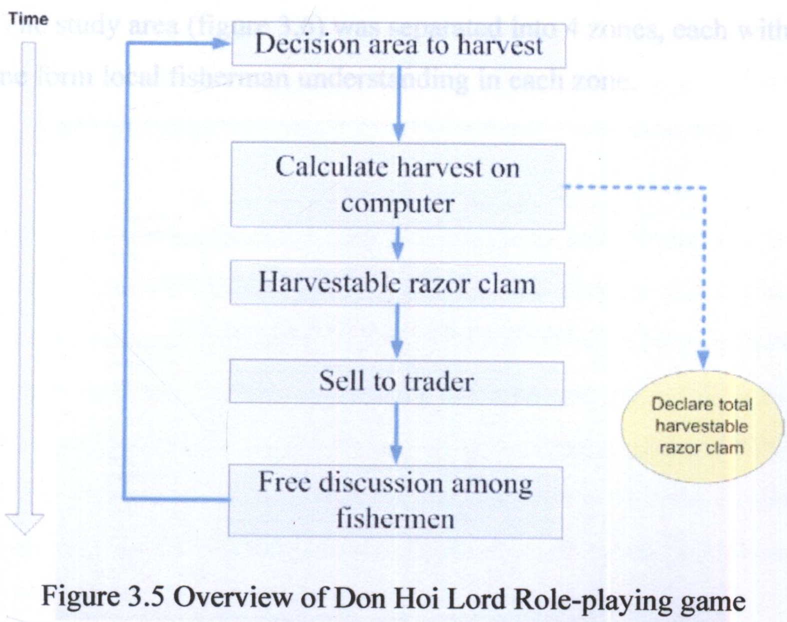


Figure 3.5 Overview of Don Hoi Lord Role-playing game

Components of the game

I Player sheets

Every local fisherman received 3 sheets: a map of study area, a decision table and an account table.

Figure 3.6 Map of study area and name of each zone in player sheets

The study area (figure 3.6) was separated into 4 zones, each with a unique name form local fisherman understanding in each zone.

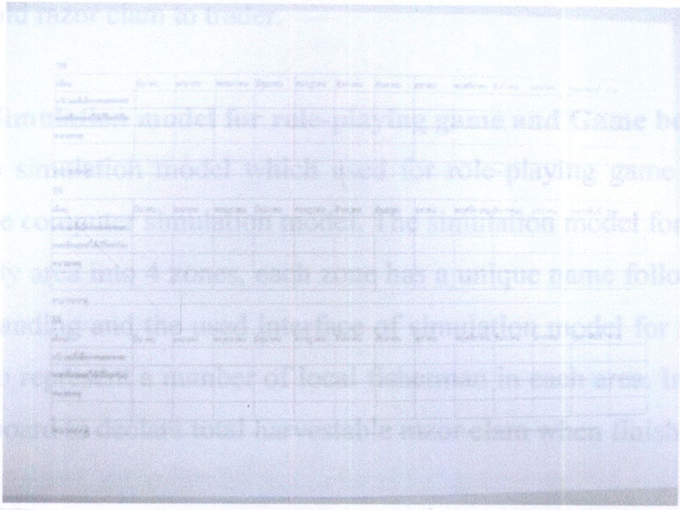


Figure 3.7 Decision table in player sheets

The decision table sheet is consisted of 3 decision tables, each represents one year. The components of table included month in year round in horizontal direction and vertical direction is selected area to harvest razor clam, harvestable razor clam and remark.

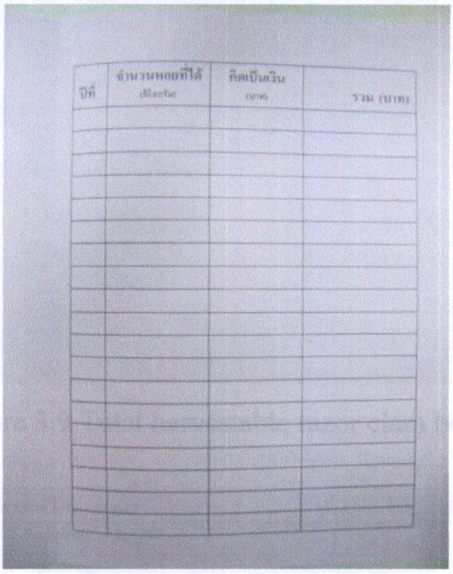


Figure 3.8 Account table in player sheets

The account table in the player sheets represent total harvestable razor clam in

each year for 1 local fisherman who own the table and total money in the year from sold razor clam to trader.

II Simulation model for role-playing game and Game board:

The simulation model which used for role-playing game was developed from the computer simulation model. The simulation model for RPG separated the study area into 4 zones, each zone has a unique name following fisherman understanding and the used interface of simulation model for RPG as a game board to represent a number of local fisherman in each area. In addition, there is one board to declare total harvestable razor clam when finish turn.

Figure 3.9 Total harvestable razor clam board

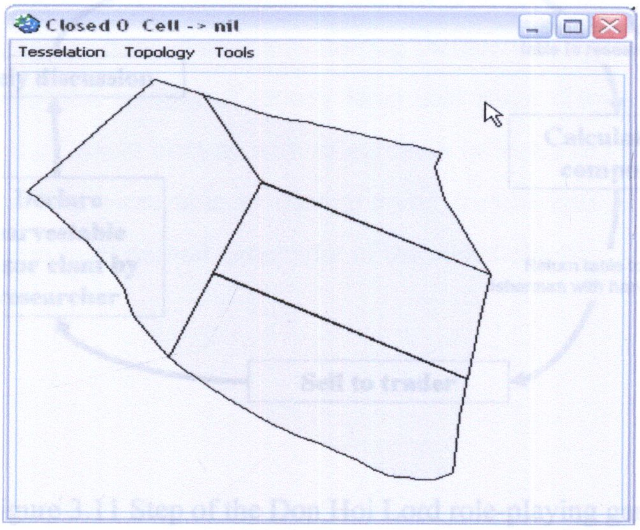


Figure 3.10 Interface of simulation model for RPG

III Gaming session

Don Hoi Lord role-playing game was conducted into 2 sessions: morning and afternoon session. In the morning session the introduction and explanation about the game were carried out to local fishermen and let them play the game 6 steps. After finish each step, local fishermen can has shot discussion among them before start new step and they can able to change some rules in the game if they had collective decision.

In the afternoon session, the game was continued for 3 steps and the researcher presented local fisherman two alternative scenarios in the game on the simulation model for RPG. Finally, the collective discussion from stakeholders (local fisherman, researchers and local government) was conducted regarding razor clam conservation until finished afternoon session.

IV Step of the game

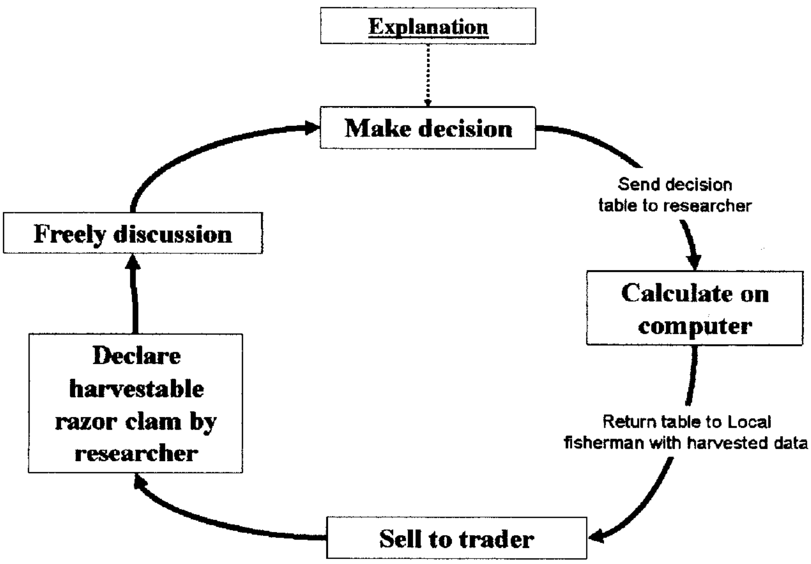


Figure 3.11 Step of the Don Hoi Lord role-playing game

The game started with the explanation of the background, the components of the game and the gaming loop (figure 3.11).

First step, <u>Make decision</u>; the local fishermen makes decision from the map in player sheet: where they want to go to harvest razor clam for each month? They wrote their decision for all 12 months in the decision table. In addition, local fisherman can decide to get another job but they have write in the decision table also in the remark box.

Second step, Calculate on computer; player sheets were returned to the researcher. Selected area data from each fisherman were put in the simulation model to calculated harvested razor clam. During the calculation, the interface showed the number of local fishermen in each area in each month. When the calculation was finished, harvested razor clam of each fisherman was written in decision table and returned to local fishermen.

Third step, Sell to trader; every local fisherman went to the trader desk and sold harvested razor clam to the trader. Total money from selling razor clam was written in to the account table which was then to local fisherman.

Fourth step, Declare harvestable razor clam; Total harvested clam from the computer simulation in each area and size were declared on total harvestable razor clam board and let local fisherman see productions of the razor clam.

Lastly, Freely discussion. Before the end of each turn, local fishermen were allowed to have discussions among themselves regarding production of razor clam, total amount of money from sold razor clam and other issue. In addition, they could discuss with researchers in terms of rules or steps of the game, and they were able to change some components of the game, if the change came from mutual agreement of the stakeholders.

CHAPTER IV

RESULTS AND DISCUSSIONS

4.1 STUDY AREA AND LOCATION OF RAZOR CLAM POPULATION DATA COLLECTION

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

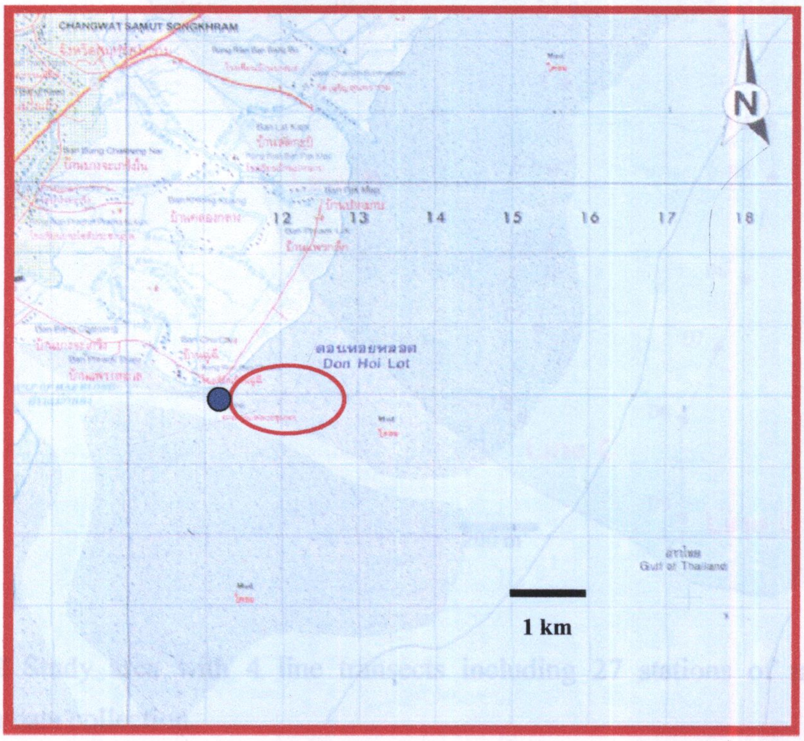


Figure 4.1 Study area in Don Hoi Lord (red eclipse) and Prince Chumporn Khedudomsak Memorial (dark blue spot)

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

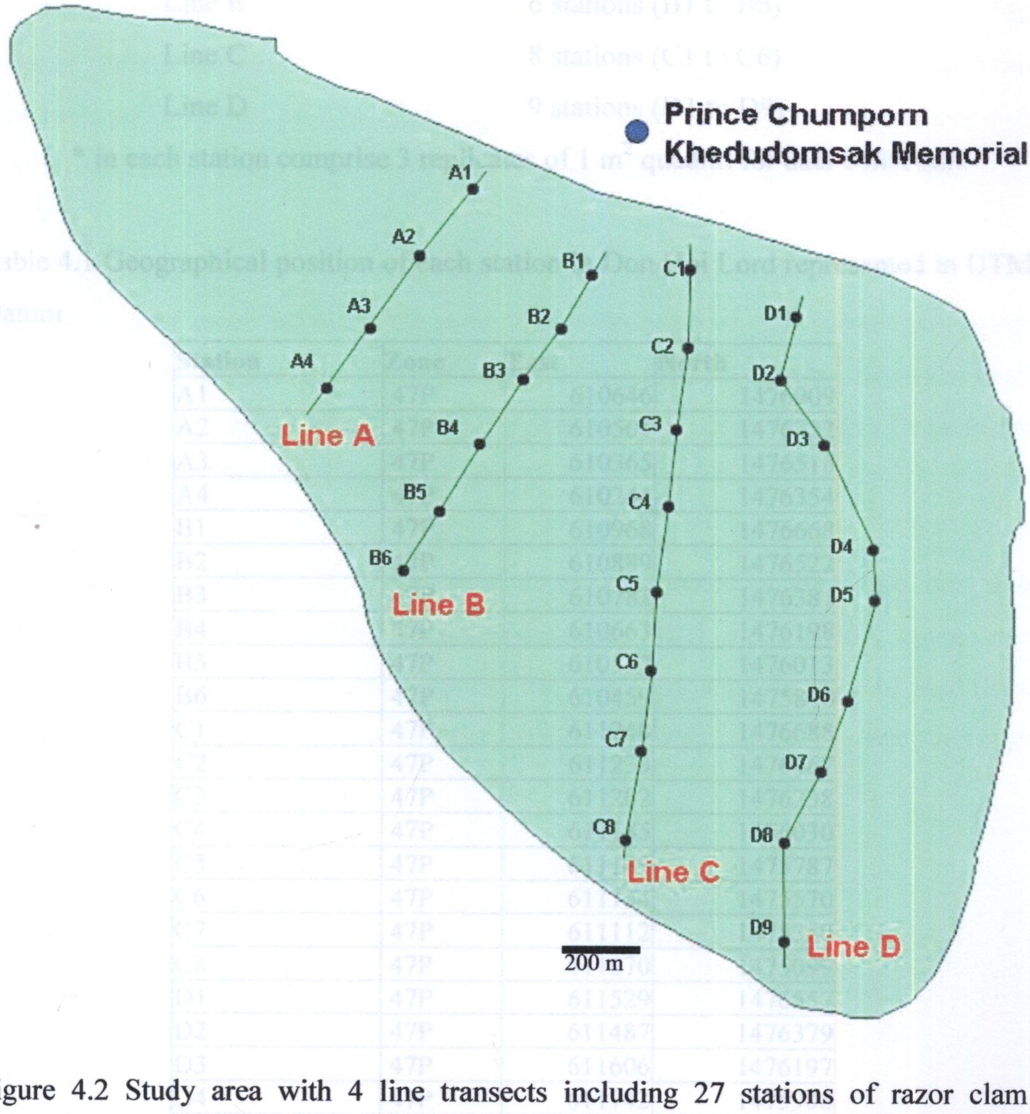


Figure 4.2 Study area with 4 line transects including 27 stations of razor clam population data collection.

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

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

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

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

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

4.2 PHYSICAL CHARACTERISTICS OF STUDY AREA

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

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

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

Table 4.2 Sequential data collection by monthly.

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

* Time on next day

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

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

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

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

4.3 RAZOR CLAM POPULATION

4.3.1 Density of razor clam

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

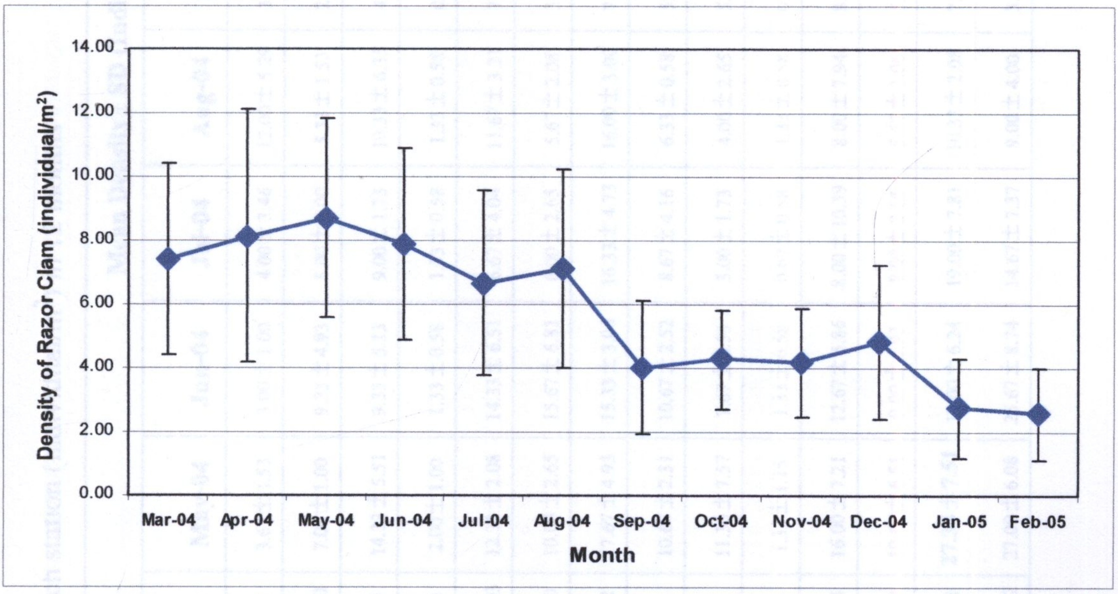


Figure 4.3 Mean of razor clam density (individual/m^2) in this study

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

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

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

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

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

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

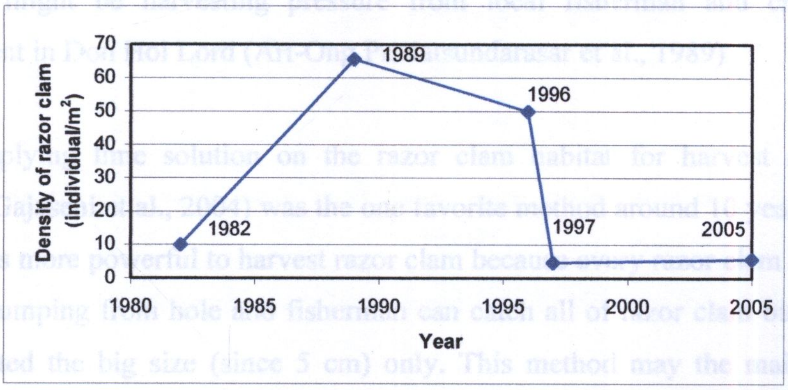
Table 4.4 Statistical analysis of razor clam density (Independent Sample T-Test at $P < 0.05$)

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

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

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

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



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

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

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

Month	Year & Density (individual/m²)				
	I (1981)	II (1988)	III (1996)	IV (1997)	**V (2004)**
March	9.5	17.3	N/A	3.4	**7.4**
April	N/A	30.9	12.6	10.6	**8.1**
May	11.7	33.7	49.5	7.4	**8.7**
June	N/A	37.0	18.9	2.7	**7.9**
July	N/A	29.9	129.1	9.4	**6.7**
August	8.8	102.9	87.1	7.9	**7.1**
September	N/A	40.9	N/A	N/A	**4.0**
October	N/A	N/A	84.7	2.8	**4.3**
November	N/A	87.5	31.6	1.5	**4.1**
December	N/A	209.6	24.1	4.5	**4.8**
January	N/A	N/A	N/A	0.2	**2.7**
February	N/A	N/A	8.1	0.1	**2.6**
Mean	**10**	**65.5**	**49.5**	**4.6**	**5.7**

I Art-ong Pradatsundarasar, 1982

II Art-ong Pradatsundarasar et al., 1989

III Thaviongse Sriburi and Nantana Gajaseni, 1996

IV Rangsimant Bautong, 1997

V this study, 2005

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

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

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

4.3.2 Razor clam weight

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

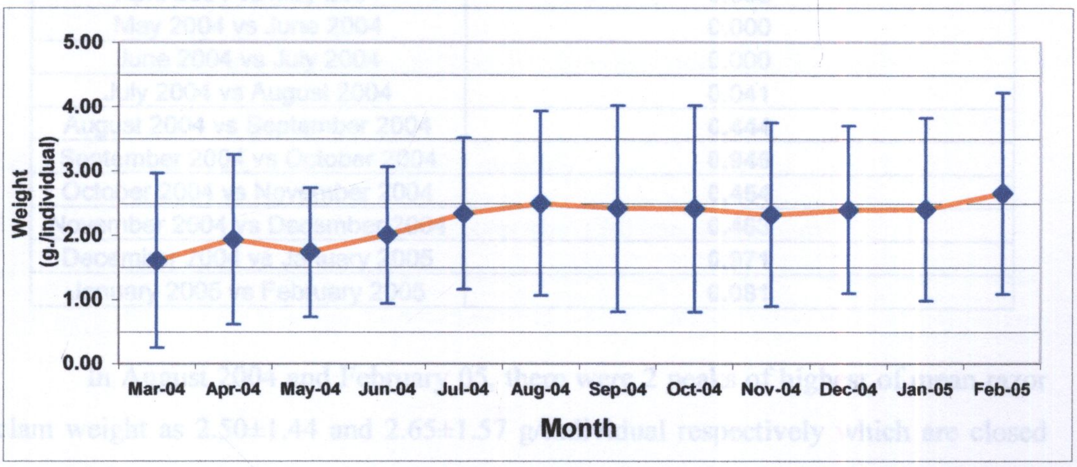


Figure 4.5 Mean of razor clam weight (g/individual) in this study

Table 4.6 Mean of razor clam weight by monthly

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

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

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

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

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

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

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

4.3.3 Razor clam size

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

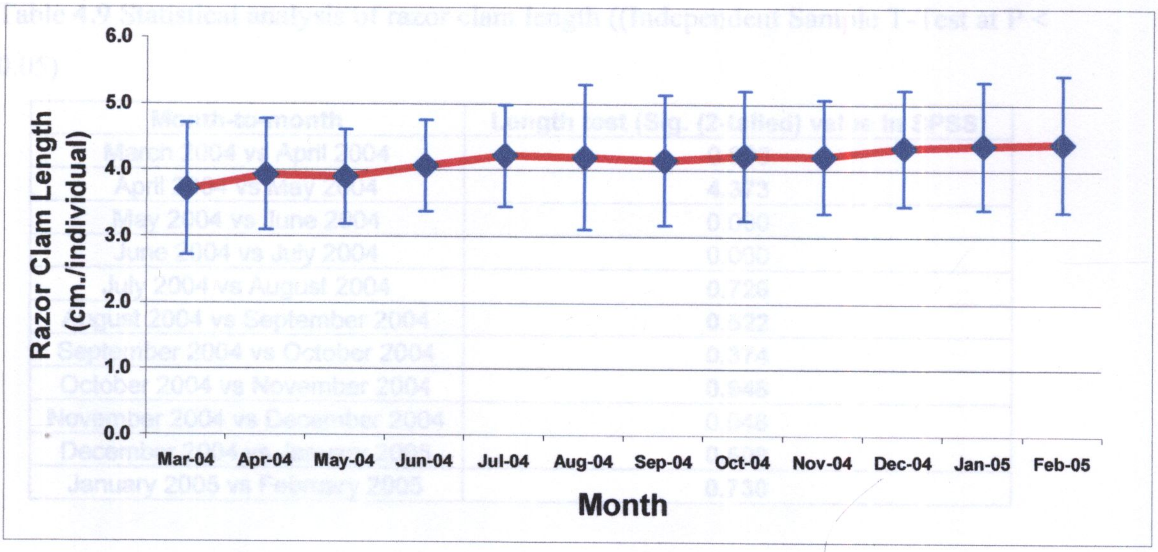


Figure 4.6 Mean of razor clam size (cm/individual) in this study

Table 4.8 Mean of razor clam length by monthly

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

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

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

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

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

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

4.3.4 Population structure of razor clam

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

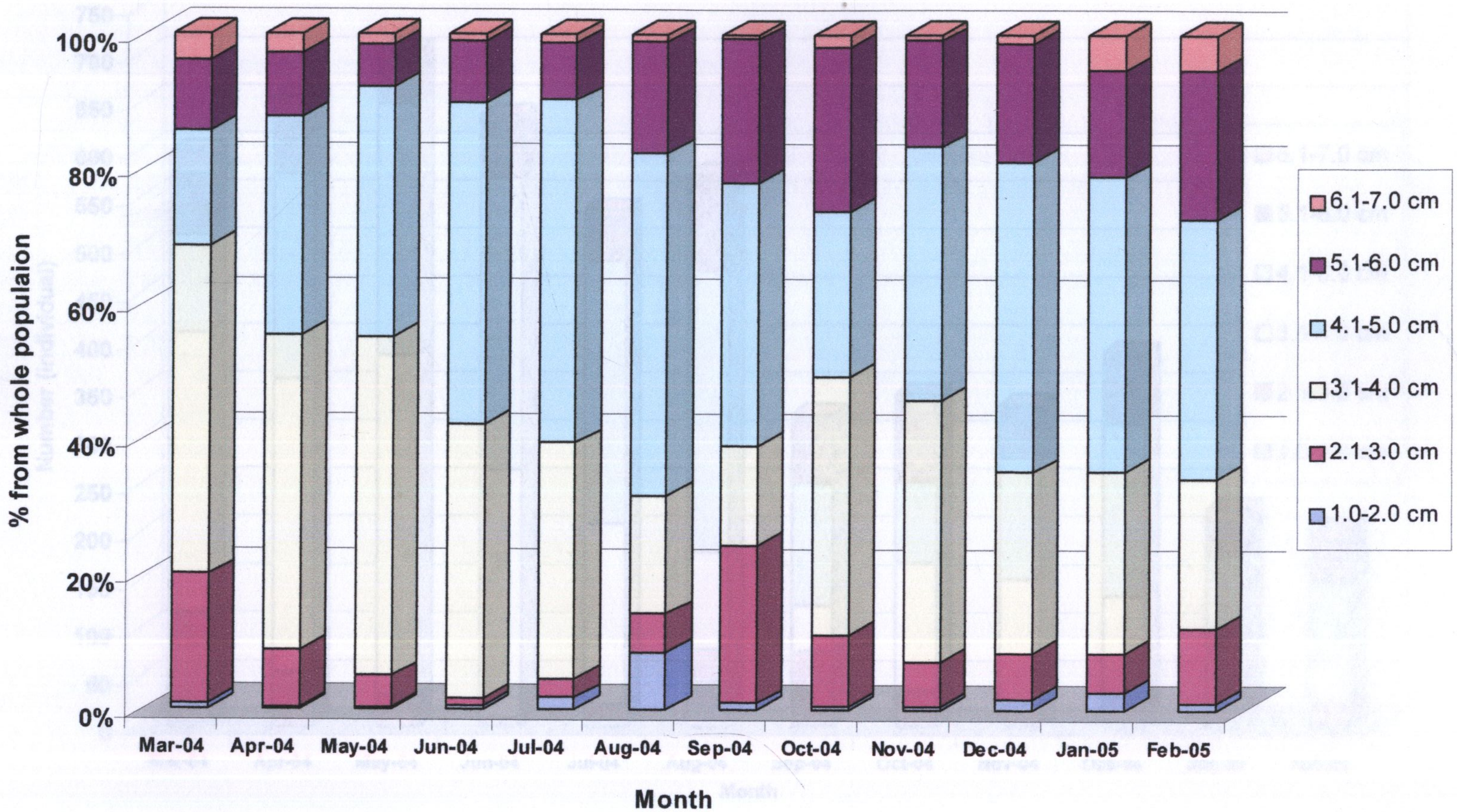


Figure 4.7 Total population structure of razor clam in percentage scale

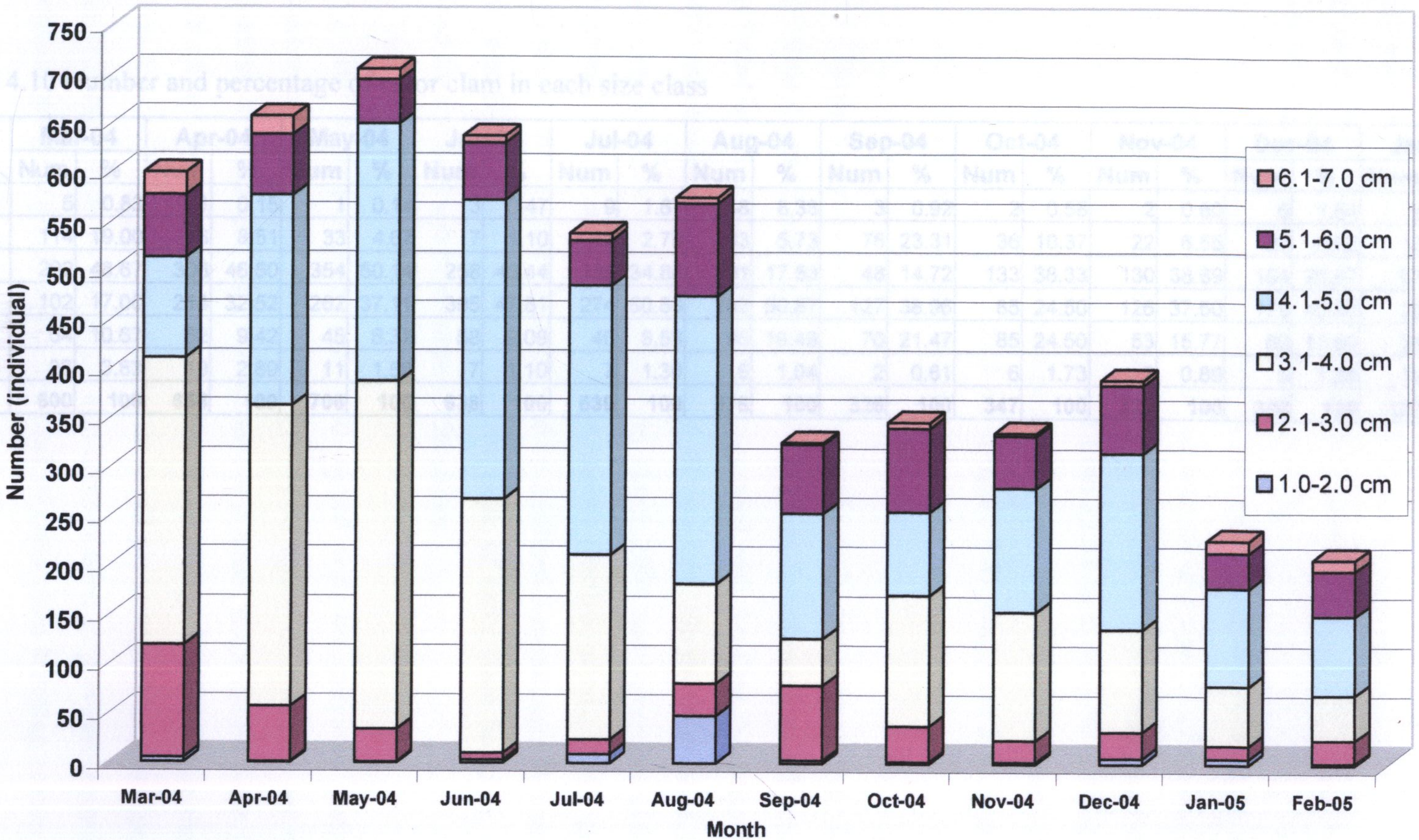


Figure 4.8 Total population structure of razor clam in number scale

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

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

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

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

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

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

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

4.3.5 Relationship between weight and length of razor clam

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

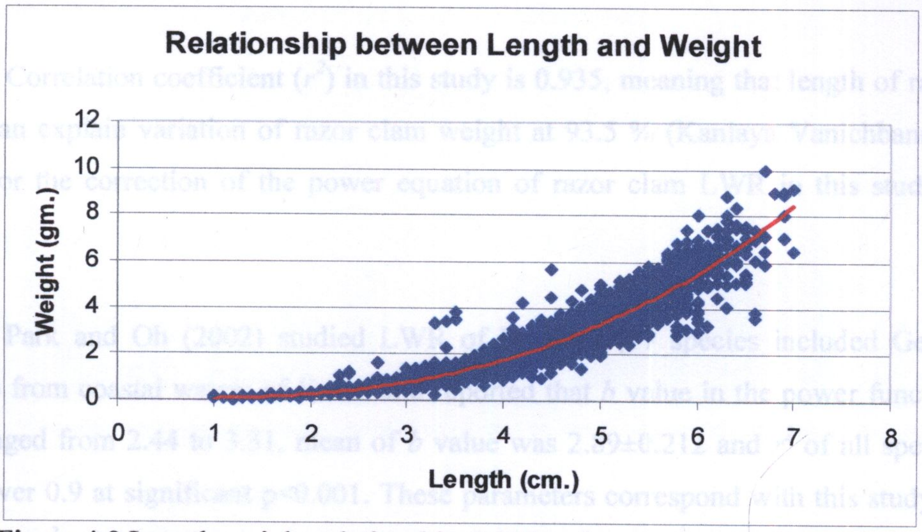


Figure 4.9 Length-weight relationship (LWR) of razor clam in this study

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

$$W = aL^b$$

When W = razor clam weight

L = razor clam length

a = specific gravity or intercept

b = growth constant or slope

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

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

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

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

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

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

4.4 HUMAN ACTIVITIES

4.4.1 Number of local fisherman

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

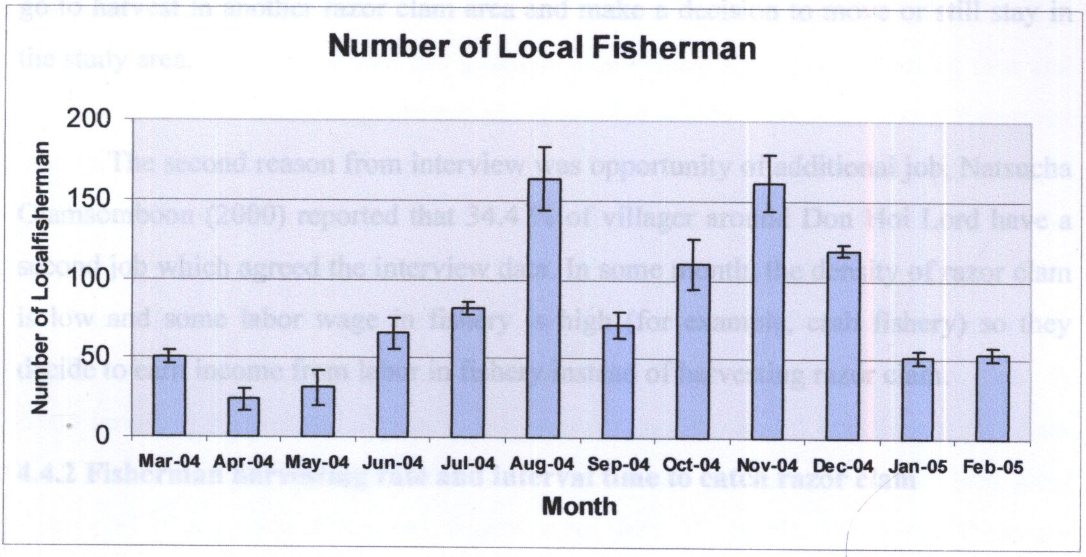


Figure 4.10 Mean of number of local fisherman (person/day) in study area in each month

Table 4.11 Mean of local fisherman number in the study area

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

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

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

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

4.4.2 Fisherman harvesting rate and interval time to catch razor clam

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

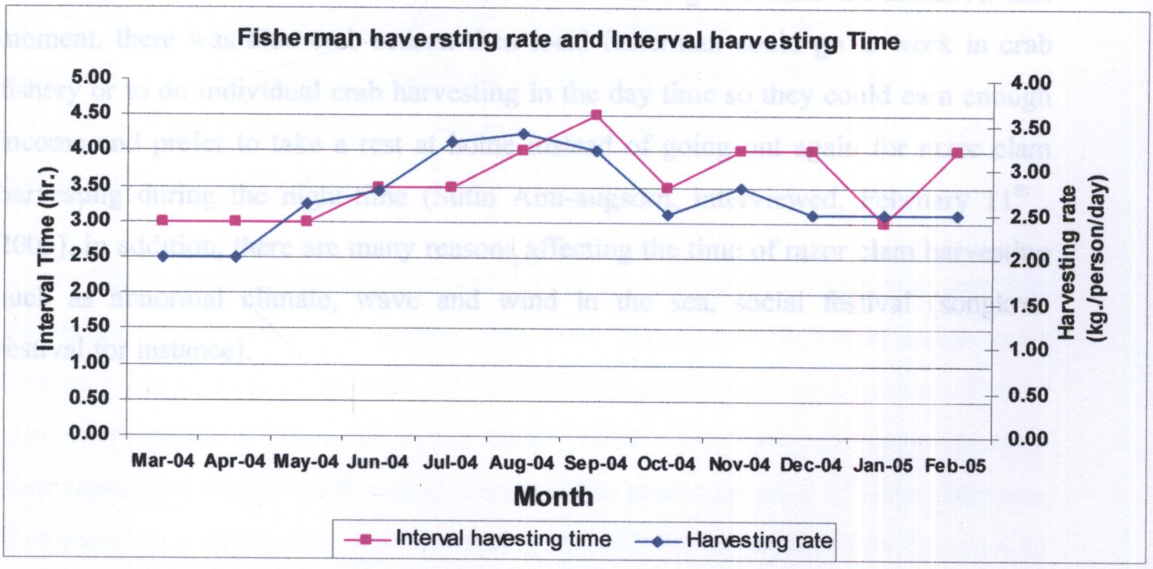


Figure 4.11 Fisherman harvesting rate and interval time to catch razor clam

(Note: Harvesting rate on right X axis and interval time on left X axis)

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

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

4.4.3 Razor clam price

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

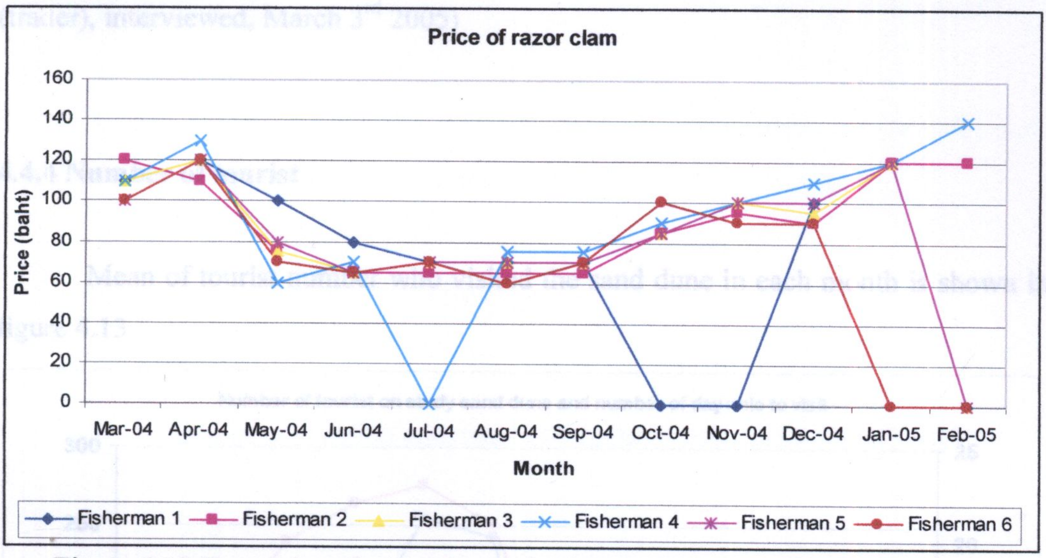


Figure 4.12 Dynamics of razor clam price in one year from 6 local fishermen (* price = 0 mean local fisherman decided to get additional job in that month)

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

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

4.4.4 Number of tourist

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

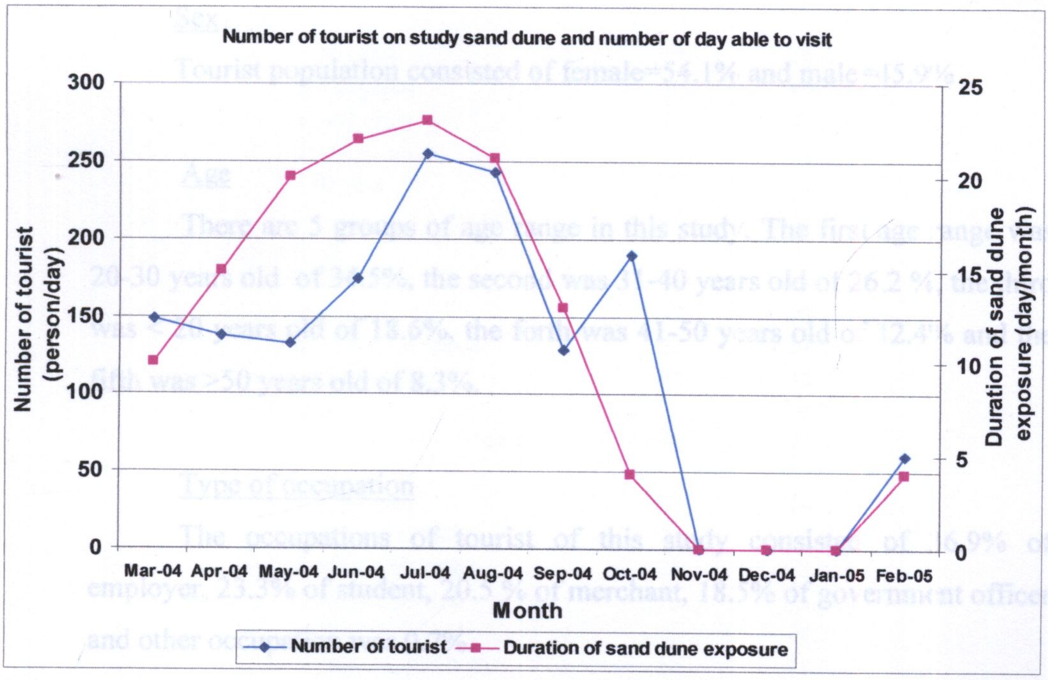


Figure 4.13 Mean of tourist number on the study sand dune and duration of sand dune exposure.

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

4.4.5 Tourist behavior

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

General characteristics of tourist

Sex

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

Age

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

Type of occupation

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

Income

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

Visit to Don Hoi Lord

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

Table 4.12 Number and percentage of general characteristics of tourist

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

Purposes to visit Don Hoi Lord

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

Look around area

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

Have a meal

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

Pay respect to Prince Chumporn Khedudomsak memorial

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

Buy seafood product

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

Traveling on sand dune

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

Table 4.13 Frequency of purpose to visit Don Hoi Lord

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

Tourist behavior on razor clam population

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

Catch razor clam

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

Razor clam catching ability of tourist

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

Left lime on sand dune

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

Table 4.14 Frequency of tourist behavior on razor clam population

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

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

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

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

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

4.5 MULTI-AGENT SIMULATION MODEL CONSTRUCTION

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

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

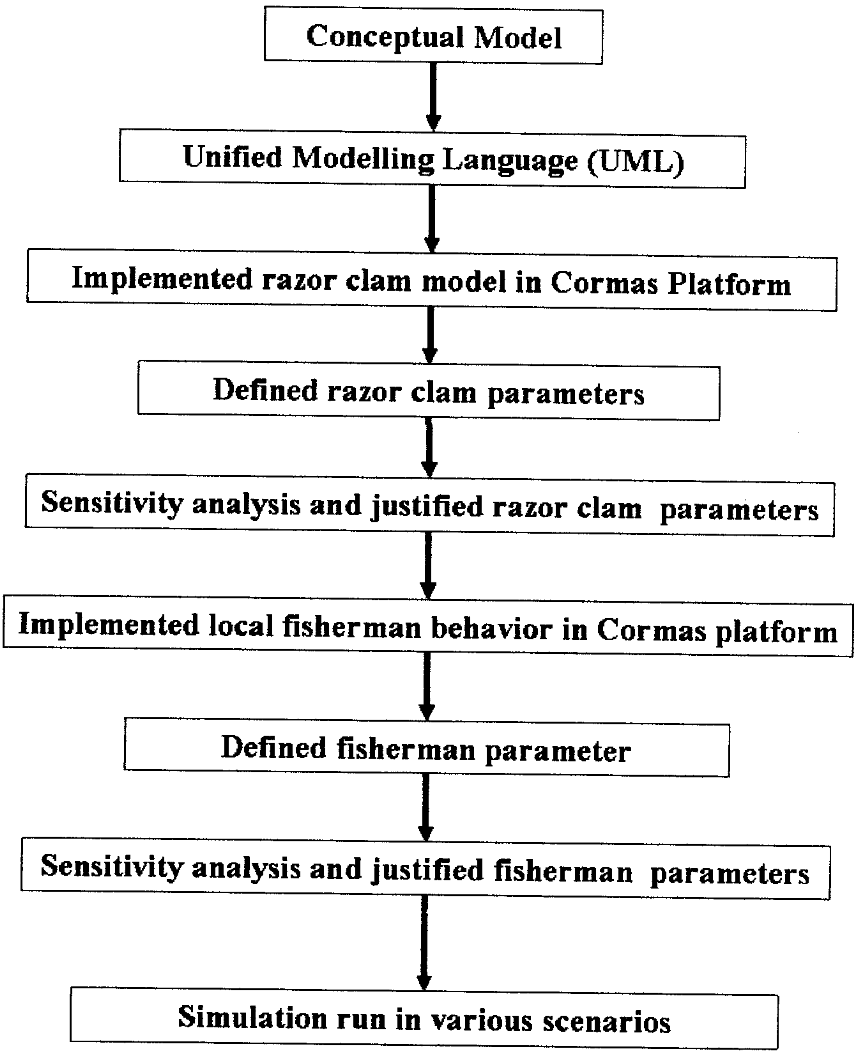


Figure 4.14 Overview of the multi-agent simulation model construction

4.5.1 Conceptual model and UML class diagram

- <u>Conceptual model</u>

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

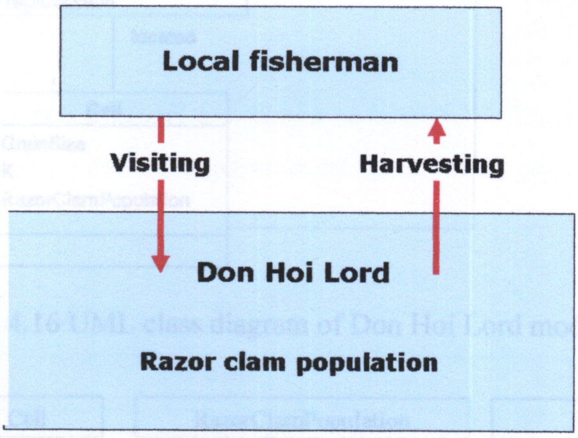


Figure 4.15 Conceptual model for model construction

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

- <u>UML class diagram</u>

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

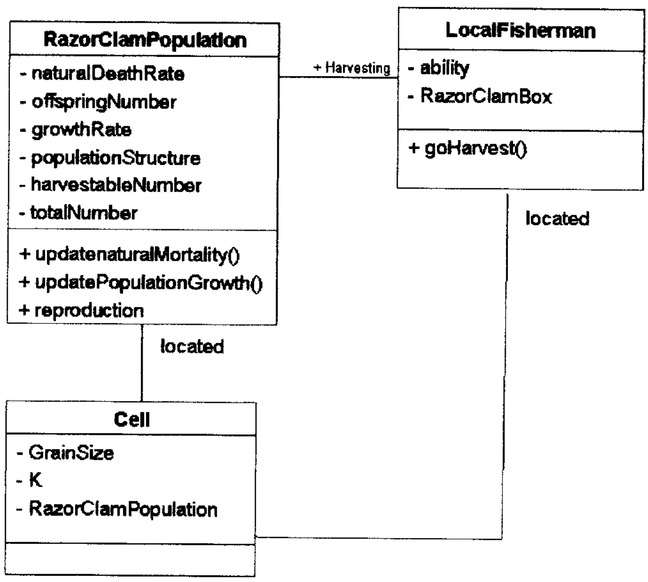


Figure 4.16 UML class diagram of Don Hoi Lord model

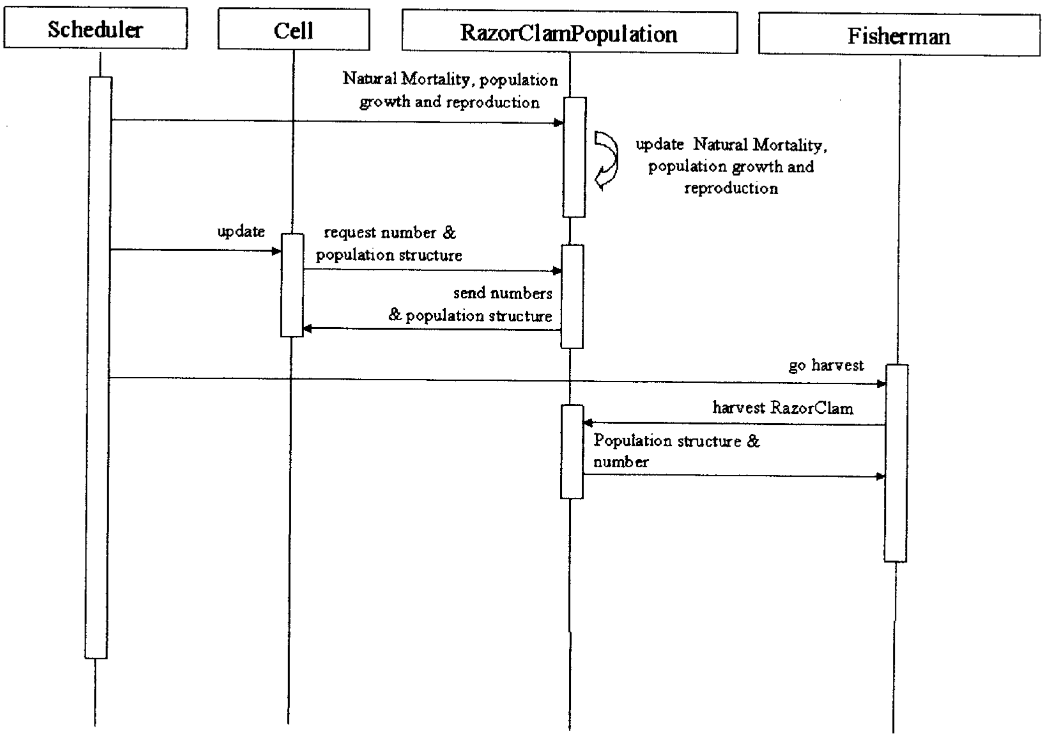


Figure 4.17 Sequential diagram of Don Hoi Lord model

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

4.5.2 Parameters

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

Table 4.15 Don Hoi Lord model parameters

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

Table 4.15 continue

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

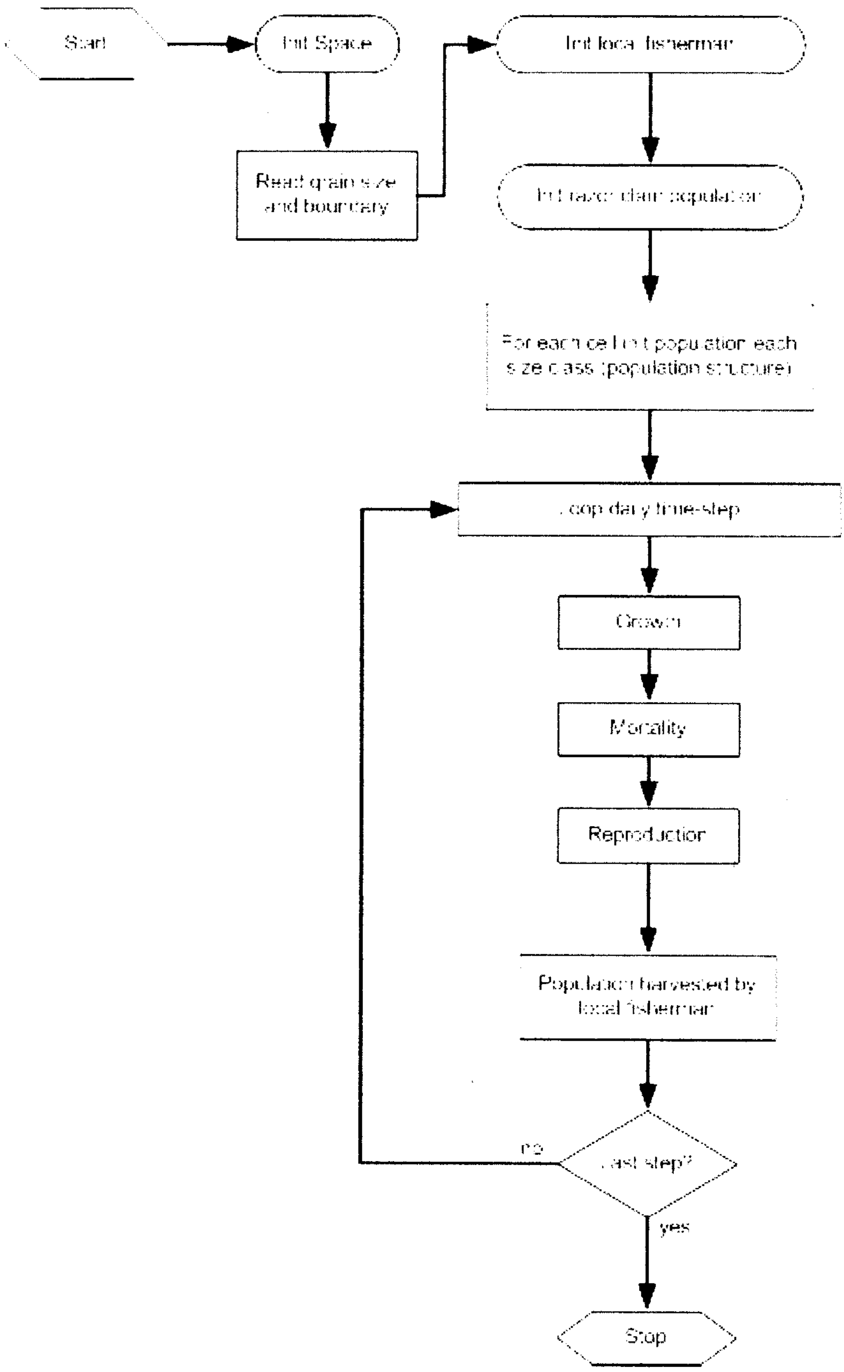


Figure 4.18 Overall flow chart of Don Hoi Lord model

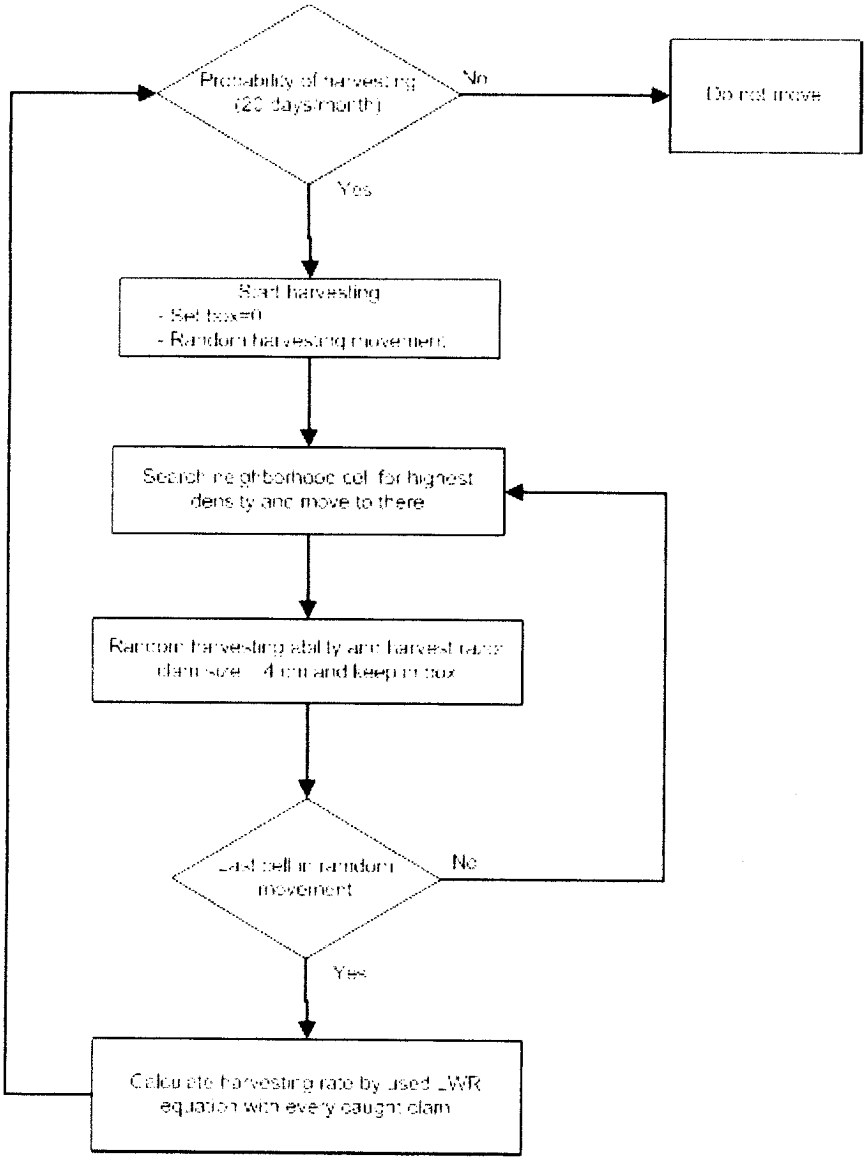


Figure 4.19 Flow chart of local fisherman activity (*LWR see chapter 4.3.5)

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

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

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

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

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

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

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

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

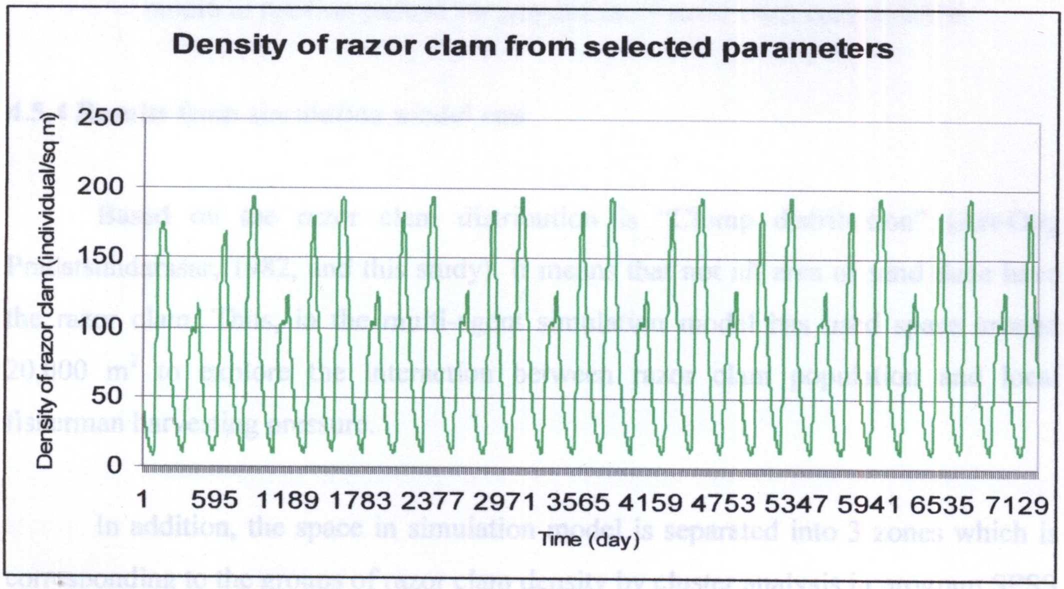


Figure 4.20 Density of razor clam from selected parameters (20 years simulation run)

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

4.5.3 Scenarios

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

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

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

4.5.4 Results from simulation model run

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

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

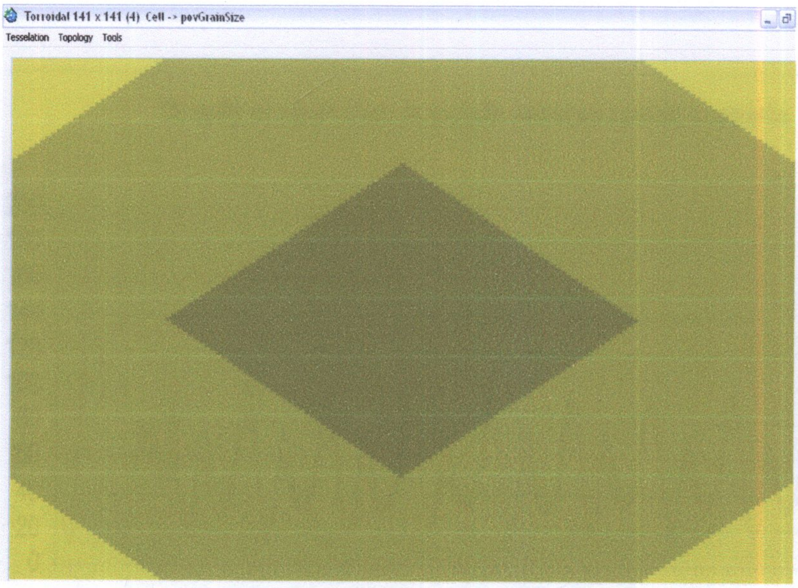


Figure 4.21 Multi-agent simulation interface represent the difference 3 zones in the model

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

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

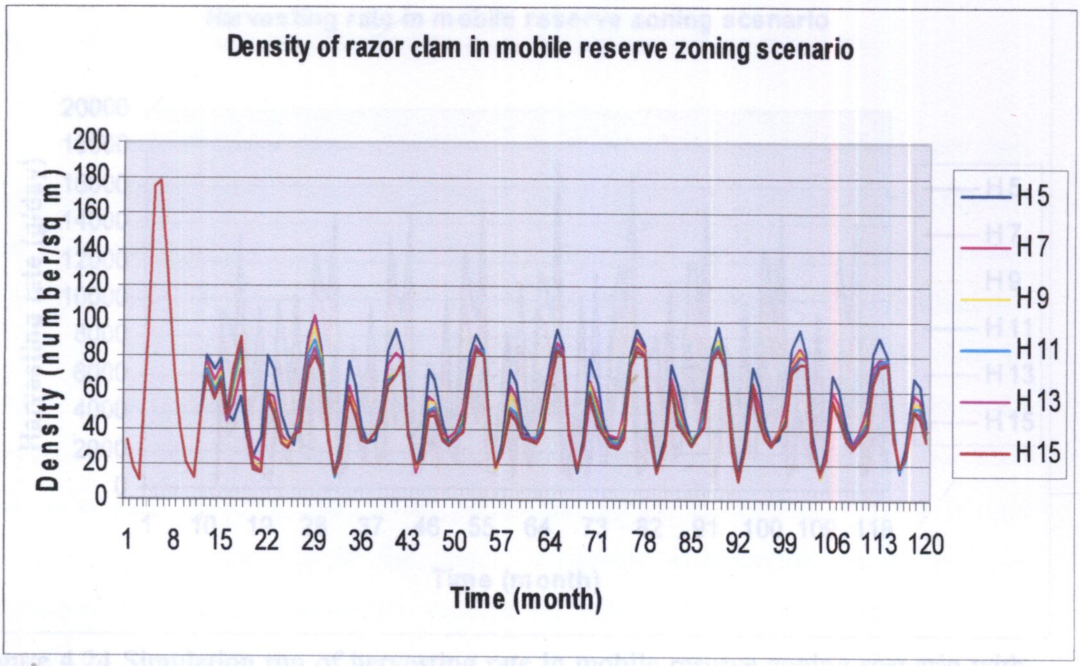


Figure 4.22 Simulation run in density of razor clam in mobile reserve zoning scenario with difference local fisherman number (H5-H15=Density at 5-15 fishermen)

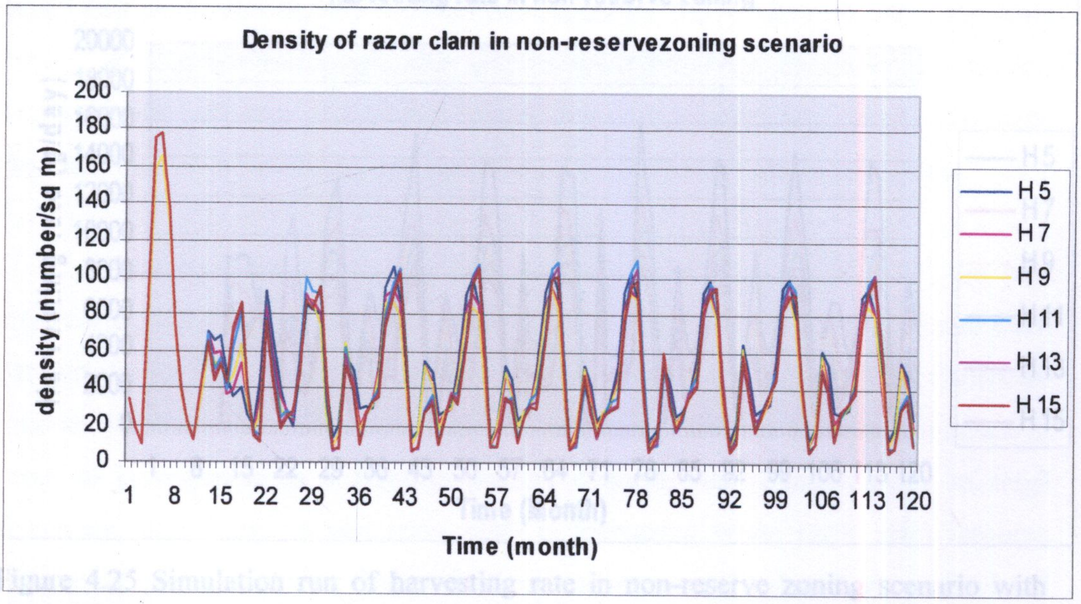


Figure 4.23 Simulation run in density of razor clam in non-reserve zoning scenario with difference local fisherman number (H5-H15=Density at 5-15 fishermen)

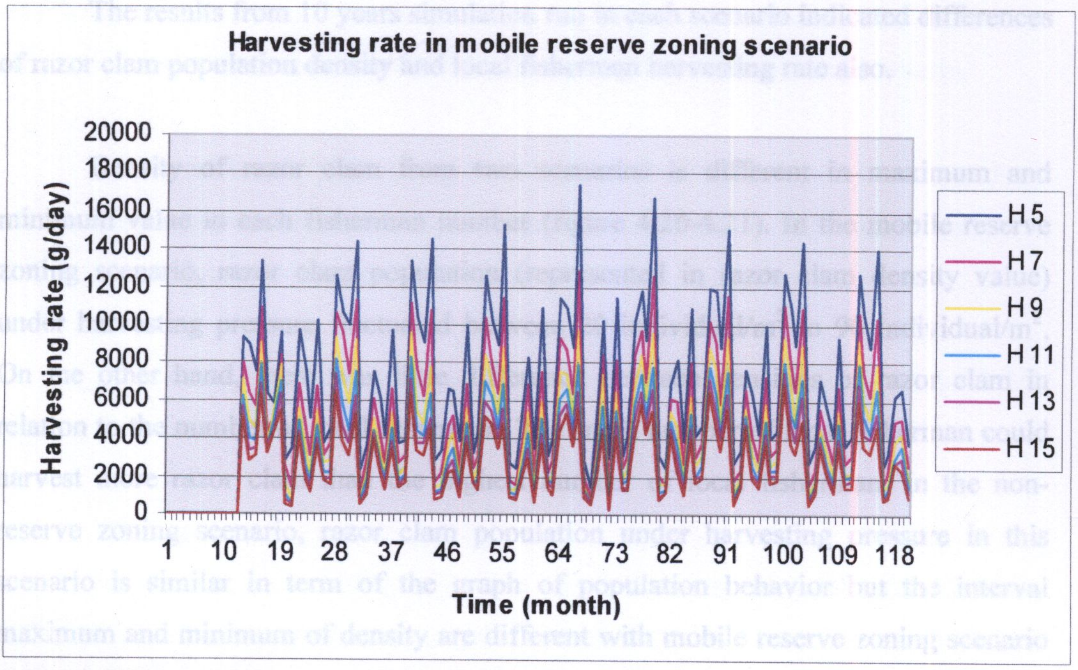


Figure 4.24 Simulation run of harvesting rate in mobile reserve zoning scenario with difference number of fisherman. (H5-H15=Harvesting at 5-15 fishermen)

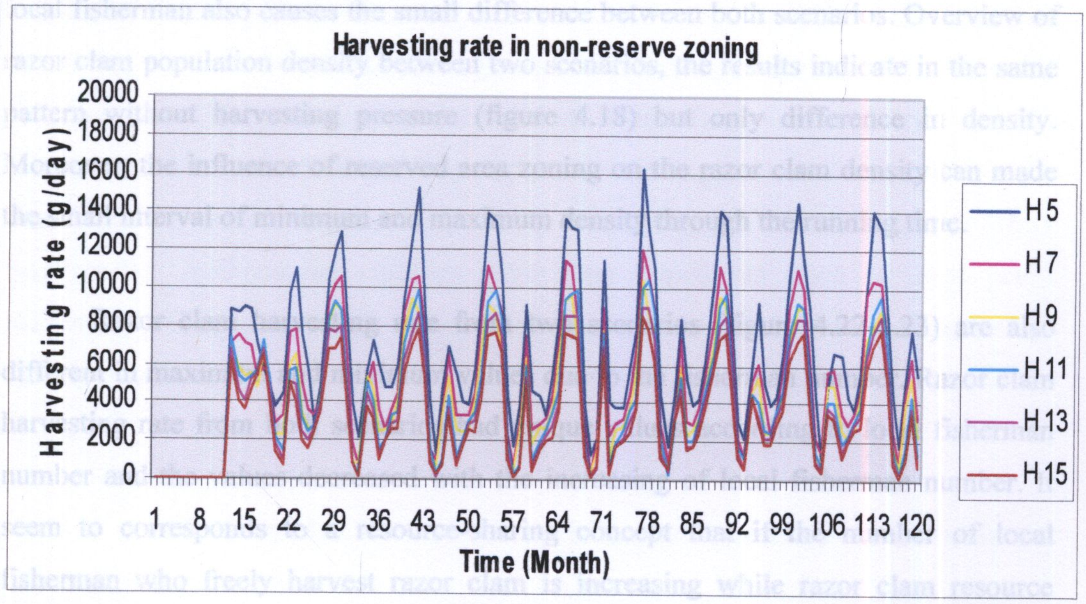


Figure 4.25 Simulation run of harvesting rate in non-reserve zoning scenario with difference number of fisherman. (H5-H15=Harvesting at 5-15 fishermen)

(* see more detail both scenarios at appendix D2)

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

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

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

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

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

- The resilience of razor clam resource

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

- Multi-agent simulation model

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

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

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

4.6 ROLE-PLAYING GAME (RPG)

4.6.1 Overviews of the game

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

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

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

- Simulation model accompany with both role-playing game

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

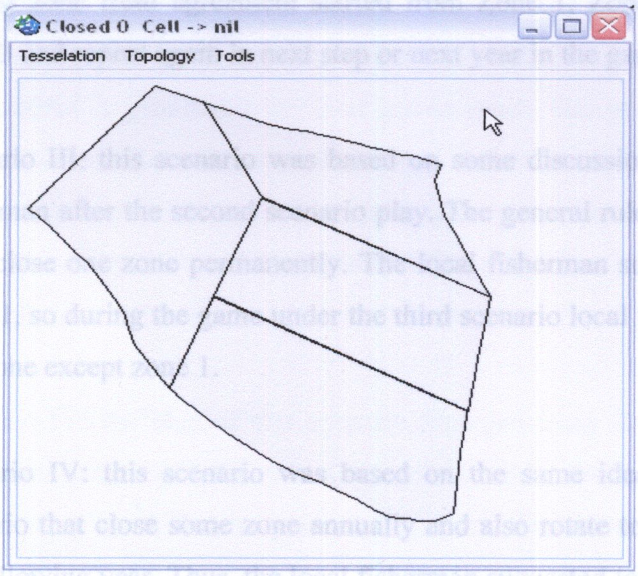


Figure 4.26 Interface of simulation model for RPG

- Scenarios

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

First role-playing game

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

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

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

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

Second role-playing game

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

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

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

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

4.6.2 Understanding of the fisherman acting

- Local fisherman's zone selection

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

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

- Additional jobs

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

- Discussion session among local fisherman

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

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

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

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

Figure 4.27 Discussion process among fisherman

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

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

4.6.3 Summary of the game

- Results from scenarios

First role-playing game

- First scenario: Freely harvesting

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

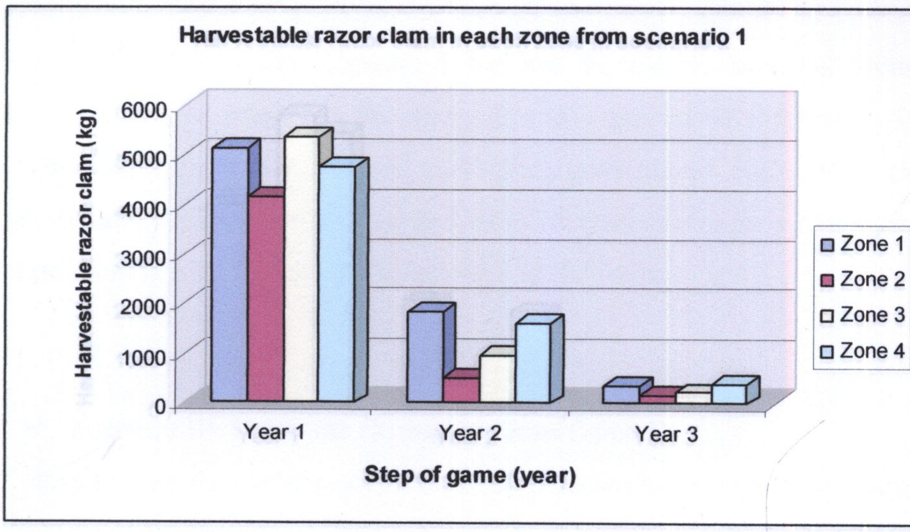


Figure 4.30 Harvestable razor clam in each zone in scenario I in 1st RPG

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

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

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

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

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

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

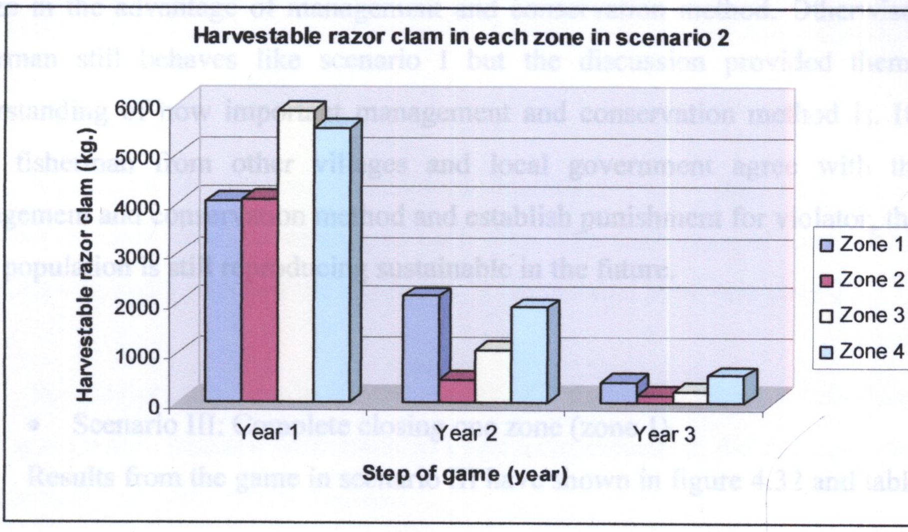


Figure 4.31 Harvestable razor clam in each zone in scenario II in 1st RPG

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

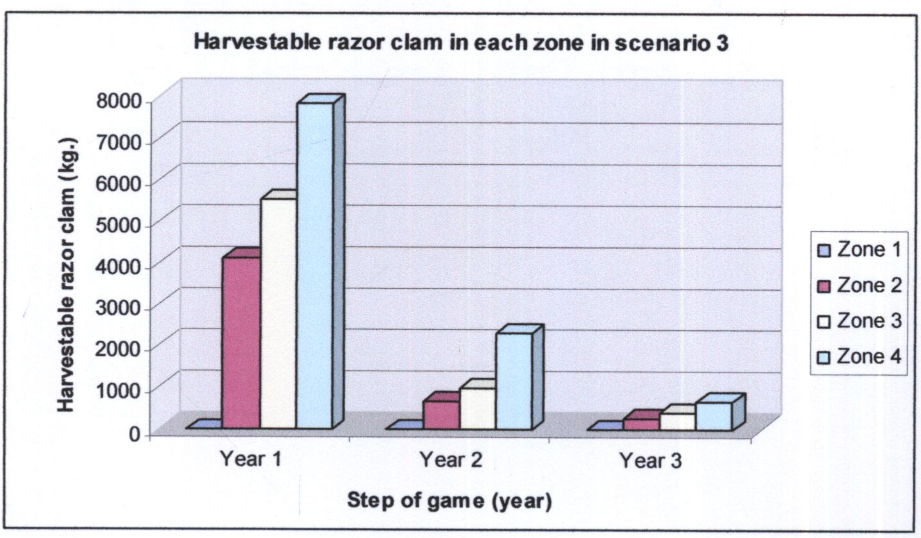
Zone / year	Zone 1	Zone 2	Zone 3	Zone 4	Total
Year 1	4044	4089	5845	5502	19480
Year 2	2133	434	1048	1906	5521
Year 3	420	135	238	545	1338

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

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

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

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



*Complete closing zone 1

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

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

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

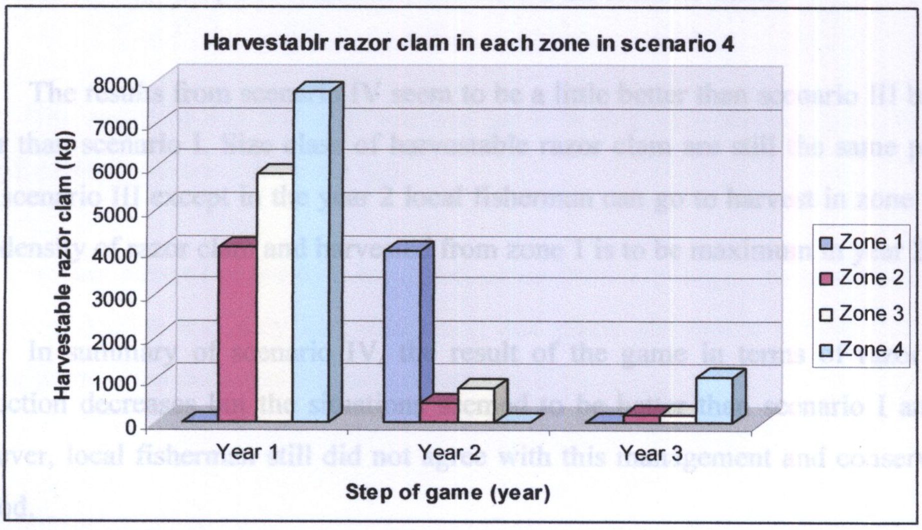
The idea of this scenario based on local fisherman idea during their discussion by complete closing zone 1 as preserved razor clam breeding ground. In this scenario local fisherman did not play by them self but researcher run the computer simulation and shown the result to them.

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

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

- Scenario IV: Annual switch closing one zone

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



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

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

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

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

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

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

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

Second role-playing game

- Scenario I: Freely harvesting

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

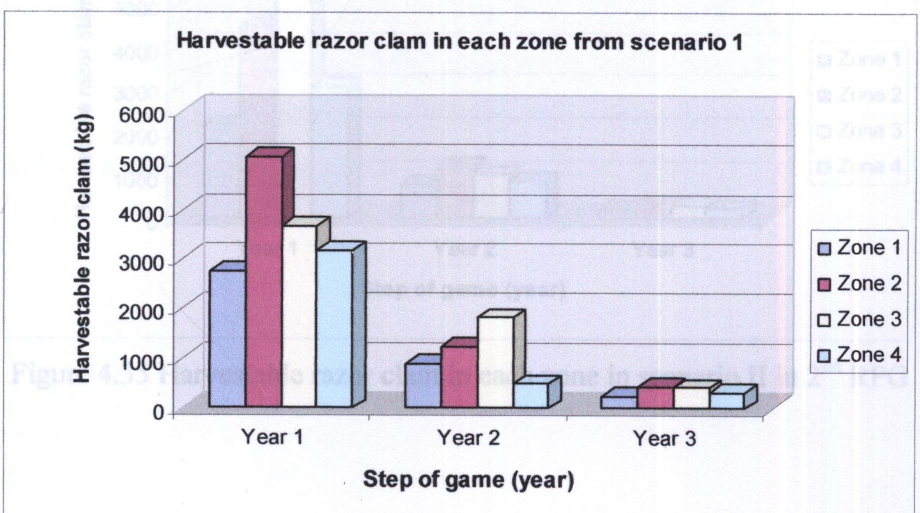


Figure 4.34 Harvestable razor clam in each zone in scenario I in 2nd RPG

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

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

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

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

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

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

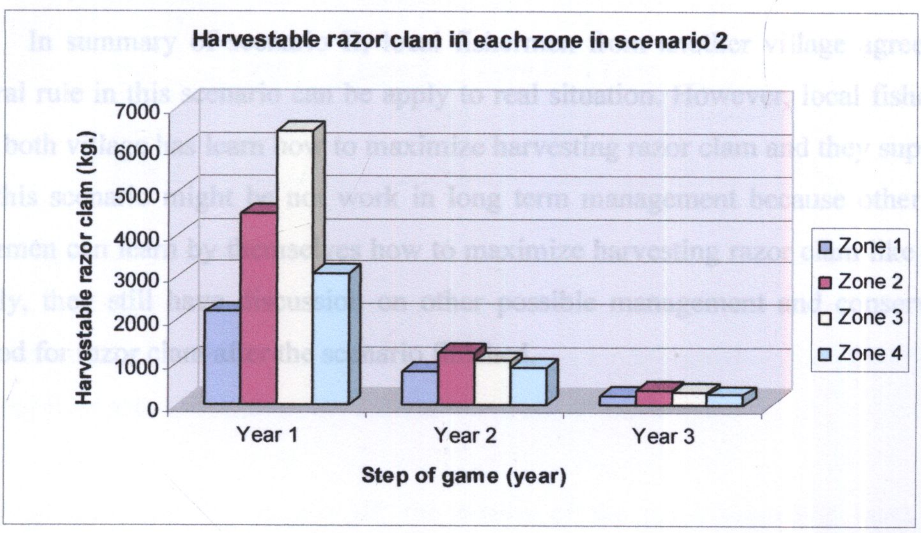


Figure 4.35 Harvestable razor clam in each zone in scenario II in 2nd RPG

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

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

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

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

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

- Scenario III: Dressing lime solution method

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

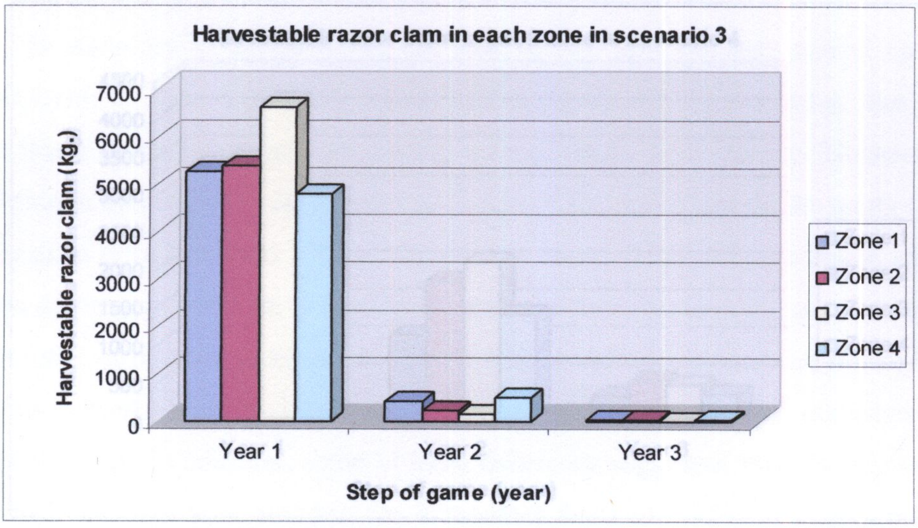


Figure 4.36 Harvestable razor clam in each zone in scenario III in 2nd RPG

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

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

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

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

- Scenario IV: Quota system

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

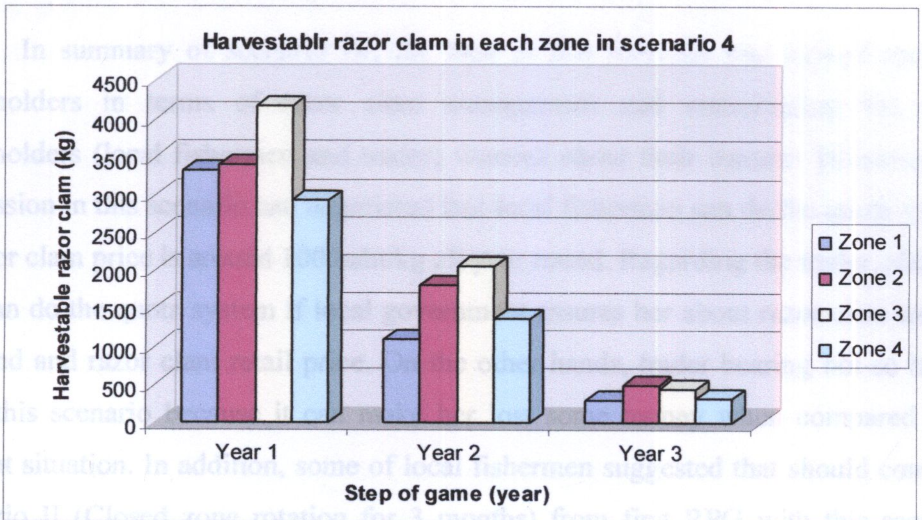


Figure 4.37 Harvestable razor clam in each zone in scenario IV in 2nd RPG

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

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

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

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

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

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

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

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

4.7 DISCUSSION ON COMPANION MODELLING

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

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

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

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 RAZOR CLAM POPULATION

Population dynamic of razor clam at Don Hoi Lord from this study can be represented as follows:

- Density of razor clam through year round was 5.71±2.49 individula/m^2, density of razor clam during daytime low tide was higher than density during nighttime low tide.
- Average razor clam weight from this study was 2.14±0.33 g/individual. In addition, razor clam weight in this study seems increase when it close to breeding season.
- Average of razor clam size from this study was 4.15±0.90 cm/individual. From Sunan Tuaycharoen and Phanit Voraingtara, (1991) reported razor clam can reproduce at size over 4.24 cm. from this study, razor clam population seemed to have a risk of population reduction because the average razor clam size cannot breed until its size reaches 4.24 cm. Therefore, it mean that the marketable size is in reproductive stage of population structure from this effect the population will decline in the near future.
- Population structure of razor clam, majority size class of razor in this study was 3-5 cm. Besides, size classes more than 5 cm are caught by local fisherman.
- Razor clam breeding season, can confirm that the breeding season is all year long but there are 2 peaks of breeding season during May-July and November to December.

Overall the of razor clam population seems to start recovering (when compare with Rangsimant Bauthong, 1997) from the inappropriate harvesting method from the past after local government released some regulations.

5.2 FISHERMAN BEHAVIOR AND IMPACT ON RAZOR CLAM RESOURCE

Local fisherman behavior pattern in this study was based on monthly personal interviews and observations in the field study. The study indicated that their behavior depend on razor clam population density. They have their own perception in razor clam harvesting but they usually imitate other local fisherman when their harvesting rate is decreased. They communicate to each other about density, size and razor clam habitat occasionally. In addition, traders or razor clam buyers play role on density, size and habitat of razor clam as information distributor with local fisherman. However, local fisherman has additional job to make more income without only depending on razor clam harvesting.

Current local fisherman harvesting behavior can affect razor clam population of size classes over 4 cm because the regulation of local government allows only the dipping lime method. This method is a selective method; local fisherman can select razor clam in certain size and neglect small razor clam as a clam stock. Nevertheless, the effect of harvesting on razor clam population from local fisherman is occurred all year long because local fisherman goes to harvest razor clam every month.

5.3 MANAGEMENT GUIDELINE FOR RAZOR CLAM CONSERVATION FROM COLLECTIVE DISCUSSION

Collective discussion among stakeholders was organized during RPG session and the main agreement provided a razor clam management and conservation should emphasis on mobile reserved area which described as scenario II in RPG and multi-agent simulation model. Furthermore, during the RPG session there are many suggestions on razor clam management and conservation from all stakeholders and these can be described and shown in figure 5.1

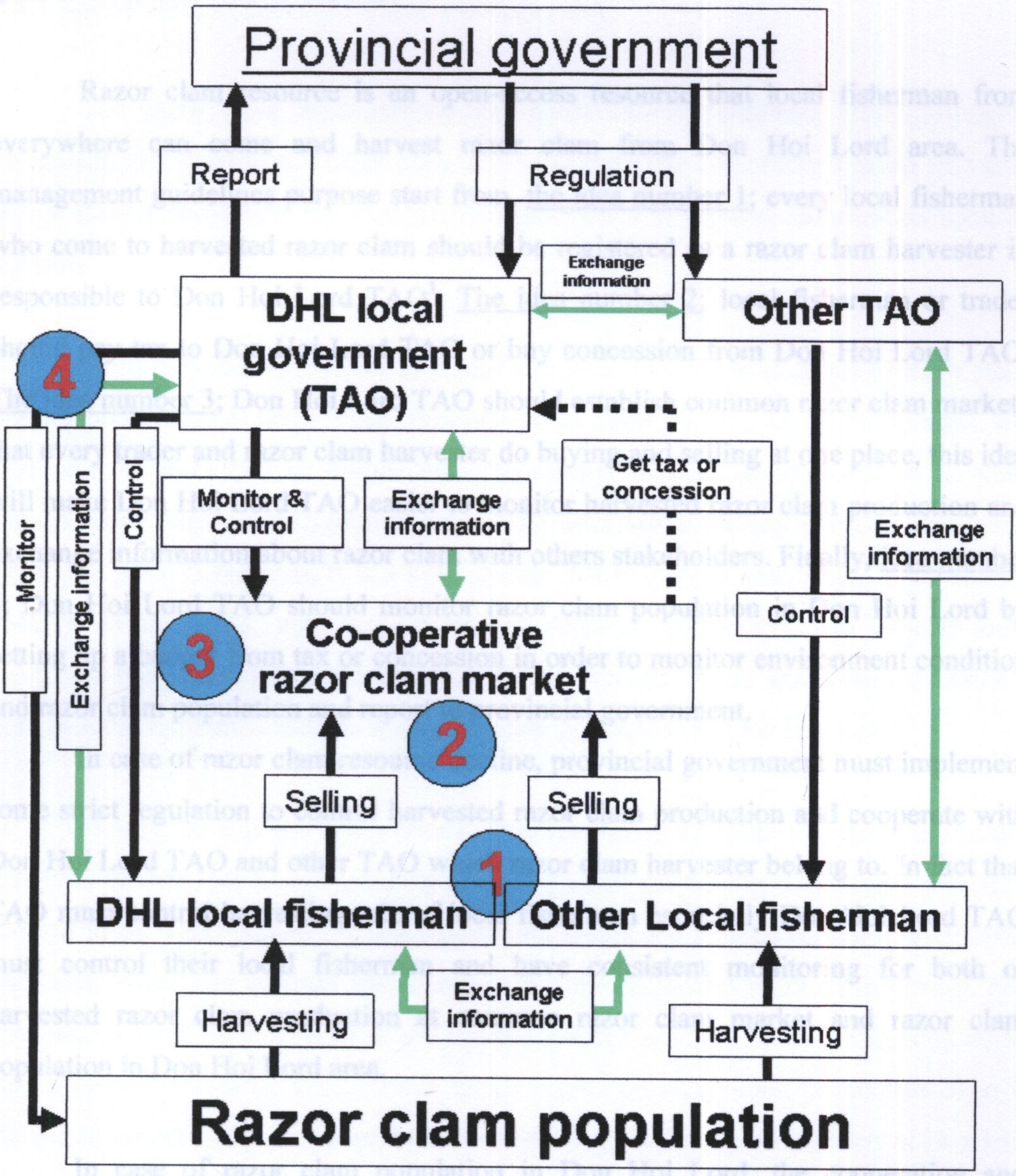

Figure 5.1 Razor clam management and conservation guideline from collective discussion

(* TAO= Tumbon Administrative Organization)

Figure 5.1 there is a bottom up management guidelines and number 1-4 are the additional idea from researcher and stakeholders during discussion. The management guideline can describe as follows:

Razor clam resource is an open-access resource that local fisherman from everywhere can come and harvest razor clam from Don Hoi Lord area. The management guidelines purpose start from, the idea number 1; every local fisherman who come to harvested razor clam should be registered as a razor clam harvester in responsible to Don Hoi Lord TAO[1]. The idea number 2; local fisherman or trader should pay tax to Don Hoi Lord TAO or buy concession from Don Hoi Lord TAO. The idea number 3; Don Hoi Lord TAO should establish common razor clam markets that every trader and razor clam harvester do buying and selling at one place, this idea will make Don Hoi Lord TAO easier to monitor harvested razor clam production and exchange information about razor clam with others stakeholders. Finally, idea number 4; Don Hoi Lord TAO should monitor razor clam population in Don Hoi Lord by setting up a budget from tax or concession in order to monitor environment condition and razor clam population and report to provincial government.

In case of razor clam resource decline, provincial government must implement some strict regulation to control harvested razor clam production and cooperate with Don Hoi Lord TAO and other TAO which razor clam harvester belong to. In fact that TAO must control harvesting rate of local fisherman especially Don Hoi Lord TAO must control their local fisherman and have consistent monitoring for both of harvested razor clam production at common razor clam market and razor clam population in Don Hoi Lord area.

In case of razor clam population in Don Hoi Lord, the cooperation and responsibility of local fisherman must be monitored in order to achieve conservation and management, as well as to have a systematic database for the sustainable management.

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1 In actuary almost area of Don Hoi Lord area is belong to Bangjakreng district and small piece area belong to Bangkaew district but this study use Don Hoi Lord TAO for easy to understand.

5.4 RECOMMENDATIONS

5.4.1 Razor clam conservation and management

The razor clam management and conservation guidelines from collective discussion are reliable for razor clam resource from the researcher's point of view. But it should implement the management guidelines in the real situation as soon as possible.

From personal interviews of trader and local fisherman in terms of razor clam price and harvested razor clam production in each month, in some months the harvested razor clam was higher than the market demand so trader have to store surplus razor clam in refrigerator for selling later when market demand increased. Then, the price is reduced; it is a kind of risk due to capital lost. Thus, TAO should concern in this topic and explore market demand via traders and control local fisherman harvesting rate correspond to market demand. It can guarantee sustainable both of local fisherman income and razor clam population in Don Hoi Lord.

Finally, as a result from tourist interviewed in Chapter IV, there are many activities at Don Hoi Lord especially aesthetic value for having a meal and traveling to sand dune. TAO should control restaurants which are located on the coastal zone especially waste and garbage management in order to protect razor clam habitat. For traveling on sand dune activity, some tourists always left lime on the sand dune when they tried to catch razor clam. It can make impact on razor clam population even if there is no direct study or research on that topic but TAO and stakeholders at Don Hoi Lord should respond to this issue and launch campaign or provide knowledge and information to tourist.

5.4.2 Future studies

Razor clam population data in this study is output of one year study which can be rather short to study population dynamics. However, the study should have more field data collection for better understanding of razor clam population. Then, the model would be more realistic.

The RPG sessions were organized in two villages of local fisherman so the better understanding should be expanded to cover more stakeholders of Don Hoi Lord the study should include the following components:

- Local fisherman from other village who came to harvest razor clam
- Officers from Department of Fishery who direct respond to razor clam resource through in the game.
- Officer from other TAO which has razor clam harvester belong to.
- Other trader who play role mediation between local fisherman and markets

In addition, more RPG sessions should be conducted to observe local fisherman behavior, better understanding local fisherman behavior and justify the collective discussion for more effective razor clam management and conservation method.

Regarding multi-agent simulation, more issues can be included in the future studied:

- Natural mortality of razor clam in reality and in our model
- Dispersion of razor clam offspring and razor clam movement in reality and in our model
- Total area of Don Hoi Lord should be consider into current multi-agent simulation model

All of developments will made multi-agents simulation more implicated reality and become useful tool for long term of razor clam management and conservation in the RPG.

REFFERENCES

Art-ong Pradatsundarasar, Pairath Saichuae, Kamthorn Teerakup and Nanatana Gajaseni. 1989. Changing of chemical condition in Mae Klong river and ecosystem of Mae Klong river mouth around Don Hoi Lord area, Samut Songkhram province (Phase: 2). Researching report presented to office of National Environment board. Department of Biology, Chulalongkorn University. *(In Thai)*

Art-ong Pradatsundarasar. 1982. Influences of sediment on the distribution and population density of *Solen regularis* Dunker at the Mae Klong estuary. Master's Thesis. Department of Biology, Graduate School, Chulalongkorn University. *(in Thai)*

Baron, P. J., Real, L. E., Ciocco, N. F. and Re, M. E. 2004. Morphometry, growth and reproduction of an atlantic population of the razor clam *Ensis macha* (Molina, 1782). Scientia Marina 68(2): 211-217.

Barreteau, O., Antona, M., d'Aquino, P., Aubert, S., Boissau, S., Bousquet, F., Dare, W. Eitenne, M., Le Page, C., Mathevest, R., Trebuil, G. and Weber, J. 2003. Our companion modelling approach. Journal of Artificial Societies and Social Simulation 6(1): http://jasss.soc.surrey.ac.uk/6/2/1.html [2005, May 10]

Bousquet, F. and Le page, C. 2004. Multi-agent simulation and ecosystem management: A review. Ecological Modelling 176: 313-332.

Bousquet, F., Barreteau, O., d'Aquino, P., Etienne, M., Boissau, S., Aubert, S., Le Page, C., Babin, D. and Castella, J. 2000. Multi-agent systems and role game: collective learning process for ecosystem management. In Jansen, M.

A. (ed), Complexity and ecosystem management: The theory and practices of multi-agent systems. pp. 248-284. United Kingdom: Edward Elgar.

Bousquet, F., Barreteau, O., Le Page, C., Mullan, C. and Weber, J. 1999. An environmental modelling approach. In Blasco, F. and Weill, A. (eds), The use of multi-agent simulations; Advances in environmental and ecological modelling. pp. 113-122. Paris: Elsevier.

Bousquet, F., Cambier, C. and Morand, P. 1994. Distributed artificial intelligence and object-oriented modelling of a fishery. Mathl. Comput. Modelling 20 (8): 97-107.

Bousquet, F., Le Page, C., Bakam, I. and Takforyan, A. 2001. Multiagent simulations of hunting wild meat in a village in eastern Cameroon. Ecological Modelling 138: 331-346.

Chanintorn Srithongsuk, Punya Ausawanggul, Sunan Tuycharoean, Somprssong Khuntom, Wullop Khumsupar and Witcha Thangchan. 1990. Razor clam conservation project Samut Songkhram province. Samut Sakorn Coastal Aquaculture Center. Coastal aquatic Division.(*in Thai*)

Costanza, R. and Ruth, M. 1998. Using dynamic modelling to scope environmental problems and build consensus. Environmental Management. 22 (2): 183-195.

Department of Fishery, 1995. Razor clams (*Solen Strictus* Gould). Samut Sakorn Coastal Aquaculture Center. Coastal aquatic Division.(*in Thai*)

Department of Fishery. 1990. Razor clam conservation project Samut Songkhram province. Samut Sakorn Coastal Aquaculture Center. Coastal aquatic Division.(*in Thai*)

Drogoul, A., Venbergue, D. and Meurisse, T. 2002. Multi-agent based simulation: Where are the agents?. Proceedings of MABS'02 (Multi-Agent Based Simulation), Bologna, Italy (July 2002).

Ferber, J. 1999. Mulyi-agent system an introduction to distributed artificial intelligence. 1st ed. Singapore: Addison Eesley Longman.

Gurung, R. J. 2004. Use of Multi-agent system to improve irrigation water sharing in Lingmuteychu watershed, Bhutan. Master's thesis. Department of Agricultural System. Graduate School, Chiangmai University.

Jackson, L. J., Trebitz, A. S. and Cottingham, K. L. 2000. An introduction to the practice of ecological modeling. BioScience. 50 (8): 694-706.

Jager, H. I. and King, A. W. 2004. Spatial uncertainty and ecological models. Ecosystems (2004)7: 841-847.

Jiragorn Gajaseni. 1997. Principle of ecology. 2nd ed. Bangkok: Chulalongkorn University press.

Kanlaya Vanitbancha. 2003. Statistical analysis: Statistic for administer and research. 7th ed. Bangkok: Chulalongkorn University press. (*In Thai*)

Kanoksak Jinphuhuad. 1994. Appropriate environment for razor clam survival. Diploma's project. Sumut Songkhram Technical College. (*in Thai*)

Krebs, C. J. 1989. Ecological methodology. New York: Harper Collin.

Le Page, C. and Bommel, P. 2004. A methodology for building agent-based simulations of common-pool resources management: From a conceptual model designed with UML to it implementation in Cormas. Lecture note in the international training course "Companion Modelling and Resillience of

Ecosystems in Southeast Asia Principle and Tools". December 2004. Chulalongkorn University, Bangkok.

Le Page, C., Bousquet, F., Bakam, I., Bah, A. and Baron, C. 2000. Cormas: A multiagent simulation toolkit to model natural and social dynamics at multiple scales. Proceeding of The ecology of scales, Wageningen. Netherlands (June, 2000).

Leventon, J. S. 1982. Marine ecology . Englewood cliffs, N. J., U.S.A.: Prentice-Hall.

Mathevest, R., Bousquet, F., Le Page, C. and Antona, M.. 2003. Agent-based simulations between duck population, farming decision and leasing of hunting rights in the Camargue (southern France). Ecological Modelling 165:107-126.

Ministry of Interior. 2000. Important statistic of 75 provinces [online]. Available from: http://www.moi.go.th/province.htm#3 [2005, March 11] (*in Thai*)

Nantana Gajaseni, Nittharat Paphavasit, Wichase Khonsae and Pratak Sawatdipon. 2004. A final report of Survey and monitor situation of International important wetland (Ramsar Site) at Don Hoi Lord, Samut Songkhram province. Aquatic Resources Research Institute, Chulalongkorn University.

National Economic and Social Development Board. 2005. Statistics of population number, household, birth number, death number and migration rate in province level [online]. Available from: www.nesdb.go.th [2005, March 23]

Natsucha Oiamsomboon. 2000. People's opinion towards the conservation of Don Hoi Lod amphoe Muang, changwat Samut Songkhram. Master's Thesis. Major Field Environmental Science, Graduate School, Kasetsart University. (*in Thai*)

Natthakan Suwanna, 2003. The ability of the community in managing local resource: a case study of Don Hoi Lod, Bangjakreng, Samut Songkram. Master's Thesis. Department of Environmental planning for community and rural development. Graduate School, Mahidol University. (*In Thai*)

Park, K. Y. and Oh, C. W. 2002. Length-weight relationship of bivalves from coastal waters of Korea. Naga, The ICLARM Quarterly 25(1: January-March).

Pongsak Kumpheng. Tourist, Interviewed, July 22nd, 2004.

Ram. Trader. Interviewed, March 3rd, 2005.

Ramsar. 2003. The list of wetlands of international importance[online]. Available from: http://www.ramsar.org/key_sitelist.htm [2003, December 12]

Rangsimant Bautong. 1997. Plankton population in relation to density and breeding season of razor shell genus *solen* at Don Hoi lod, Samut Songkhram province. Master's Thesis. Department of Biology, Graduate School, Chulalongkorn University. (*in Thai*)

Royal Thai Navy. 2004. Tide tables Thai waters Chaophraya river-gulf of Thailand and Andaman sea. Hydrological Department.

Royal Thai Navy. 2005. Tide tables Thai waters Chaophraya river-gulf of Thailand and Andaman sea. Hydrological Department.

Ruffolo, D., Charusiri, P., Gajaseni, N., Piumsomboon, A., Piumsomboon, P.,Pradatsundarasar, A. and Tantratian, S. 1999. Population dynamics of razor clams in Samut Songkram, Thailand. Journal of scientific Research Chulalongkron University Vol 24, No. 2:67-83.

Ruffolo, D., Charusiri, P., Gajaseni, N., Piumsomboon, A., Piumsomboon, P.,Pradatsundarasar, A. and Tantratian, S. 1997. A final report "Mathematical model of effect of environmental change on razor clam population". Faculty of Science, Chulalongkorn University. Bangkok. (*In Thai*)

Rungruang Artayagul. Local fisherman. Interviewed, July 1st, 2004.

Somprasong Kanthom, Somchart Sukawong, Songjum Kruangdai, Thanom Deeching, and Jaroon Tiemmaung. 1991. Study on effect of quick lime (CaO) on mortality rate of razor clam (*Solen strictus* Gold). Samut Sakorn Coastal Aquaculture Center. Coastal aquatic Division.(*in Thai*)

Sunan Tuycharoean and Phanit Worra-in. 1991. The reproductive biology of the razor clams (*Solen strictus* Gould) and the environmental factor in the culture area at coastline of Ban Bangboo, Samut Songkhram province. Technical Paper No. 10/1991. Samut Sakorn: Samut Sakorn Coastal Aquaculture Center, Coastal Aquaculture Division, Department of Fisheries. (*In Thai*)

Suphanchaimart, N., Bousquet, F., Wongsamun, C., Patamadit-Trebuil, I., Panthong, P. and Trebuil, G. 2003. Companion modeling to understand the expansion of sugarcane in rainfed lowland paddies of upper northeast Thailand. Khon Kaen: Faculty of Agriculture, Khon Kaen Unversity, Thailand. (Mimeographed)

Sutin Aim-Augsorn. Local fisherman. Interviewed, February 11th, 2005.

Taweewong Sriburi and Nantana Gajaseni. 1996. A final report of environmental conservation plan for Don Hoi Lord, Samut Songkram Province Project. Chulalongkorn University and Office of Policy and Planning. Bangkok. (*In Thai*)

Thanitha Thapanand. 2000. Laboratory in fishery biology (Manual). 2nd ed. Deaprtment of Fishery Biology, Kasetsart University. *(In Thai)*

The World Commission on Environment and Development (WCED), 1987. Our common future. Oxford: Oxford University Press.

Trebuild, G., Shinawatra-Ekasingh, B., Bousquet, F. and Thong-Ngam, C. 2002. Multi-Agent Systems Companion Modelling for Integrated Watershed Management: A Northern Thailand Experience. Proceedings of 3rd Montane Mainland Southeast Asia Conference. Yunan, China, (August, 2002).

Wanpen Sriprathumwong, Ritthikorn Sornkaew and Nopadol Phuwapanish. 2002. Experiment on breeding of razor clam, *Solen regularis* Dunker,1862. Technical Paper No. 19/2002. Samut Sakorn: Samut Sakorn Coastal Aquaculture Center, Coastal Aquaculture Division, Department of Fisheries. *(In Thai)*

Weerasak Jarinrattanakorn. 2001. Media exposure, awareness, and participation in razor clams conservation project among people in Muang district, Samut Songkhram province. Master's Thesis. Department of Public Relation, Graduate School, Chulalongkorn University. *(in Thai)*

Wong, T. M., Lim, T. G. and Wong, C. F. 1986. Induced spawning and larval development of the razor clam *Solen brevis* Gray (Mollusca: Solenidae) in laboratory. In Maclean, J. L., Digon, L. B. and Hosillo, L. V. (eds.), The First Asian Fisheries Forum. Asian Fisheries Society, Manila, Philipines.

Wullop Khumsupar, Panya Audsawangkul and Sunan Tuychalearn. 1991. Survey of area to the distribution of razor clam (*Solen strictus* Could) at the Mae Klong estuary, Samut Songkram province. Technical paper No. 12/1991.Samut Sakorn: Samut Sakorn Coastal Aquaculture Center, Coastal Aquaculture Division, Department of Fisheries. *(In Thai)*

APPENDICES

APPENDIX A

Questionnaires for tourist

แบบสอบถาม นักท่องเที่ยว ณ ดอนหอยหลอด จ. สมุทรสงคราม

แบบสอบถามนี้เป็นส่วนหนึ่งของการทำวิทยานิพนธ์ระดับปริญญาโท หัวข้อ “การจำลองแบบชนิดหลายตัวแทน เพื่อการอนุรักษ์หอยหลอด *Solen regularis* Dunker, 1862 บริเวณดอนหอยหลอด จังหวัดสมุทรสงคราม” โดยนายกอบชัย วรพิมพงษ์ ภาควิชาชีววิทยา, คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย **ทุกข้อมูลในแบบสอบถามนี้จะถูกปกปิดเป็นความลับเพื่อการทำวิทยานิพนธ์นี้เท่านั้น** *ขอขอบพระคุณสำหรับการสละเวลาเพื่อตอบแบบสอบถามฉบับนี้*

นายกอบชัย วรพิมพงษ์

****

*วันที่สัมภาษณ์*________________________

เวลา________________________

ผู้สัมภาษณ์________________________

ชุดที่...............

ข้อมูลทั่วไป

1. ชื่อ________________________ นามสกุล________________________

2. เพศ ❍ ชาย ❍ หญิง ☐

อายุ

❍ น้อยกว่า 20 ปี ❍ 20-30 ปี

❍ 31-40 ปี ❍ 41-50 ปี ❍ มากกว่า 50 ปี ☐

3. ที่อยู่ปัจจุบัน________________________

____

ระยะทางจากบ้านกับดอนหอยหลอด____________กิโลเมตร

4. อาชีพ

❍ นักเรียน, นักศึกษา

❍ ค้าขาย

❍ รับราชการ ☐

❍ พนักงานรัฐวิสาหกิจ

❍ พนักงานบริษัท, ธนาคาร

❍ รับจ้างทั่วไป

○ ประมง

5. รายได้เฉลี่ยต่อเดือน

○ น้อยกว่า 2,000 บาท ○ 2001-4000 บาท

○ 4,001-6,000 บาท ○ 6,001-8,000 บาท

○ 8,001-10,000 บาท ○ 10,001-12,000 บาท □

○ 12,001-14,000 บาท ○ มากกว่า14,000 บาท

6. จำนวนสมาชิกในครอบครัวท่าน

○ น้อยกว่า 3 คน ○ 3-5 คน □

○ 5-7 คน ○ มากกว่า 7 คน

จำนวนสมาชิกที่ประกอบอาชีพ และมีรายได้ ______ คน

<u>การท่องเที่ยว</u>

8. ท่านเคยมาดอนหอยหลอดมาก่อนหรือไม่

○ ไม่เคย ○ เคย _____ ครั้ง □

9 ท่านมีวัตถุประสงใดในการมาดอนหอยหลอด

□ ชมพื้นที่โดยรอบดอนหอยหลอด

□ รับประทานอาหารริมทะเล

□ กราบกรมหลวงชุมพรเขตอุดมศักดิ์

□ ซื้อผลิตภัณฑ์จากหอยหลอดและอาหารทะเลอื่นๆ

□ ลงท่องเที่ยวบริเวณหาดเลน ดอนหอยหลอด

○ ไม่ได้ซื้อปูนขาวลงไปทดลองจับหอย

○ ซื้อปูนขาวลงไปทดลองจับหอย

○ จับหอยได้_______ ตัว

○ จับไม่ได้

○ท่านไม่ได้นำปูนขาวที่เหลือกลับมาบนฝั่งด้วย

○ ท่านนำปูนขาวที่เหลือกลับมาบนฝั่งด้วย

ขอขอบพระคุณอย่างสูงที่สละเวลาให้ความร่วมมือ

กอบชัย วรพิมพงษ์

APPENDIX B

B1 Independent sample t-test for razor clam density month by month

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	March04	81	7.41	6.190	.688
	April04	81	8.12	6.319	.702

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	.369	.544	-.729	160	.467	-.72	.983	-2.657	1.225
	Equal variances not assumed			-.729	159.932	.467	-.72	.983	-2.657	1.225

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	April04	81	8.12	6.319	.702
	May04	81	8.72	7.578	.842

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	2.147	.145	-.541	160	.590	-.59	1.096	-2.758	1.573
	Equal variances not assumed			-.541	154.995	.590	-.59	1.096	-2.758	1.573

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	May04	81	8.72	7.578	.842
	June04	81	7.88	6.763	.751

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	.843	.360	.744	160	.458	.84	1.129	-1.389	3.068
	Equal variances not assumed			.744	157.970	.458	.84	1.129	-1.390	3.069

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	June04	81	7.88	6.763	.751
	July04	81	6.72	5.290	.588

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	4.103	.044	1.216	160	.226	1.16	.954	-.724	3.044
	Equal variances not assumed			1.216	151.228	.226	1.16	.954	-.724	3.045

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	July04	81	6.72	5.290	.588
	August04	81	7.11	4.785	.532

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	.022	.882	-.498	160	.619	-.40	.793	-1.960	1.170
	Equal variances not assumed			-.498	158.420	.619	-.40	.793	-1.960	1.170

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	August04	81	7.11	4.785	.532
	September04	81	4.02	3.070	.341

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	18.344	.000	4.886	160	.000	3.09	.632	1.839	4.334
	Equal variances not assumed			4.886	136.310	.000	3.09	.632	1.837	4.336

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	September04	81	4.02	3.070	.341
	October04	81	4.28	2.721	.302

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	.030	.862	-.569	160	.570	-.26	.456	-1.159	.641
	Equal variances not assumed			-.569	157.731	.570	-.26	.456	-1.160	.641

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	October04	81	4.28	2.721	.302
	November04	81	4.15	3.340	.371

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	1.243	.267	.284	160	.777	.14	.479	-.810	1.081
	Equal variances not assumed			.284	153.734	.777	.14	.479	-.810	1.081

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	November04	81	4.15	3.340	.371
	December04	81	4.81	5.070	.563

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	1.334	.250	-.988	160	.324	-.67	.675	-1.999	.665
	Equal variances not assumed			-.988	138.426	.325	-.67	.675	-2.000	.667

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	December04	81	4.81	5.070	.563
	Januaryo5	81	2.74	2.090	.232

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	8.576	.004	3.404	160	.001	2.07	.609	.871	3.277
	Equal variances not assumed			3.404	106.436	.001	2.07	.609	.866	3.282

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
DENSITY	Januaryo5	81	2.74	2.090	.232
	February05	81	2.57	2.307	.256

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DENSITY	Equal variances assumed	.011	.917	.500	160	.618	.17	.346	-.510	.856
	Equal variances not assumed			.500	158.465	.618	.17	.346	-.510	.856

B2 Independent sample t-test for razor clam weight and length month by month

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
WEIGHT	March04	600	1.6084	1.35464	.05530
	April04	658	1.9345	1.32083	.05149
LENGTH	March04	600	3.712	.9976	.0407
	April04	658	3.933	.8391	.0327

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
WEIGHT	Equal variances assumed	.030	.862	-4.321	1256	.000	-.3261	.07548	-.47418	-.17804
	Equal variances not assumed			-4.316	1238.867	.000	-.3261	.07556	-.47436	-.17787
LENGTH	Equal variances assumed	16.143	.000	-4.259	1256	.000	-.221	.0518	-.3224	-.1190
	Equal variances not assumed			-4.225	1175.203	.000	-.221	.0522	-.3232	-.1182

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	April04	658	3.933	.8391	.0327
	May05	706	3.900	.7148	.0269
WEIGHT	April04	658	1.935	1.3208	.0515
	May05	706	1.736	1.0064	.0379

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	10.487	.001	.783	1362	.434	.033	.0421	-.0497	.1156
	Equal variances not assumed			.778	1294.472	.437	.033	.0424	-.0501	.1160
WEIGHT	Equal variances assumed	23.588	.000	3.138	1362	.002	.199	.0633	.0745	.3229
	Equal variances not assumed			3.108	1225.898	.002	.199	.0639	.0733	.3241

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	May04	706	3.900	.7148	.0269
	June04	638	4.064	.6897	.0273
WEIGHT	May04	706	1.7358	1.00644	.03788
	June04	638	2.0066	1.06166	.04203

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	1.303	.254	-4.277	1342	.000	-.164	.0384	-.2396	-.0889
	Equal variances not assumed			-4.284	1336.259	.000	-.164	.0383	-.2394	-.0890
WEIGHT	Equal variances assumed	4.409	.036	-4.798	1342	.000	-.2707	.05643	-.38144	-.16005
	Equal variances not assumed			-4.785	1310.694	.000	-.2707	.05658	-.38175	-.15975

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	June04	638	4.064	.6897	.0273
	July04	539	4.218	.7657	.0330
WEIGHT	June04	638	2.0066	1.06166	.04203
	July04	539	2.3370	1.17909	.05079

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	3.255	.071	-3.625	1175	.000	-.154	.0424	-.2371	-.0706
	Equal variances not assumed			-3.593	1094.101	.000	-.154	.0428	-.2379	-.0698
WEIGHT	Equal variances assumed	5.779	.016	-5.057	1175	.000	-.3304	.06535	-.45866	-.20224
	Equal variances not assumed			-5.013	1093.936	.000	-.3304	.06592	-.45980	-.20110

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	July04	539	4.218	.7657	.0330
	August04	576	4.198	1.0916	.0455
WEIGHT	July04	539	2.3370	1.17909	.05079
	August04	576	2.4973	1.43623	.05984

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	43.702	.000	.347	1113	.729	.020	.0568	-.0918	.1312
	Equal variances not assumed			.351	1033.332	.726	.020	.0562	-.0905	.1300
WEIGHT	Equal variances assumed	24.060	.000	-2.029	1113	.043	-.1603	.07900	-.31531	-.00531
	Equal variances not assumed			-2.042	1094.655	.041	-.1603	.07849	-.31432	-.00631

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	August04	576	4.198	1.0916	.0455
	September04	326	4.150	1.0878	.0602
WEIGHT	August04	576	2.4973	1.43623	.05984
	September04	326	2.4173	1.54591	.08562

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	6.198	.013	.640	900	.522	.048	.0756	-.0999	.1967
	Equal variances not assumed			.641	676.773	.522	.048	.0755	-.0998	.1966
WEIGHT	Equal variances assumed	5.612	.018	.782	900	.434	.0801	.10235	-.12080	.28095
	Equal variances not assumed			.767	634.505	.444	.0801	.10446	-.12506	.28520

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	September04	326	4.150	1.0878	.0602
	October04	347	4.221	.9840	.0528
WEIGHT	September04	326	2.4173	1.54591	.08562
	October04	347	2.4090	1.60595	.08621

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	3.708	.055	-.890	671	.374	-.071	.0799	-.2279	.0858
	Equal variances not assumed			-.887	653.819	.376	-.071	.0801	-.2284	.0863
WEIGHT	Equal variances assumed	.336	.562	.068	671	.946	.0083	.12165	-.23058	.24714
	Equal variances not assumed			.068	670.600	.946	.0083	.12150	-.23030	.24685

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	October04	347	4.221	.9840	.0528
	November04	336	4.216	.8566	.0467
WEIGHT	October04	347	2.4090	1.60595	.08621
	November04	336	2.3220	1.42219	.07759

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	21.093	.000	.064	681	.949	.005	.0707	-.1342	.1433
	Equal variances not assumed			.065	673.452	.948	.005	.0705	-.1339	.1430
WEIGHT	Equal variances assumed	10.651	.001	.748	681	.454	.0870	.11621	-.14121	.31514
	Equal variances not assumed			.750	675.662	.454	.0870	.11598	-.14076	.31470

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	November04	336	4.216	.8566	.0467
	December04	390	4.344	.8727	.0442
WEIGHT	November04	336	2.3220	1.42219	.07759
	December04	390	2.3963	1.30301	.06598

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	.003	.957	-1.978	724	.048	-.127	.0644	-.2538	-.0010
	Equal variances not assumed			-1.981	711.837	.048	-.127	.0643	-.2537	-.0011
WEIGHT	Equal variances assumed	1.147	.285	-.734	724	.463	-.0743	.10119	-.27292	.12440
	Equal variances not assumed			-.729	685.842	.466	-.0743	.10185	-.27423	.12571

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	December04	390	4.344	.8727	.0442
	January05	227	4.382	.9598	.0637
WEIGHT	December04	390	2.3963	1.30301	.06598
	January05	227	2.4004	1.42131	.09434

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	2.288	.131	-.513	615	.608	-.039	.0756	-.1873	.1097
	Equal variances not assumed			-.500	437.038	.617	-.039	.0775	-.1912	.1136
WEIGHT	Equal variances assumed	.919	.338	-.037	615	.971	-.0041	.11251	-.22506	.21683
	Equal variances not assumed			-.036	440.020	.972	-.0041	.11512	-.23037	.22214

Group Statistics

	MONTH	N	Mean	Std. Deviation	Std. Error Mean
LENGTH	January05	227	4.382	.9598	.0637
	February05	208	4.415	1.0340	.0717
WEIGHT	January05	227	2.4004	1.42131	.09434
	February05	208	2.6527	1.57186	.10899

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LENGTH	Equal variances assumed	1.515	.219	-.345	433	.730	-.033	.0956	-.2209	.1549
	Equal variances not assumed			-.344	421.972	.731	-.033	.0959	-.2215	.1555
WEIGHT	Equal variances assumed	4.603	.032	-1.758	433	.079	-.2523	.14351	-.53437	.02977
	Equal variances not assumed			-1.750	418.302	.081	-.2523	.14415	-.53564	.03104

B1 Questionnaire SPSS analysis

SEX

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	67	45.9	45.9	45.9
	Female	79	54.1	54.1	100.0
	Total	146	100.0	100.0	

AGE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 20	27	18.5	18.6	18.6
	20-30	50	34.2	34.5	53.1
	31-40	38	26.0	26.2	79.3
	41-50	18	12.3	12.4	91.7
	> 50	12	8.2	8.3	100.0
	Total	145	99.3	100.0	
Missing	System	1	.7		
Total		146	100.0		

Occupation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	student	34	23.3	23.3	23.3
	merchant	30	20.5	20.5	43.8
	goverment officer	19	13.0	13.0	56.8
	พนักงาน รัฐวิสาหกิจ	8	5.5	5.5	62.3
	company or bank officer	17	11.6	11.6	74.0
	employee	37	25.3	25.3	99.3
	fisherman	1	.7	.7	100.0
	Total	146	100.0	100.0	

INCOME

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 2000	21	14.4	14.6	14.6
	2001-4000	20	13.7	13.9	28.5
	4001-6000	20	13.7	13.9	42.4
	6001-8000	23	15.8	16.0	58.3
	8001-10000	24	16.4	16.7	75.0
	10001-14000	17	11.6	11.8	86.8
	> 14000	19	13.0	13.2	100.0
	Total	144	98.6	100.0	
Missing	System	2	1.4		
Total		146	100.0		

Ever been here

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	never	30	20.5	20.5	20.5
	ever	116	79.5	79.5	100.0
	Total	146	100.0	100.0	

Look around area

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	22	15.1	15.1	15.1
	Yes	124	84.9	84.9	100.0
	Total	146	100.0	100.0	

Have a meal

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	52	35.6	35.6	35.6
	Yes	94	64.4	64.4	100.0
	Total	146	100.0	100.0	

Pay obeisance to Khommaluang

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	57	39.0	39.0	39.0
	Yes	89	61.0	61.0	100.0
	Total	146	100.0	100.0	

Buy product from seafood

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	86	58.9	58.9	58.9
	Yes	60	41.1	41.1	100.0
	Total	146	100.0	100.0	

Travelling sand on dune

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	26	17.8	17.8	17.8
	Yes	120	82.2	82.2	100.0
	Total	146	100.0	100.0	

Catch a Razor Clam

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	26	17.8	17.8	17.8
	Yes	120	82.2	82.2	100.0
	Total	146	100.0	100.0	

Can you catch razor clam

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	98	67.1	81.7	81.7
	yes	22	15.1	18.3	100.0
	Total	120	82.2	100.0	
Missing	System	26	17.8		
Total		146	100.0		

How many a Razor Clam did you catch?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	98	67.1	83.8	83.8
	1	3	2.1	2.6	86.3
	2	3	2.1	2.6	88.9
	3	2	1.4	1.7	90.6
	4	1	.7	.9	91.5
	5	2	1.4	1.7	93.2
	6	1	.7	.9	94.0
	10	4	2.7	3.4	97.4
	12	1	.7	.9	98.3
	30	1	.7	.9	99.1
	50	1	.7	.9	100.0
	Total	117	80.1	100.0	
Missing	System	29	19.9		
Total		146	100.0		

Leaved Lime on Sand dune

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	101	69.2	84.2	84.2
	Yes	19	13.0	15.8	100.0
	Total	120	82.2	100.0	
Missing	System	26	17.8		
Total		146	100.0		

B2 Length and Weight Relationship (LWR)of Razor clam from SPSS analysis

---

Curve Fit

MODEL: MOD_1.

_

Dependent variable.. WEIGHT   Method.. POWER

Listwise Deletion of Missing Data

Multiple R   .96701
R Square   .93512
Adjusted R Square   .93511
Standard Error   .17979

Analysis of Variance:

	DF	Sum of Squares	Mean Square
Regression	1	2585.2100	2585.20995
Residuals	5549	179.3724	.03233

F = 79975.13626   Signif F = .0000

-------------------- Variables in the Equation --------------------

Variable	B	SE B	Beta	T	Sig T
LENGTH	2.811829	.009943	.967015	282.799	.0000
(Constant)	.035608	.000496		71.745	.0000

B3 Cluster analysis of Density of razor clam from SPSS

Cluster

Case Processing Summary(a,b)

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
27	100.0	0	.0	27	100.0

a Squared Euclidean Distance Undefined error #14704 - Cannot open tex
b Average Linkage (Between Groups)

Average Linkage (Between Groups)

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	6	15	.000	0	0	16
2	3	8	.000	0	0	4
3	17	21	.001	0	0	12
4	3	12	.007	2	0	11
5	16	18	.012	0	0	15
6	7	14	.012	0	0	22
7	5	11	.019	0	0	19
8	4	10	.019	0	0	25
9	20	25	.028	0	0	14
10	24	27	.028	0	0	17
11	3	22	.051	4	0	16
12	17	26	.056	3	0	17
13	2	19	.062	0	0	18
14	1	20	.069	0	9	15
15	1	16	.195	14	5	21
16	3	6	.233	11	1	20
17	17	24	.234	12	10	21
18	2	9	.252	13	0	20
19	5	23	.676	7	0	22
20	2	3	.910	18	16	23
21	1	17	.956	15	17	23
22	5	7	2.872	19	6	24
23	1	2	4.785	21	20	25
24	5	13	8.867	22	0	26
25	1	4	19.220	23	8	26
26	1	5	33.890	25	24	0

Cluster Membership

Case	3 Clusters
1:A1	1
2:A2	1
3:A3	1
4:A4	2
5:B1	3
6:B2	1
7:B3	3
8:B4	1
9:B5	1
10:B6	2
11:C1	3
12:C2	1
13:C3	3
14:C4	3
15:C5	1
16:C6	1
17:C7	1
18:C8	1
19:D1	1
20:D2	1
21:D3	1
22:D4	1
23:D5	3
24:D6	1
25:D7	1
26:D8	1
27:D9	1

APPENDIX C

Important source code of Don Hoi Lord Model

RazorClamPopulation

```
breeding: t
	"each female gives 36 offspring"

	| newClams r |
	r := self breedingProbability: t \\ 365.
	newClams := self femaleNumber * self offSpringsNumber * r
				* (1 - (self totalNumber / self patch carryingCapacity)).
	newClams < 0 ifTrue: [newClams := 0].
	self offsprings add: newClams.
	self populationStructure at: 3
		put: (self populationStructure at: 3) + self offsprings first.
	self offsprings removeFirst

breedingProbability: t
	t <= 31 ifTrue: [^0.0324].
	t <= 61 ifTrue: [^0.0268].
	t <= 92 ifTrue: [^0.0302].
	t <= 122 ifTrue: [^0.01].
	t <= 153 ifTrue: [^0.004].
	t <= 183 ifTrue: [^0.031].
	t <= 214 ifTrue: [^0.032].
	t <= 244 ifTrue: [^0.0023].
	t <= 275 ifTrue: [^0.014].
	t <= 305 ifTrue: [^0.016].
	t <= 336 ifTrue: [^0.016].
	t <= 365 ifTrue: [^0.018]
```

naturalMortality

"naturalMortallity it's mean Death rate in every size class in every step t"

populationStructure keysAndValuesDo: [:key :value | populationStructure at: key put: (value- (value * self naturalDeathRate))]

updatePopulationGrowth

"updatePopulationGrowth it's mean Pupulation structure will update every step from previous step and add new number to population structure"

```
| newPopulationStructure |
newPopulationStructure := Dictionary new.
newPopulationStructure at: 7
        put: (populationStructure at: 7) + (populationStructure at: 6).
4 to: 6
        do: [:i | newPopulationStructure at: i put: (populationStructure at: i -
1)].
newPopulationStructure at: 3 put: 0.
self populationStructure: newPopulationStructure
```

init

"initiation of razor clam population by put 0 (zero) in every size class"

```
populationStructure := Dictionary new.
populationStructure at: 3 put: (Cormas randomFrom: 15 to: 20).
populationStructure at: 4 put: (Cormas randomFrom: 10 to: 15).
populationStructure at: 5 put: (Cormas randomFrom: 5 to: 10).
populationStructure at: 6 put: (Cormas randomFrom: 3 to: 5).
populationStructure at: 7 put:(Cormas randomFrom: 1 to: 5).
offsprings :=OrderedCollection new.
90 timesRepeat:  [offsprings add: 0]
```

povHarvestableNumber

"HavestableNumber it's mean Number of razor clam are collect from cell. If no razor clam is collected color of this cell is white but if one or more razor clam are collect color of this cell will become blue and more blue following collect number (Maximun number is 30)."

```
^self
        povAttribute: #harvestableNumber
        min: 0
        max: 30
        color: ColorValue blue
"^ColorValue white"
```

Fisherman

stepOneGoodMove

"GoodMove is one walk method of fisherman, this method they try to walk to a cell has a hight abundance of razor clam population "

```
self nCellsHarvested < self totalCellsToHarvest
        ifTrue:
                [nCellsHarvested := nCellsHarvested + 1.

                self walkToMaxOf: #totalClams.
                [self patch totalClams < 1] whileTrue:
                                [self randomWalk.
                                self patch color: #red].
                self harvest]
```

stepOneGoodMoveConstrained

```
"GoodMove is one  walk method of fisherman, this method they try to walk to
a cell has a hight abundance of razor clam population "

    | |
    self nCellsHarvested < self totalCellsToHarvest
        ifTrue:
            [
            nCellsHarvested := nCellsHarvested + 1.
            self walkToMaxOf: #totalClams constrainedBy: [:c | c
isAllowed ].
            self patch accessAllowed = 0 ifTrue: [self halt].
            self harvest]


harvest
    | rc harvestRate h |
"rc is the RCP located in the patch of the fisherman "
" fisherman can take from thirty to one hundred percent of the clams"
"loop on each size class of the rcp. If size > 3 then h is the harevested qty of clams
from this size class. Remove h from the rcp and add it to the box of the fisherman"
    rc := (self patch occupantsAt: #RazorClamPopulation) first.
    harvestRate := (Cormas randomFrom: 100 to: 100) / 100.
    rc populationStructure keysAndValuesDo:
            [:key :value |
            key > 3
                ifTrue:
                    [h := (value * harvestRate) rounded.
                    rc populationStructure at: key put: value - h.
                    self clams at: key put: ((self clams at: key) +
h)]].
"self patch defineVisualState; show"
totalWeigthHarvested
```

"tatal weight harvested calculate from all of clam in fisherman box by use a size (length) of each razor clam and take its in following equasion : weight = 0.364* lenght^2.8003 . Finally,combine every razor clams weight together"

```
| x |
x := 0.
self clams
    keysAndValuesDo: [:key :value | x := x + (value * (0.0364 * (key raisedTo: 2.8003)))].
^x
```

DonHoiLord Initial instanciation

stepGoodMoveOneByOne: t

"*Step GoodMove represent growth of razor clam population* every 30 days or 1 month and fisherman harvesting behavior in Good Move method"

```
| activeFishermen |
t \\ 30 = 0
    ifTrue:
        [self theRazorClamPopulations do: [:a | a step: (t \\ 30 - 1) \\ 12 + 1]].
self theRazorClamPopulations do: [:a | a stepBreeding: t].
activeFishermen := OrderedCollection new.
t >365
    ifTrue:
        [self theFishermans do:
            [:a |
            a release.
```

```
                                    Cormas random < 0.66 ifTrue: [activeFishermen
add: a]].
                        [activeFishermen contains: [:b | b nCellsHarvested < b
totalCellsToHarvest]]
                              whileTrue: [activeFishermen do: [:f | f
stepOneGoodMove. f patch color: #red]]]


stepGoodMoveOneByOneWithReserve: t
     "Step GoodMove represent growth of razor clam population every 30 days or
1 month and fisherman harvesting behavior in Good Move method"

     | activeFishermen |
     t \\ 30 = 0
          ifTrue:
               [self theRazorClamPopulations do: [:a | a step: (t \\ 30 - 1) \\ 12
+ 1]].
     self theRazorClamPopulations do: [:a | a stepBreeding: t].
     self moveZones: t.
     activeFishermen := OrderedCollection new.
     t > 365
          ifTrue:
               [self theFishermans do:
                         [:a |
                         a release.
                         Cormas random < 0.66 ifTrue: [activeFishermen
add: a]].
               [activeFishermen contains: [:b | b nCellsHarvested < b
totalCellsToHarvest]]
                         whileTrue: [activeFishermen do: [:f | f
stepOneGoodMoveConstrained]]]
stepNoFishermen: t
```

```
"Step GoodMove represent growth of razor clam population every 30 days or
1 month and fisherman harvesting behavior in Good Move method"
    t \\ 30 = 0
        ifTrue:
            [self theRazorClamPopulations do: [:a | a step: (t \\ 30 - 1) \\ 12
+ 1]].
    self theRazorClamPopulations do: [:a | a stepBreeding: t].


createZones
    self
        zone1: (self theCells select:
                    [:a |
                    a numLine < (self spaceModel line  /2 )
                        and: [a numCol < (self spaceModel
column/2)]]).
    self
        zone2: (self theCells select:
                    [:a |
                    a numLine >= (self spaceModel line/2)
                        and: [a numCol < (self spaceModel
column/2)]]).
    self
        zone3: (self theCells select:
                    [:a |
                    a numLine < (self spaceModel line/2 )
                        and: [a numCol >= (self spaceModel
column/2)]]).
    self
        zone4: (self theCells select:
                    [:a |
                    a numLine >= (self spaceModel line/2)
```

```
                                        and: [a numCol >= (self spaceModel
column/2)]])


initAgents
	"Initiation of model, First initiate razor clam poulation (rp) in each cell and
add new rp in each step second initiate located fisherman"

	| rp |
	super initAgents.
	self theCells do:
			[:c |
			rp := RazorClamPopulation new.
			rp init.
			rp moveTo: c.
			self theRazorClamPopulations add: rp].
	self setRandomlyLocatedAgents: Fisherman n: self nFishermen


initAgentsReserve
	"Initiation of model, First initiate razor clam poulation (rp) in each cell and
add new rp in each step second initiate located fisherman"

	| rp |
	super initAgents.
	self theCells do:
			[:c |
			rp := RazorClamPopulation new.
			rp init.
			rp moveTo: c.
			self theRazorClamPopulations add: rp].
	self setRandomlyLocatedAgents: Fisherman n: self nFishermen.
```

```
initCells
	"Initiation of soil by set area proportion in each value of soil quality. It's
represent the quantity of razor clam production and razor clam population"
	| c |
	super initCells.
	c := self spaceModel centralLocation.
	(c recursiveNeighbourhood: (self spaceModel line * 4 / 5) rounded)
		do: [:a | a grainSize: 2].
	(c recursiveNeighbourhood: (self spaceModel line * 1.5/ 5) rounded)
		do: [:a | a grainSize: 3]


initSoilCells
	"Initiation of soil by set area proportion in each value of soil quality. It's
represent the quantity of razor clam production and razor clam population"
	| c |
	super initCells.
	c := self spaceModel centralLocation.
	(c recursiveNeighbourhood: (self spaceModel line * 3 / 5) rounded)
		do: [:a | a grainSize: 2].
	(c recursiveNeighbourhood: (self spaceModel line * 1.5 / 5) rounded)
		do: [:a | a grainSize: 3]


moveZones: t
```

```
| possibleCells cell |
t \\ 365 = 1
        ifTrue:
                [self zone1 do:
                                [:a |
                                a accessAllowed: 0.
                                a
                                        defineVisualState;
                                        show].
                possibleCells := self theCells reject: [:a | self zone1 includes: a].
                self theFishermans
                        do:
                                [:f |
                                cell := Cormas selectRandomlyFrom:
possibleCells.
                                f moveTo: cell]. self
                                        zone4
                        do:
                                [:a |
                                a accessAllowed: 1.
                                a
                                        defineVisualState;
                                        show]].
t \\ 365 = 91
        ifTrue:
                [self zone1 do:
                                [:a |
                                a accessAllowed: 1.
                                a
                                        defineVisualState;
                                        show].
                possibleCells := self theCells reject: [:a | self zone2 includes: a].
```

```
                    self theFishermans do:
                              [:f |
                              cell := Cormas selectRandomlyFrom:
possibleCells.
                              f moveTo: cell].
                    self zone2 do:
                              [:a |
                              a accessAllowed: 0.
                              a
                                   defineVisualState;
                                   show]].
     t \\ 365 = 182
          ifTrue:
                    [self zone2 do:
                              [:a |
                              a accessAllowed: 1.
                              a
                                   defineVisualState;
                                   show].
                    possibleCells := self theCells reject: [:a | self zone3 includes: a].
                    self theFishermans do:
                              [:f |
                              cell := Cormas selectRandomlyFrom:
possibleCells.
                              f moveTo: cell].
                    self zone3 do:
                              [:a |
                              a accessAllowed: 0.
                              a
                                   defineVisualState;
                                   show]].
     t \\ 365 = 273
```

```
ifTrue:
        [self zone3 do:
                [:a |
                a accessAllowed: 1.
                a
                        defineVisualState;
                        show].
        possibleCells := self theCells reject: [:a | self zone4 includes: a].
        self theFishermans do:
                [:f |
                cell := Cormas selectRandomlyFrom:
possibleCells.
                f moveTo: cell].
        self zone4 do:
                [:a |
                a accessAllowed: 0.
                a
                        defineVisualState;
                        show]]
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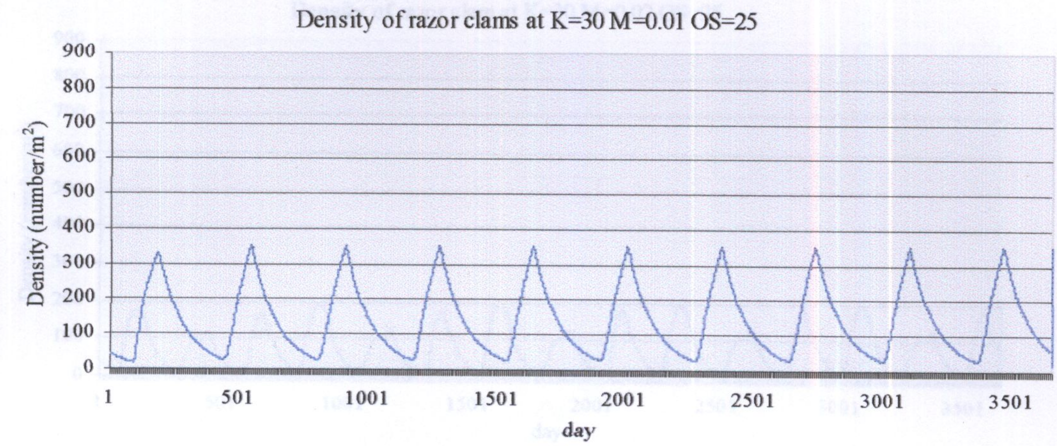
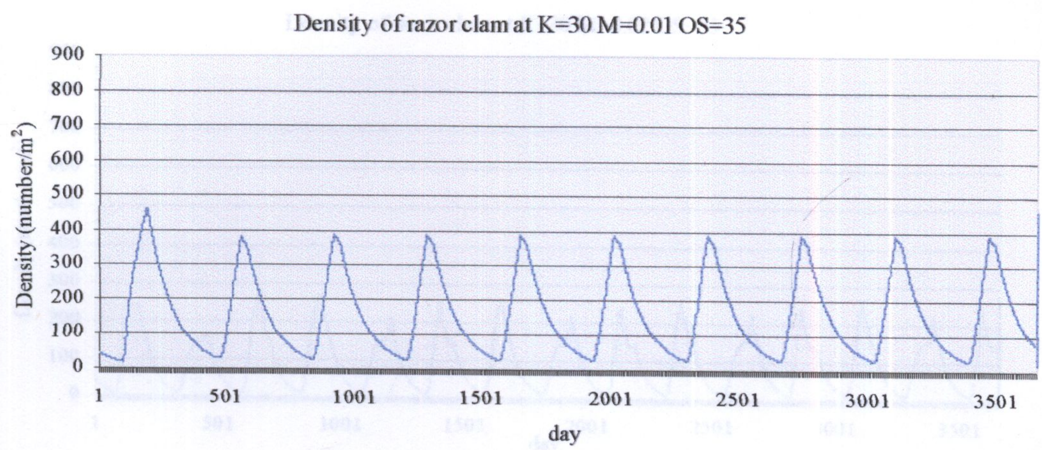
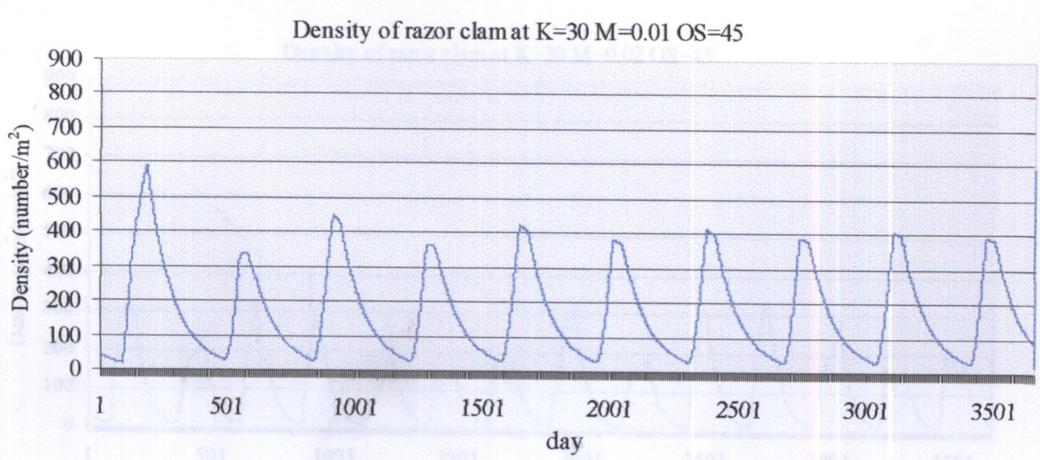
APPENDIX D

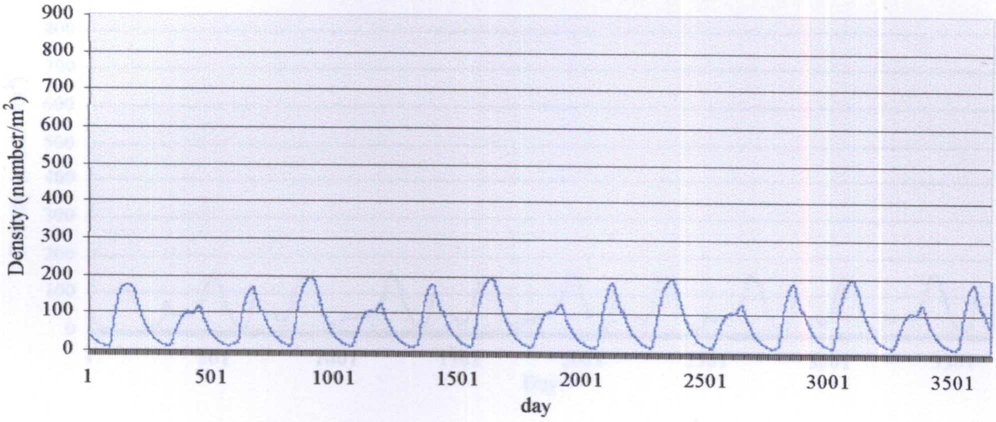
D1 Sensitivity analysis to select parameter



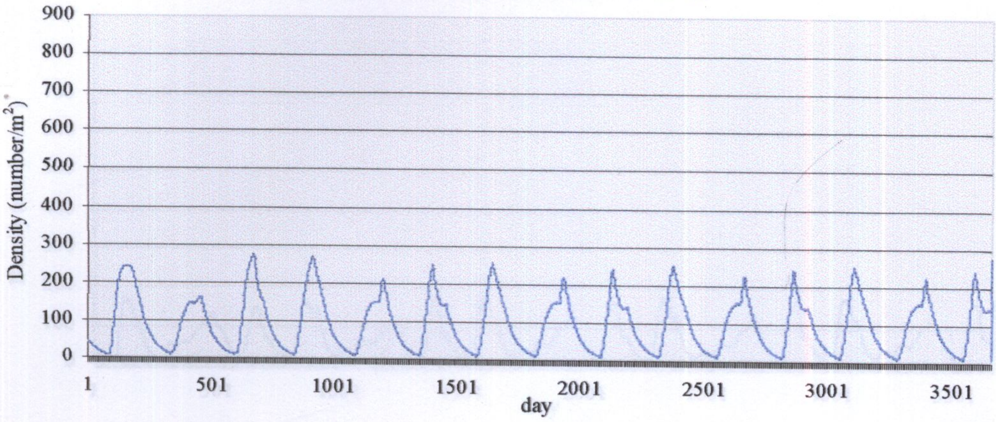




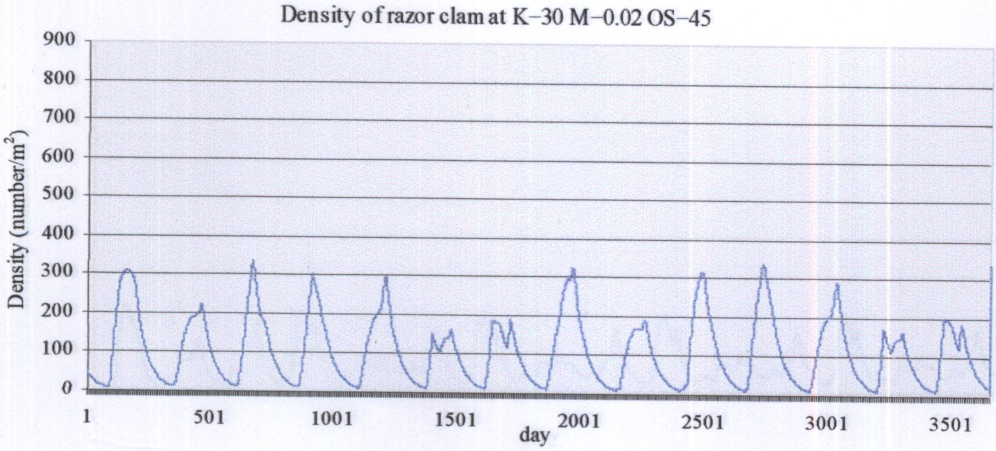
Density of razor clam at K=30 M=0.02 OS=25

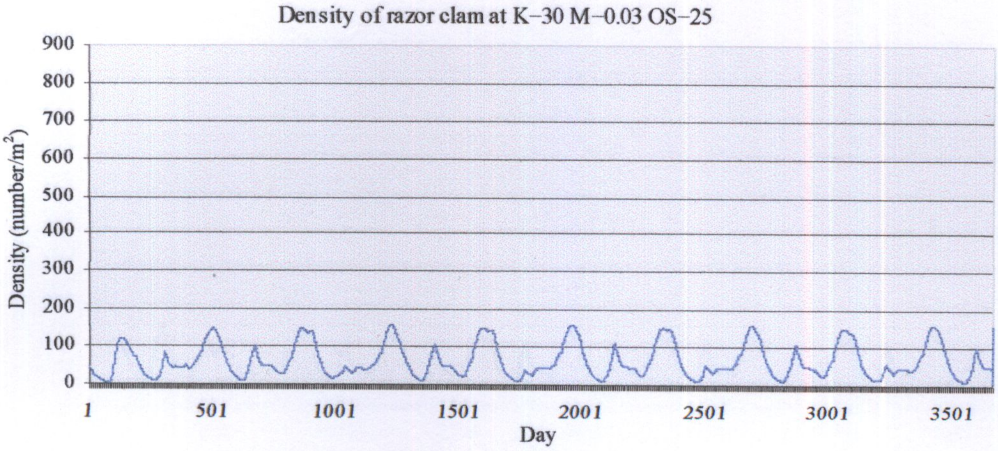


Density of razor clam at K=30 M=0.02 OS=35



Density of razor clam at K=30 M=0.02 OS=45




Density of razor clam at K-30 M-0.03 OS-25
Density (number/m2)
900
800
700
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500
400
300
200
100
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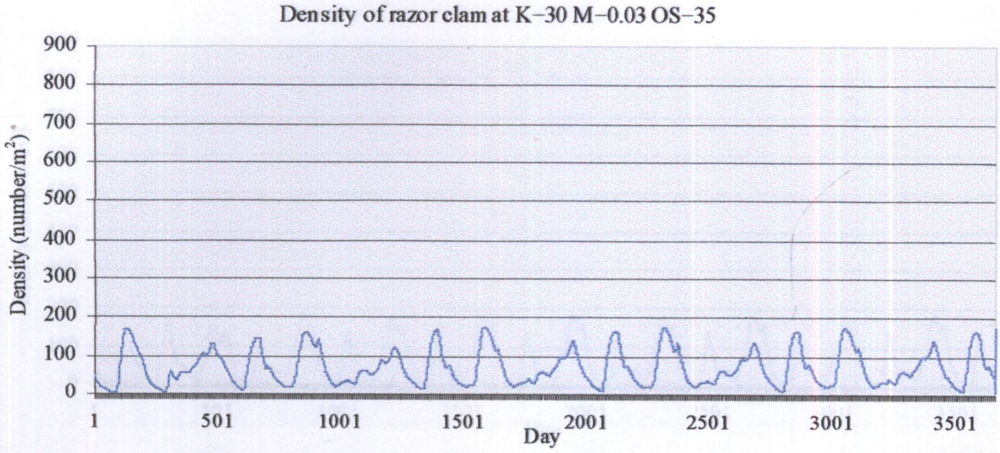
2501
3001
3501
Day


Density of razor clam at K-30 M-0.03 OS-35
Density (number/m2)
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500
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300
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100
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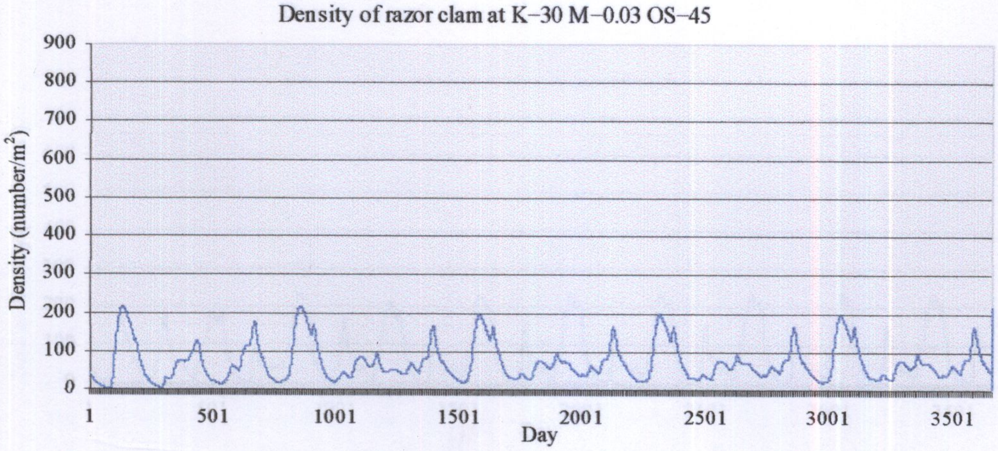
3001
3501
Day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Density (number/m2)
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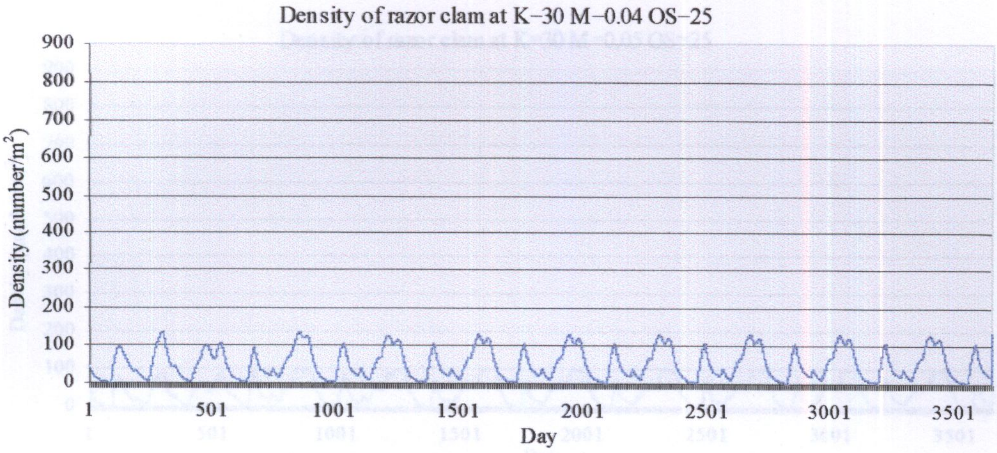
3001
3501
Day


Density of razor clam at K–30 M–0.04 OS–25
Density (number/m2)
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700
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0
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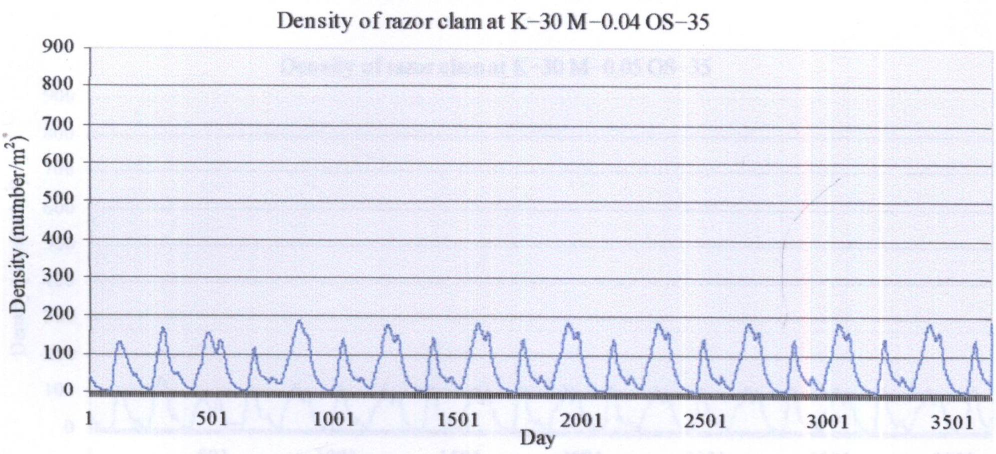
501
1001
1501
2001
2501
3001
3501
Day


Density of razor clam at K–30 M–0.04 OS–35
Density (number/m2)
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800
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400
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1501
2001
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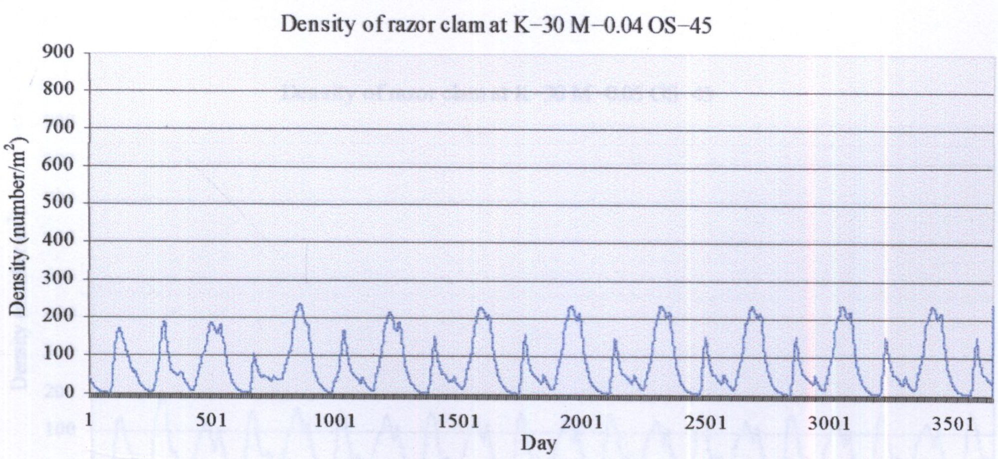
3001
3501
Day


Density of razor clam at K–30 M–0.04 OS–45
Density (number/m2)
900
800
700
600
500
400
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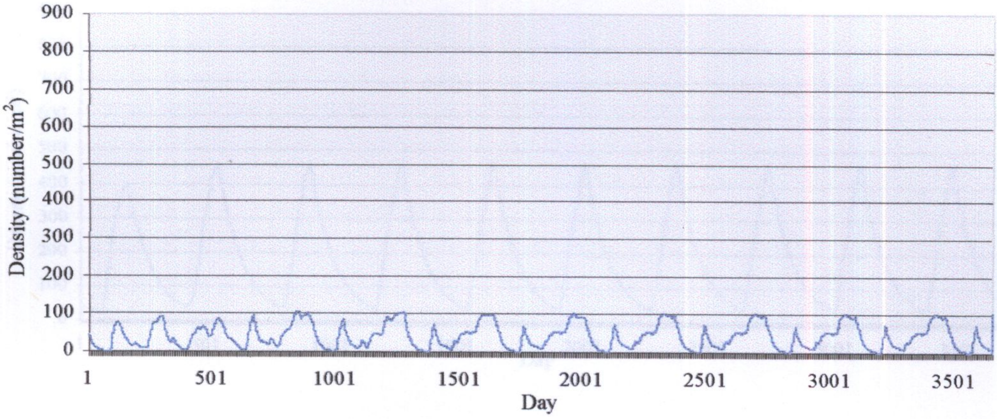
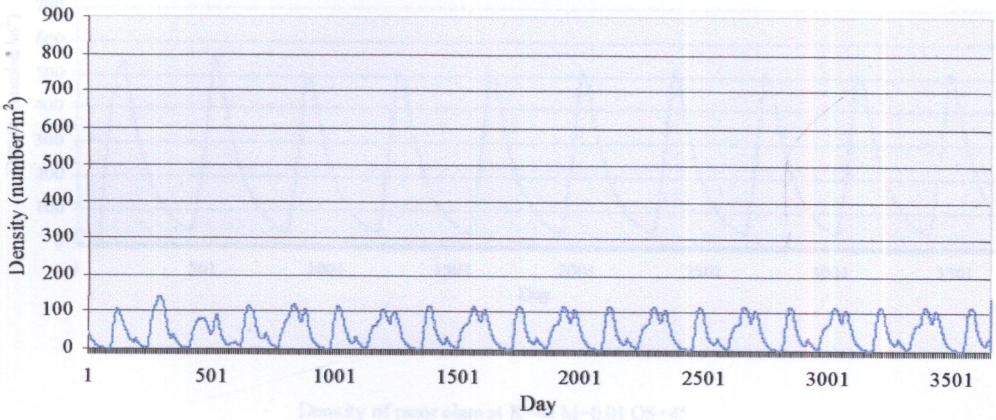
200
100
0
1
501
1001
1501
2001
2501
3001
3501
Day

Density of razor clam at K=30 M=0.05 OS=25



Density of razor clam at K=30 M=0.05 OS=35



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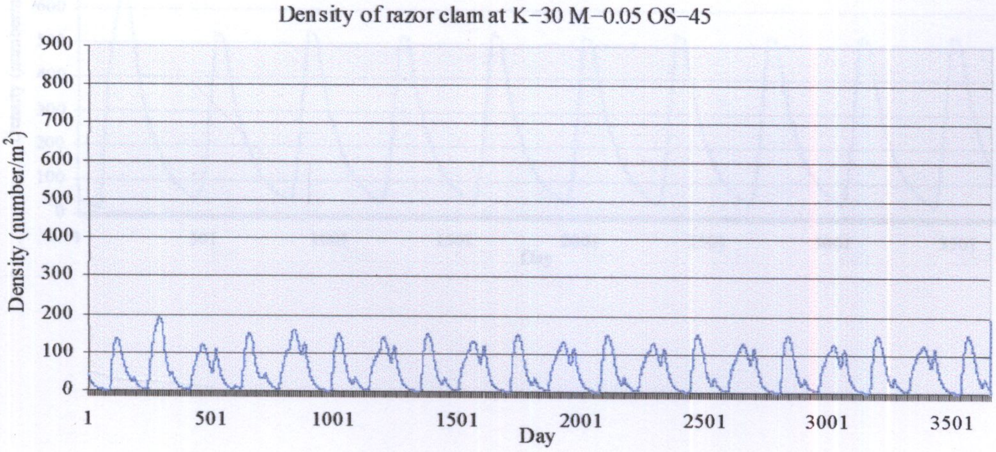

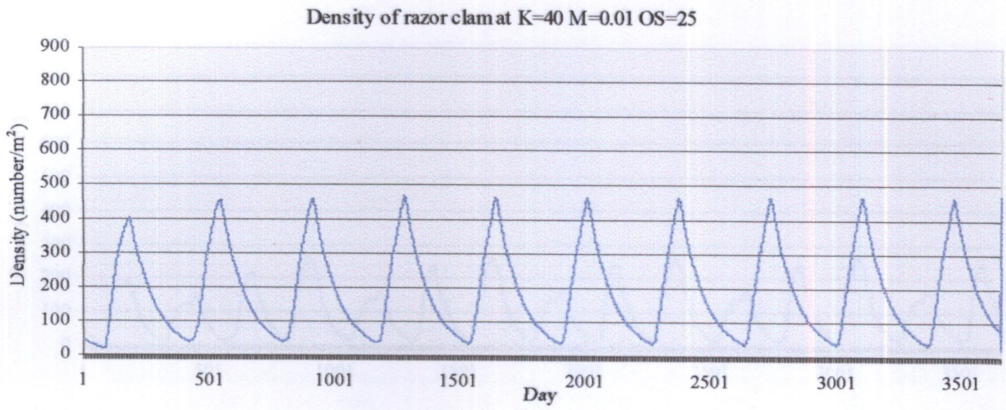
Density of razor clam at K=40 M=0.01 OS=25
Density (number/m2)
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800
700
600
500
400
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100
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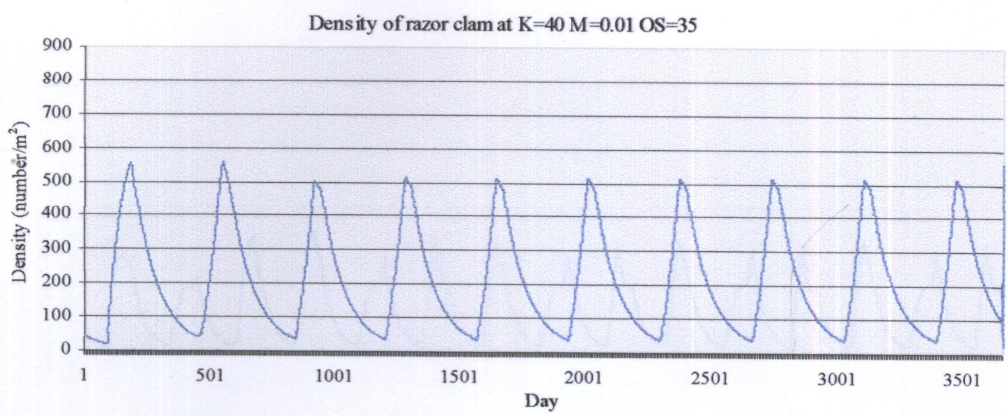
2501
3001
3501
Day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Density (number/m2)
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100
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1001
1501
2001
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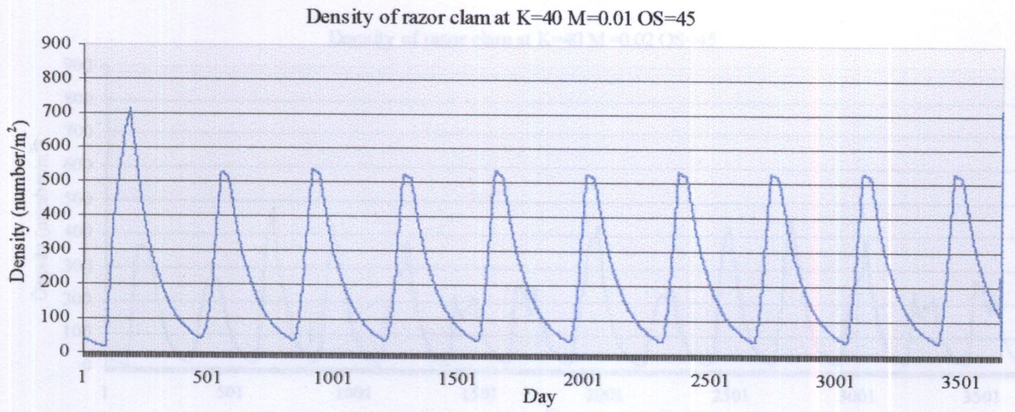
3001
3501
Day


Density of razor clam at K=40 M=0.01 OS=45
Density (number/m2)
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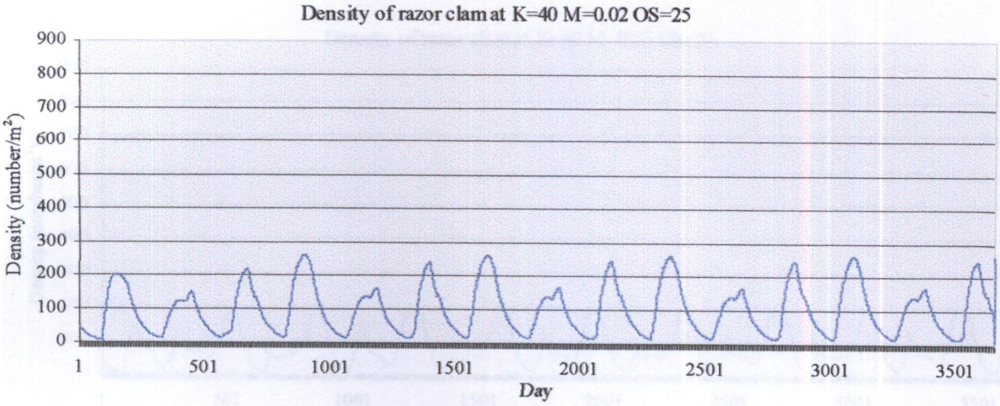
Day


Density of razor clam at K=40 M=0.02 OS=25
Density (number/m2)
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2001
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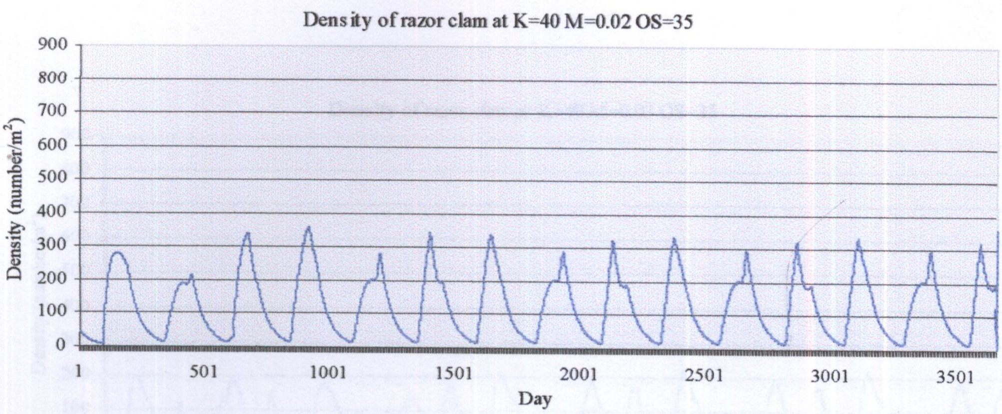
3001
3501
Day


Density of razor clam at K=40 M=0.02 OS=35
Density (number/m2)
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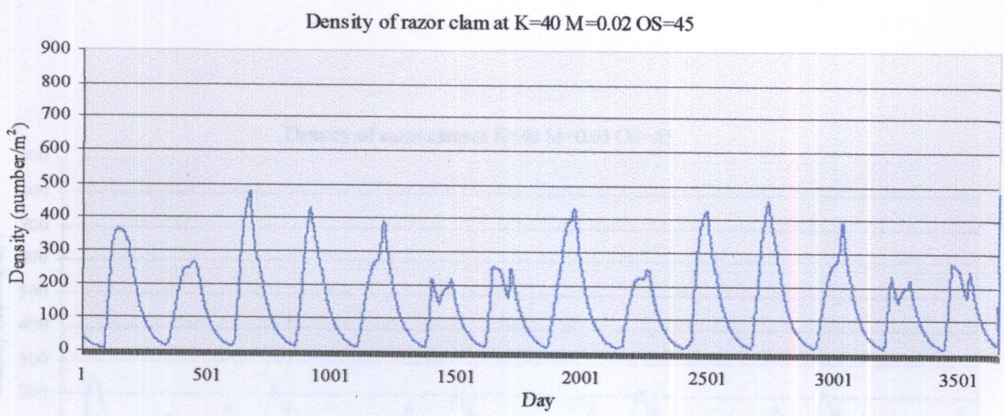
2501
3001
3501
Day


Density of razor clam at K=40 M=0.02 OS=45
Density (number/m2)
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800
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400
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2501
3001
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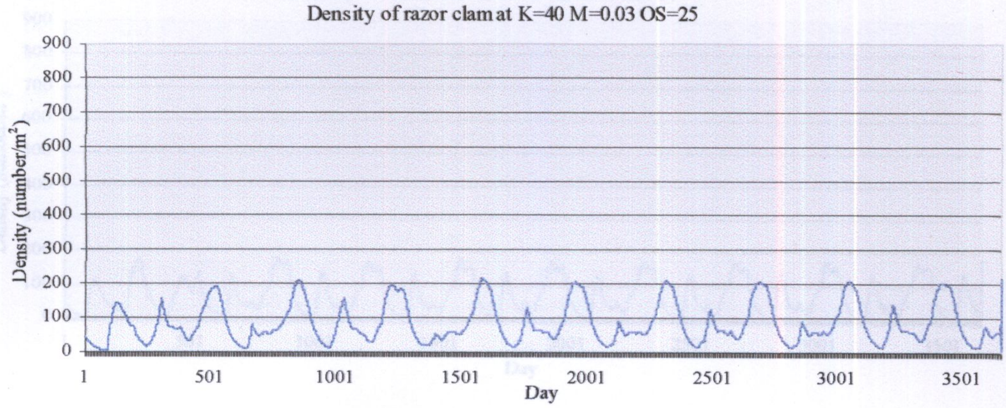
Day


Density of razor clam at K=40 M=0.03 OS=25
Density (number/m2)
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300
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3001
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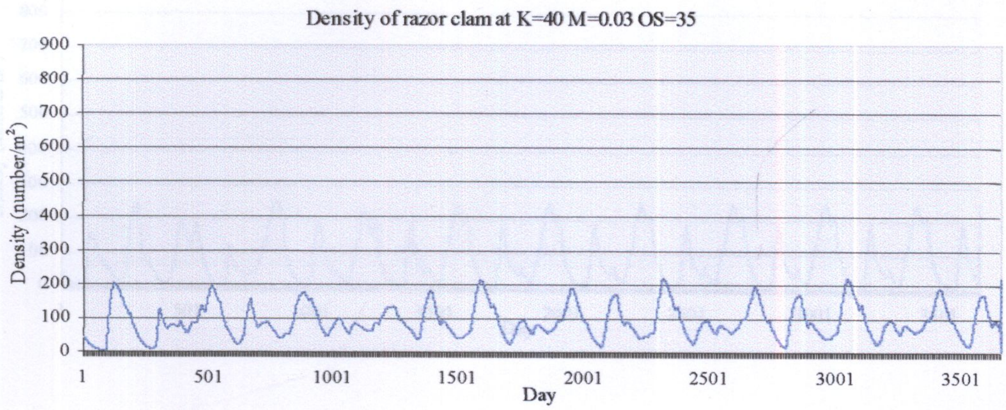
Day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Density (number/m2)
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3001
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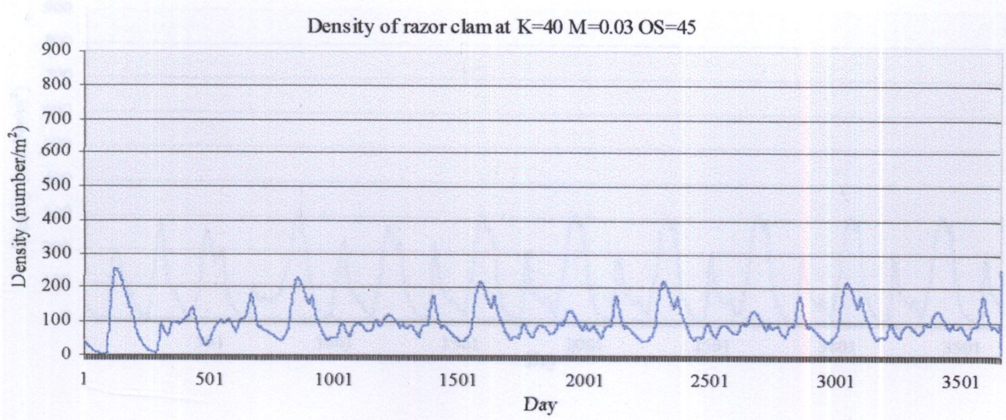
Day


Density of razor clam at K=40 M=0.03 OS=45
Density (number/m2)
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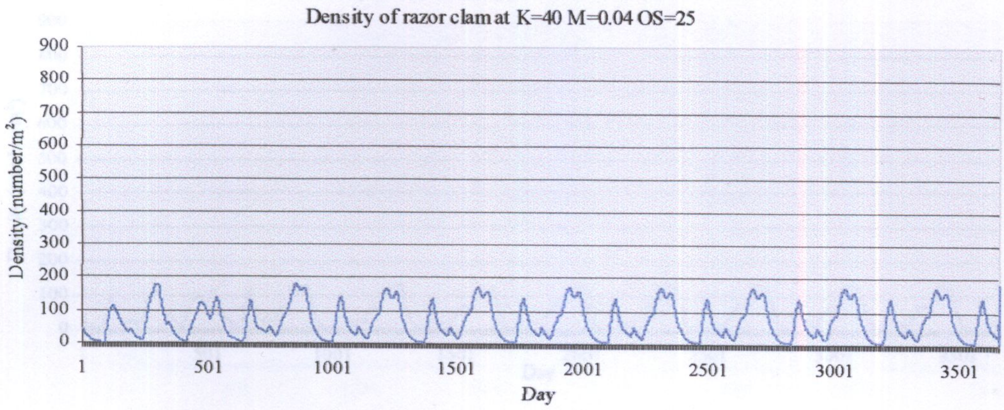
Day


Density of razor clam at K=40 M=0.04 OS=25
Density (number/m2)
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300
200
100
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2501
3001
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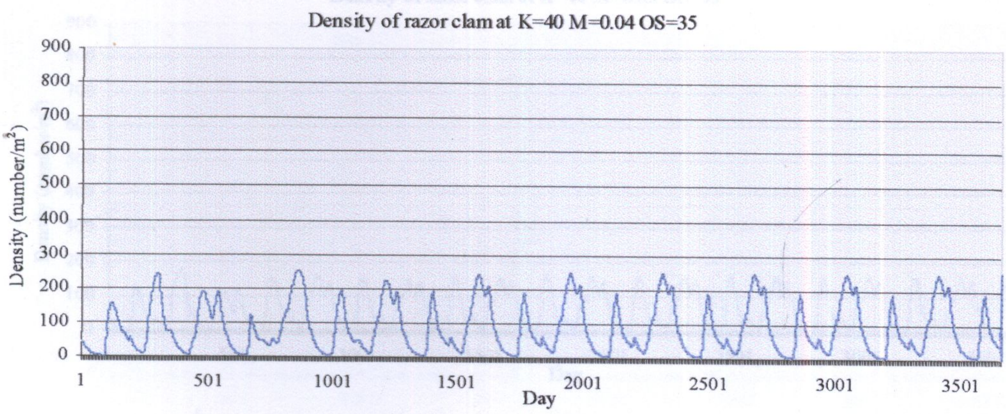
Day


Density of razor clam at K=40 M=0.04 OS=35
Density (number/m2)
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800
700
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500
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2501
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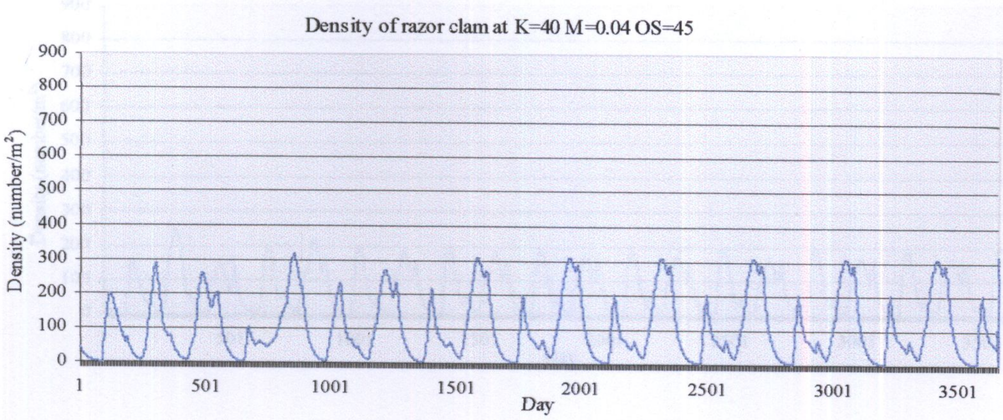
Day


Density of razor clam at K=40 M=0.04 OS=45
Density (number/m2)
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800
700
600
500
400
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200
100
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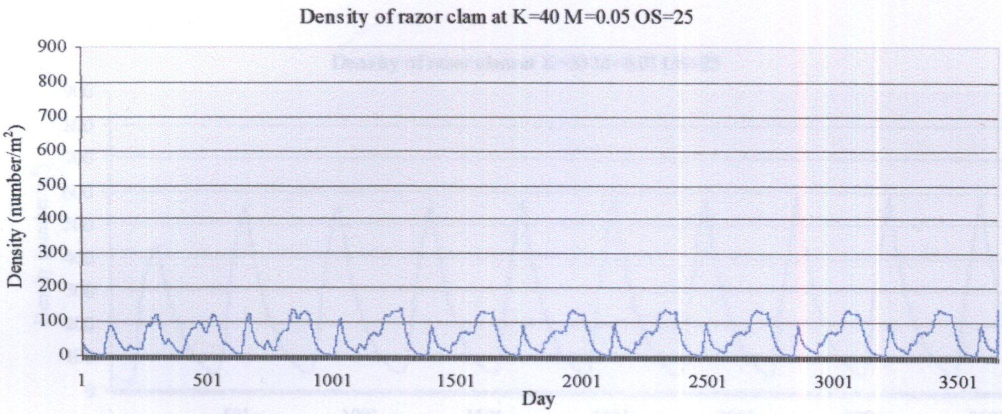
2501
3001
3501
Day


Density of razor clam at K=40 M=0.05 OS=25
Density (number/m²)
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800
700
600
500
400
300
200
100
0
1
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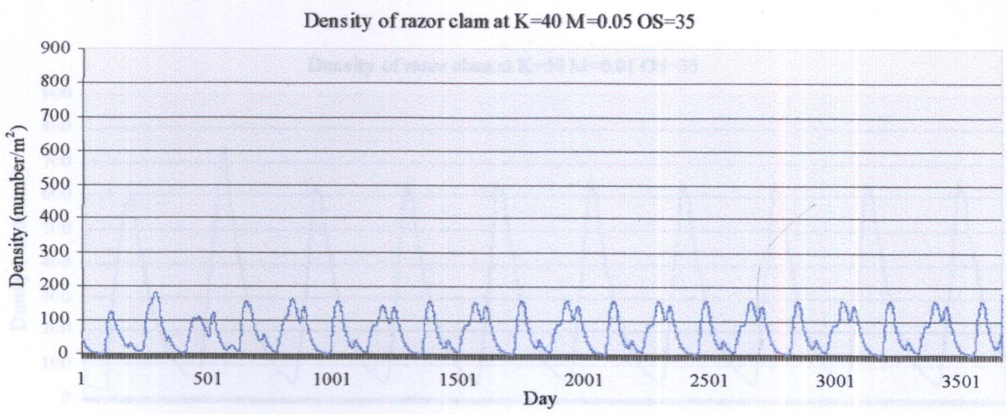
1001
1501
2001
2501
3001
3501
Day


Density of razor clam at K=40 M=0.05 OS=35
Density (number/m²)
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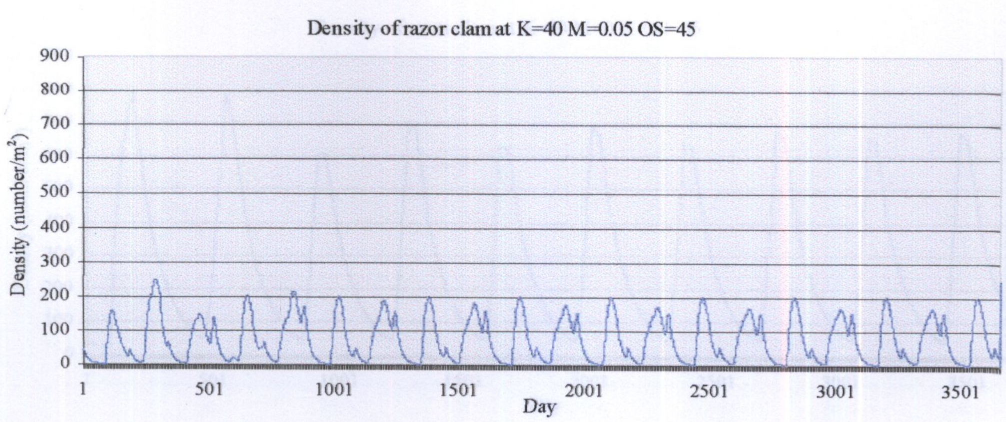
800
700
600
500
400
300
200
100
0
1
501
1001
1501
2001
2501
3001
3501
Day


Density of razor clam at K=40 M=0.05 OS=45
Density (number/m²)
900
800
700
600
500
400
300
200
100
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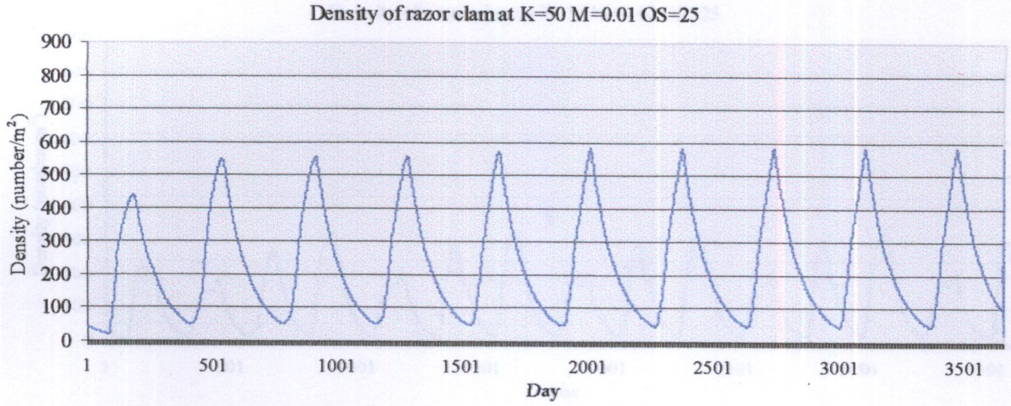
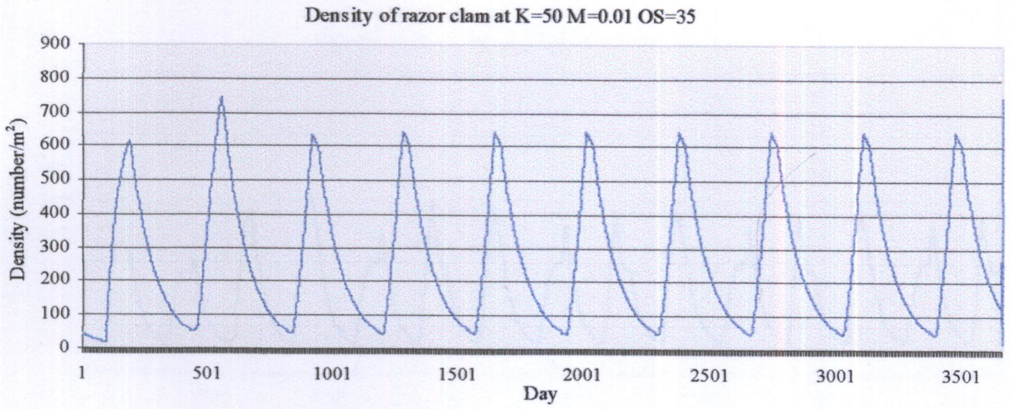
501
1001
1501
2001
2501
3001
3501
Day


Density of razor clam at K=50 M=0.01 OS=25
900
800
700
600
500
400
300
200
100
0
Density (number/m²)
1
501
1001
1501
2001
2501
3001
3501
Day


Density of razor clam at K=50 M=0.01 OS=35
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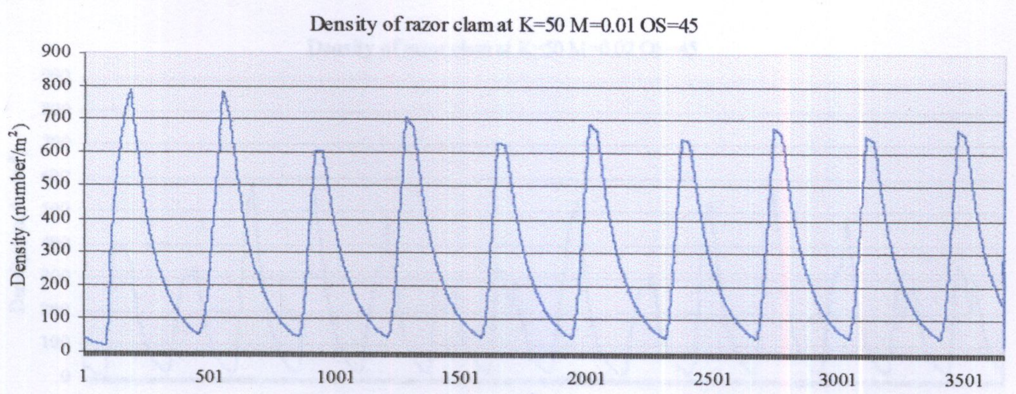
800
700
600
500
400
300
200
100
0
Density (number/m²)
1
501
1001
1501
2001
2501
3001
3501
Day


Density of razor clam at K=50 M=0.01 OS=45
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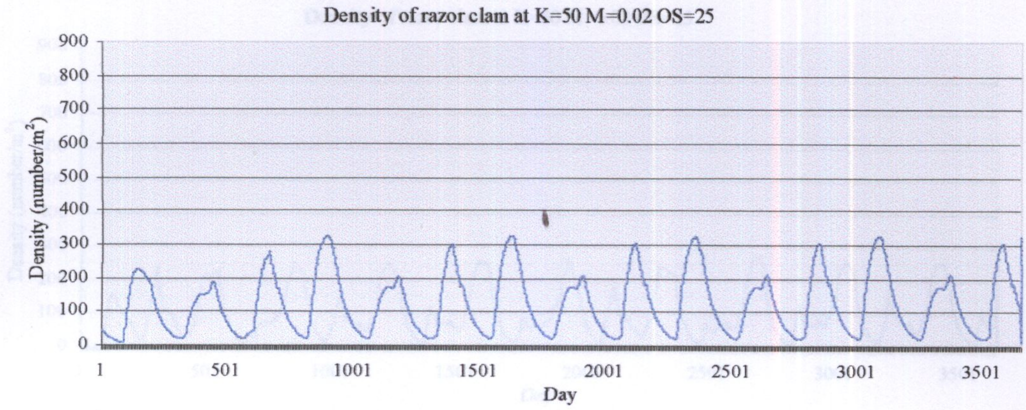
800
700
600
500
400
300
200
100
0
Density (number/m²)
1
501
1001
1501
2001
2501
3001
3501
Day


Density of razor clam at K=50 M=0.02 OS=25
Density (number/m2)
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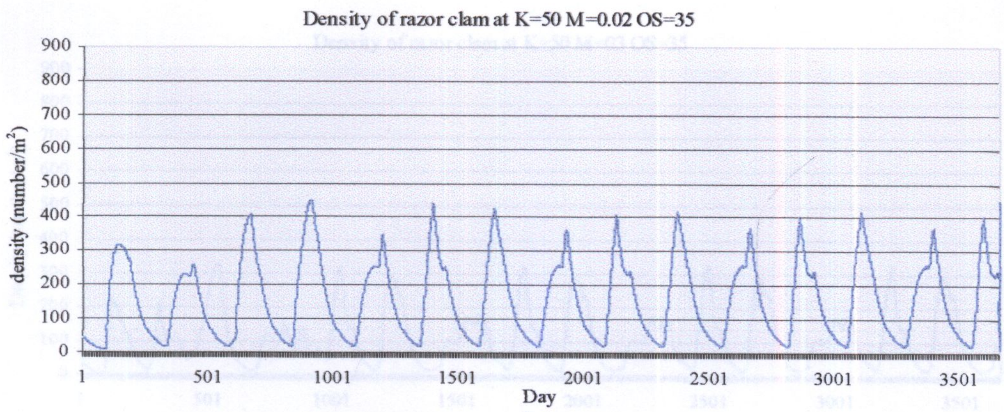
3001
3501
Day


Density of razor clam at K=50 M=0.02 OS=35
density (number/m2)
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800
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400
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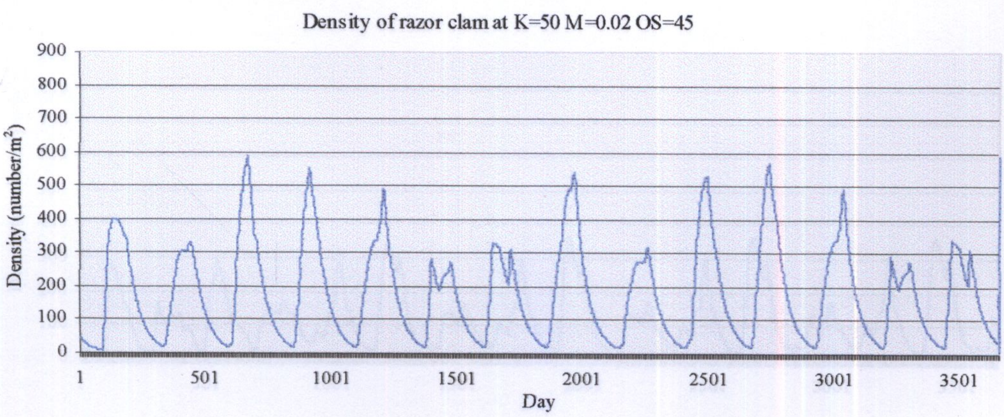
1001
1501
2001
2501
3001
3501
Day


Density of razor clam at K=50 M=0.02 OS=45
Density (number/m2)
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1001
1501
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2501
3001
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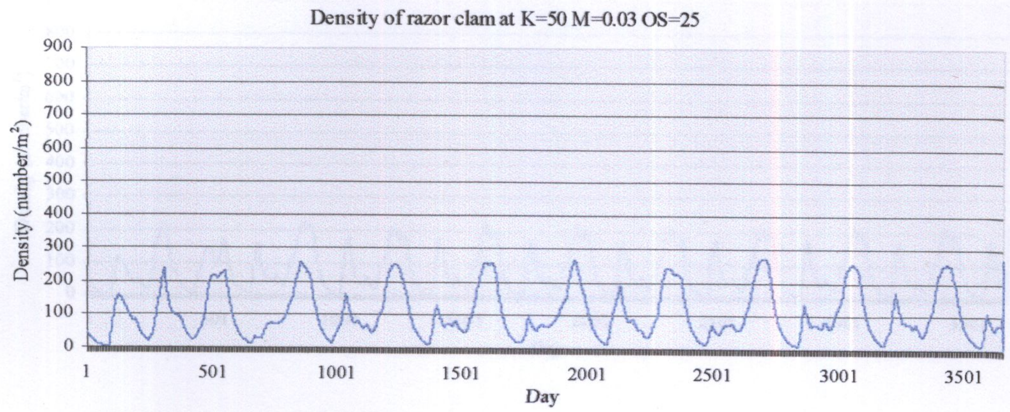
Day



Density of razor clam at K=50 M=0.03 OS=25
Density (number/m2)
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500
400
300
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1001
1501
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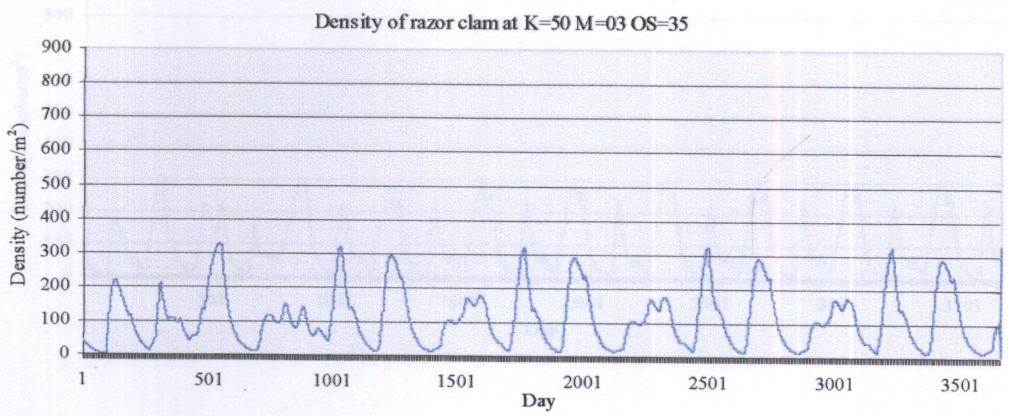
2501
3001
3501
Day



Density of razor clam at K=50 M=03 OS=35
Density (number/m2)
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800
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600
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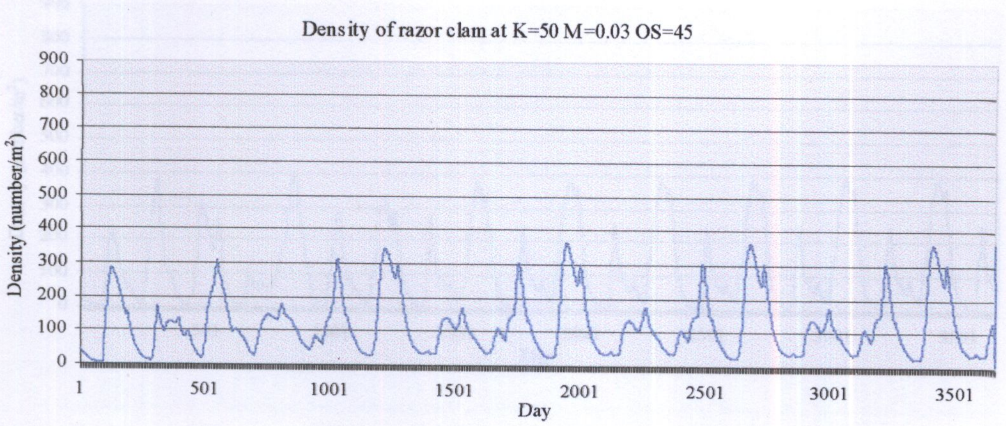
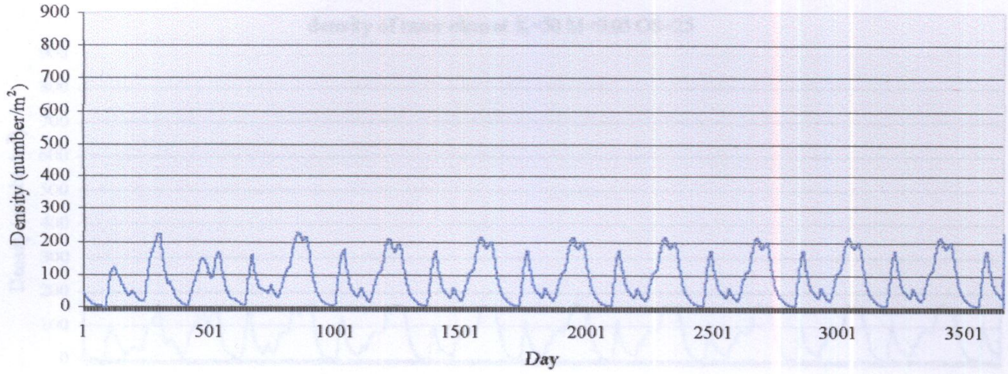
400
300
200
100
0
1
501
1001
1501
2001
2501
3001
3501
Day



Density of razor clam at K=50 M=0.03 OS=45
Density (number/m2)
900
800
700
600
500
400
300
200
100
0
1
501
1001
1501
2001
2501
3001
3501
Day

Density of razor clam at K=50 M=0.04 OS=25



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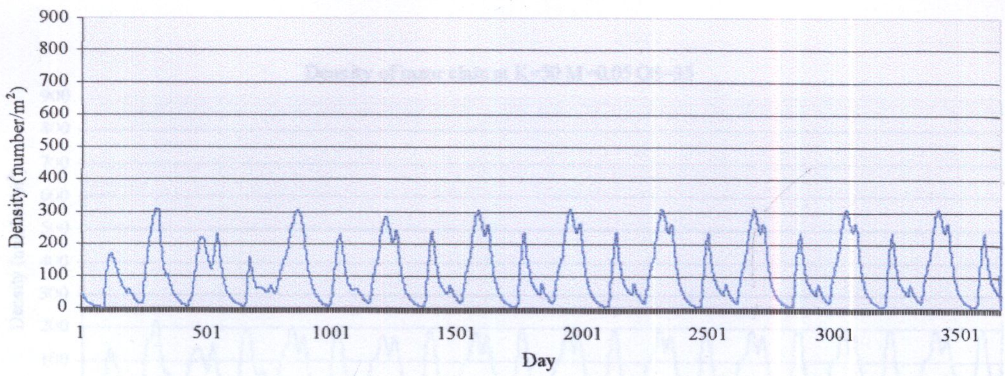
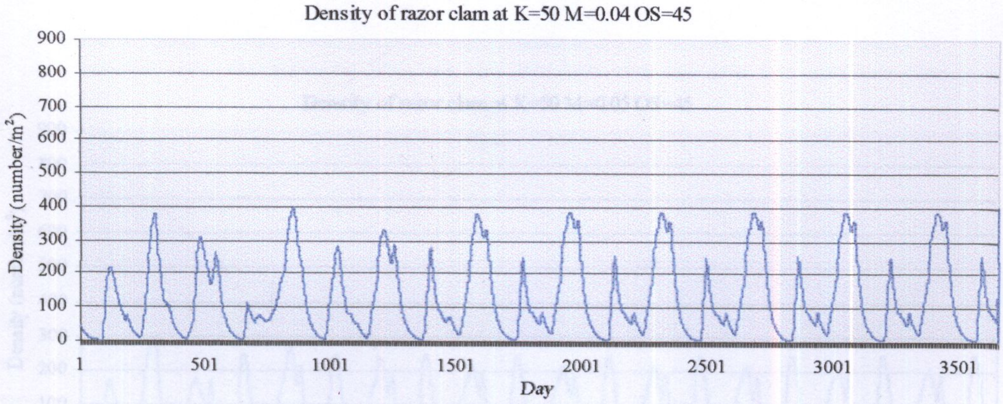
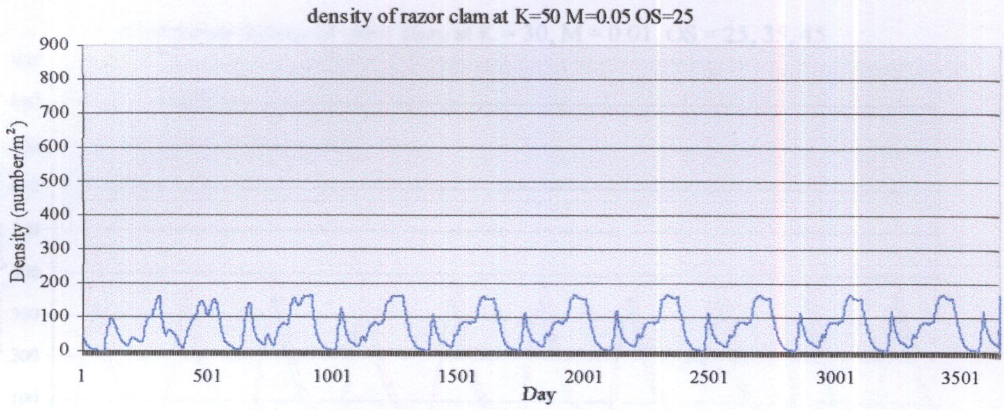


Density of razor clam at K=50 M=0.04 OS=45




density of razor clam at K=50 M=0.05 OS=25
Density (number/m2)
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500
400
300
200
100
0
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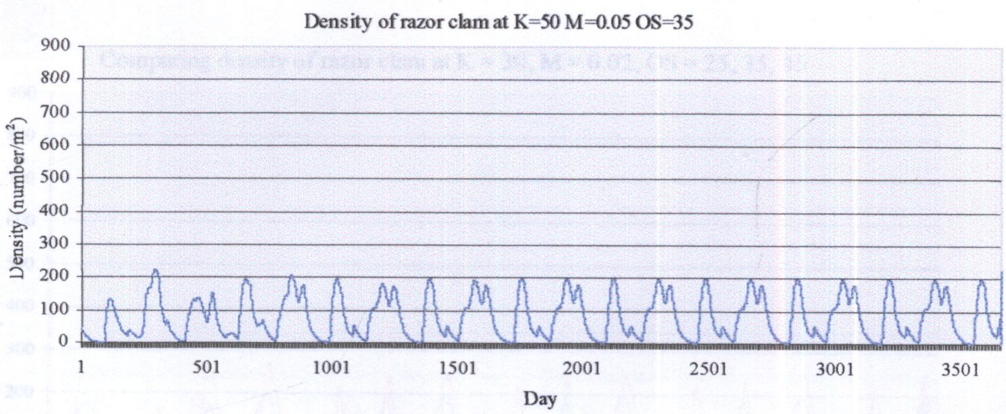
2501
3001
3501
Day


Density of razor clam at K=50 M=0.05 OS=35
Density (number/m2)
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400
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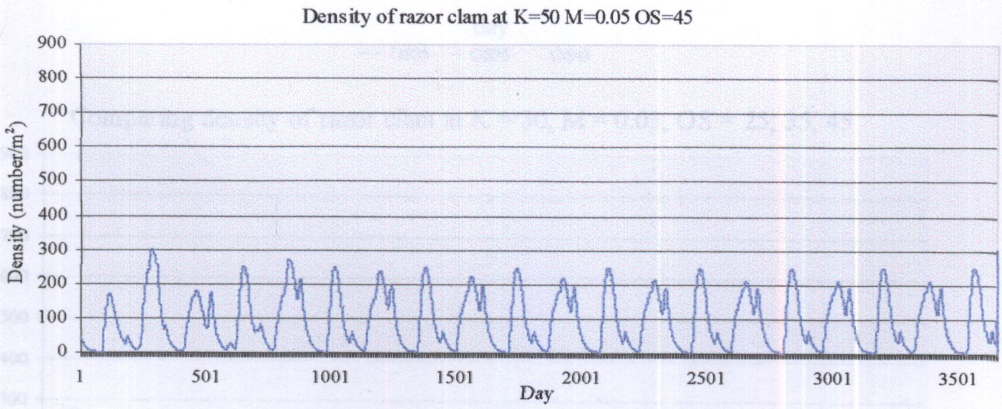
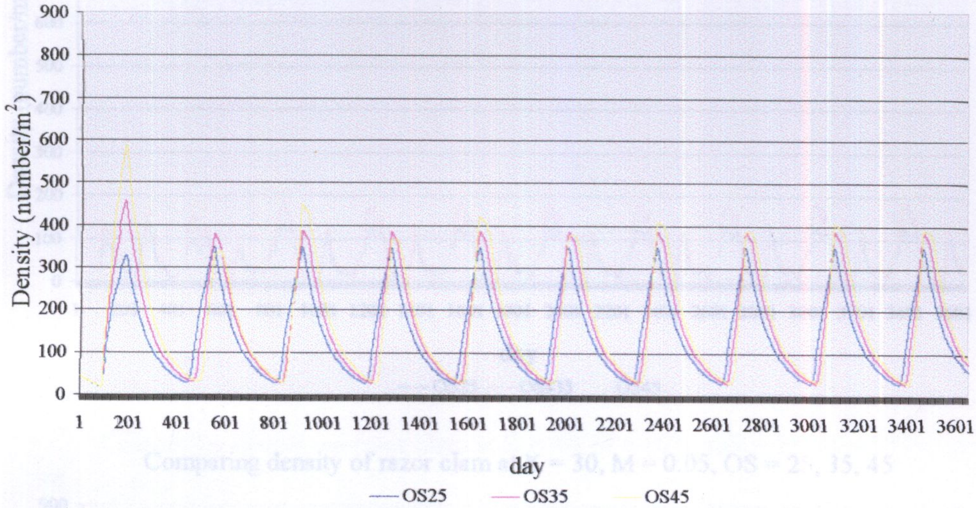
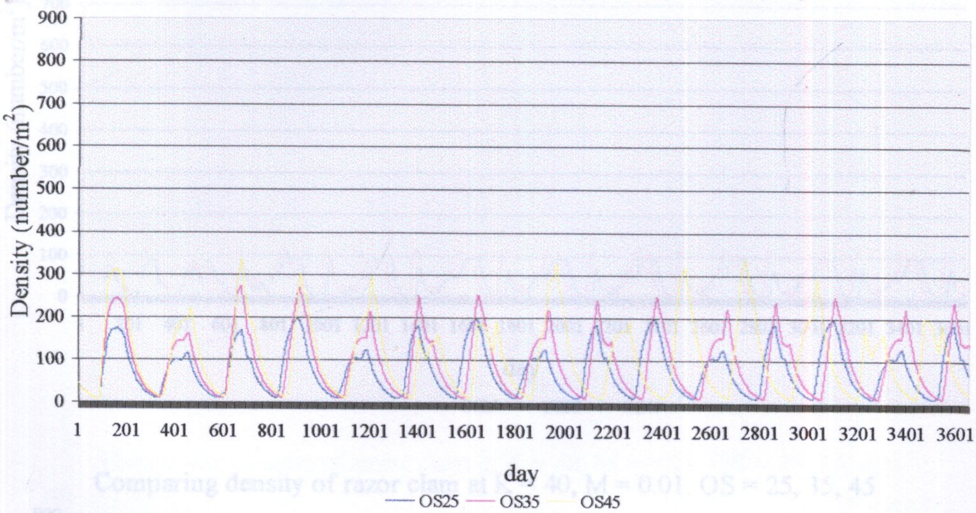
2501
3001
3501
Day


Density of razor clam at K=50 M=0.05 OS=45
Density (number/m2)
900
800
700
600
500
400
300
200
100
0
1
501
1001
1501
2001
2501
3001
3501
Day

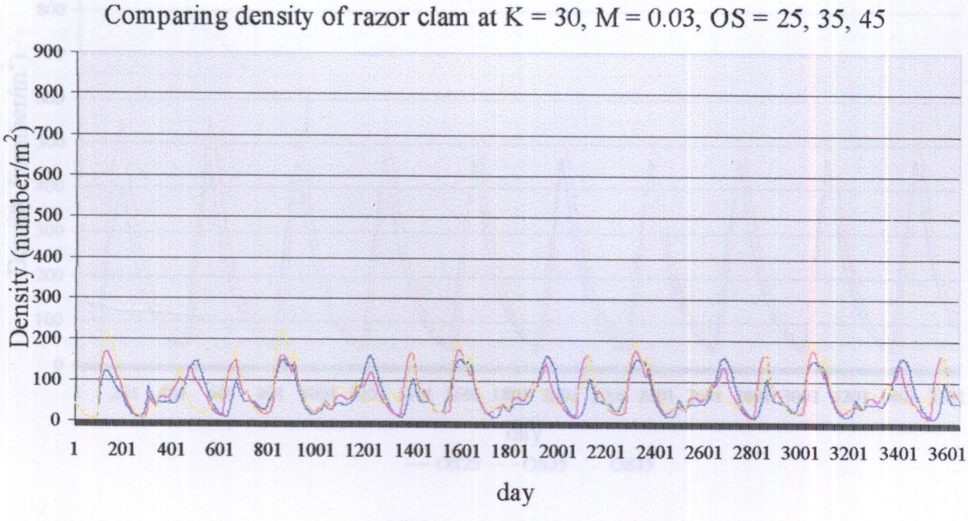
Comparing density of razor clam at K = 30, M = 0.01, OS = 25, 35, 45



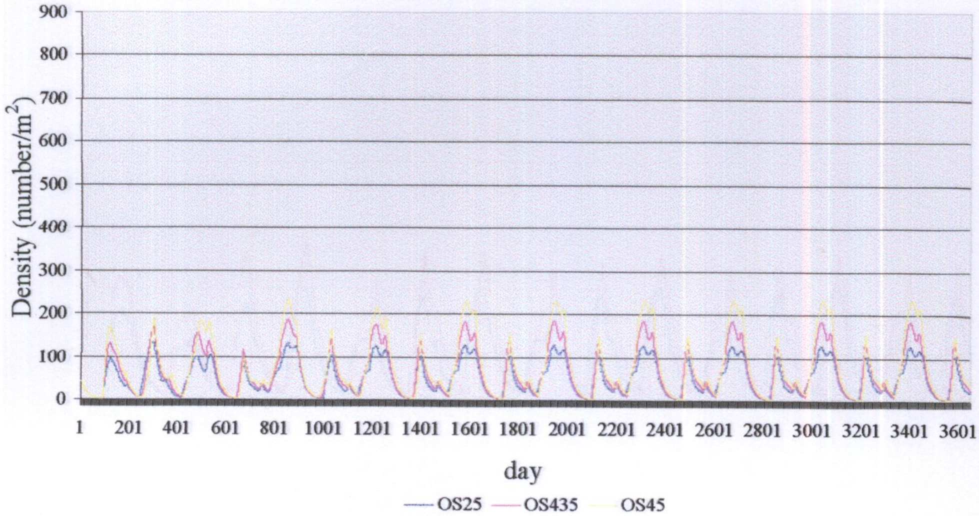
Comparing density of razor clam at K = 30, M = 0.02, OS = 25, 35, 45



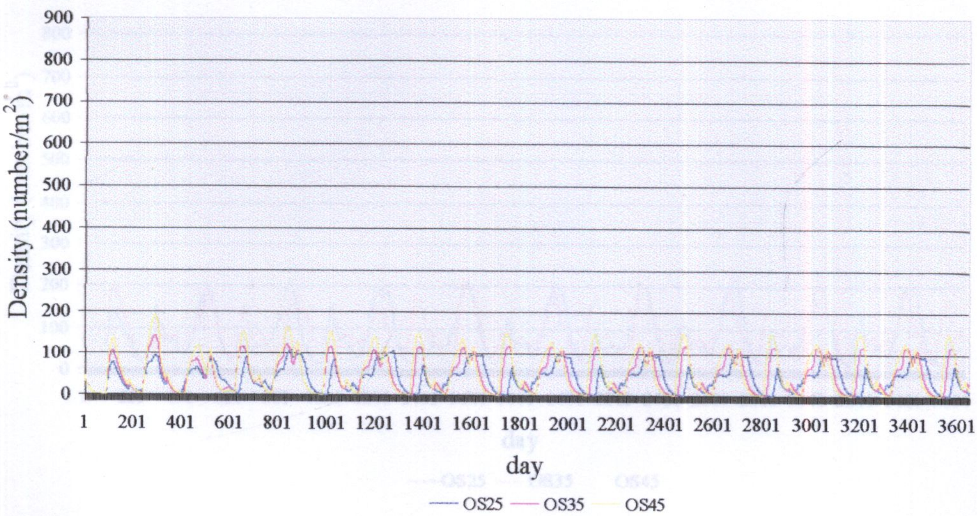
Comparing density of razor clam at K = 30, M = 0.03, OS = 25, 35, 45



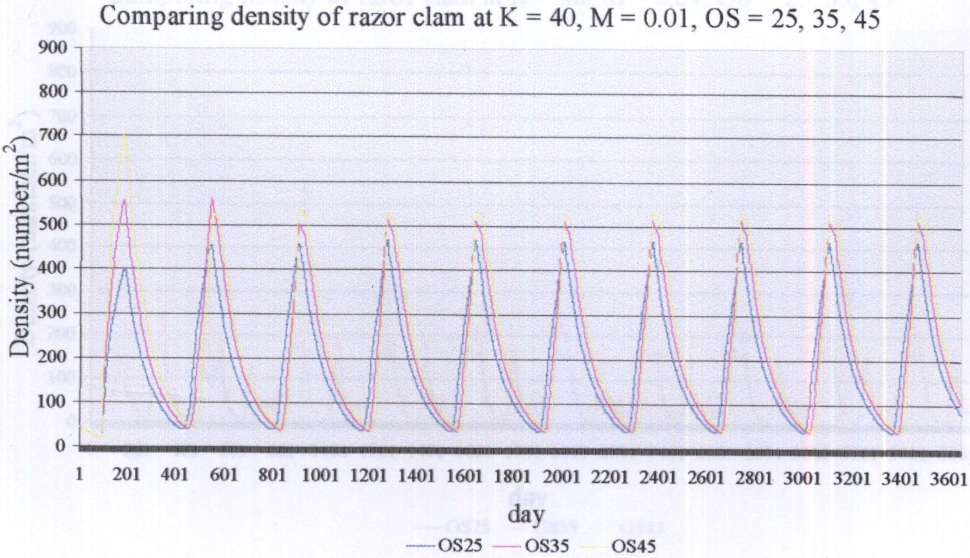
Comparing density of razor clam at K = 30, M = 0.04, OS = 25, 35, 45



Comparing density of razor clam at K = 30, M = 0.05, OS = 25, 35, 45



Comparing density of razor clam at K = 40, M = 0.01, OS = 25, 35, 45



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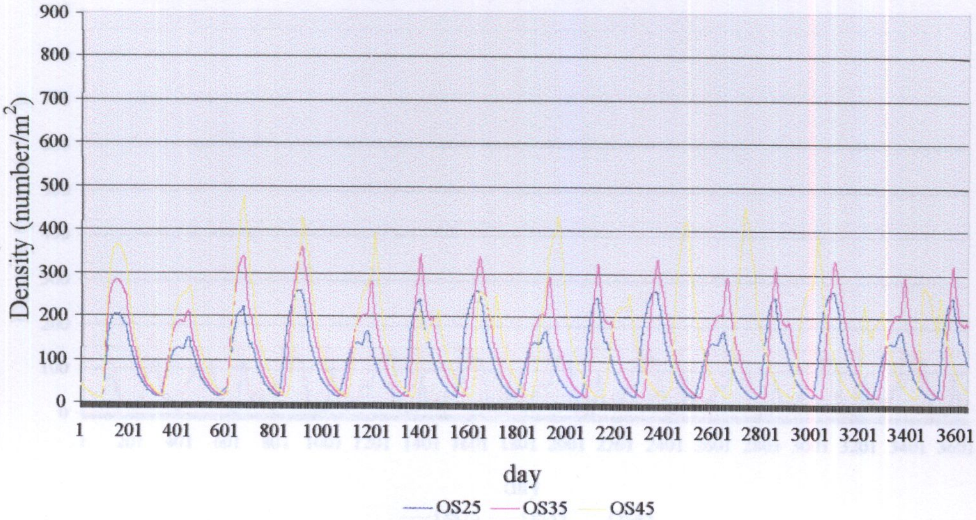
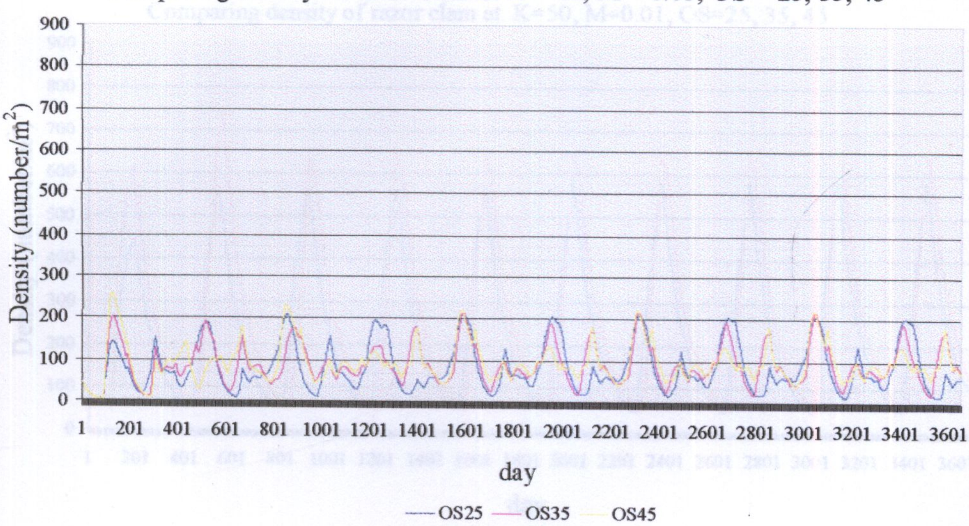
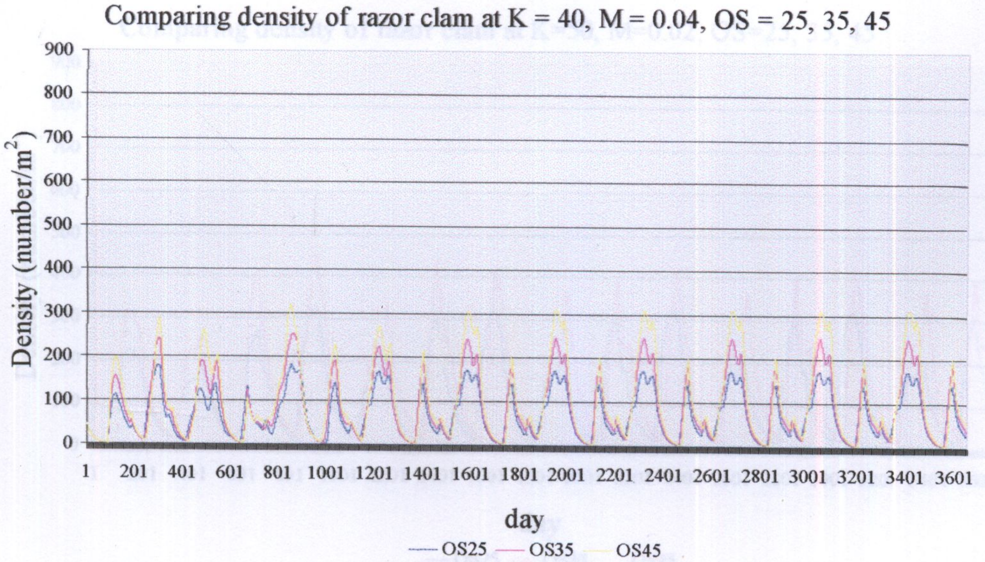


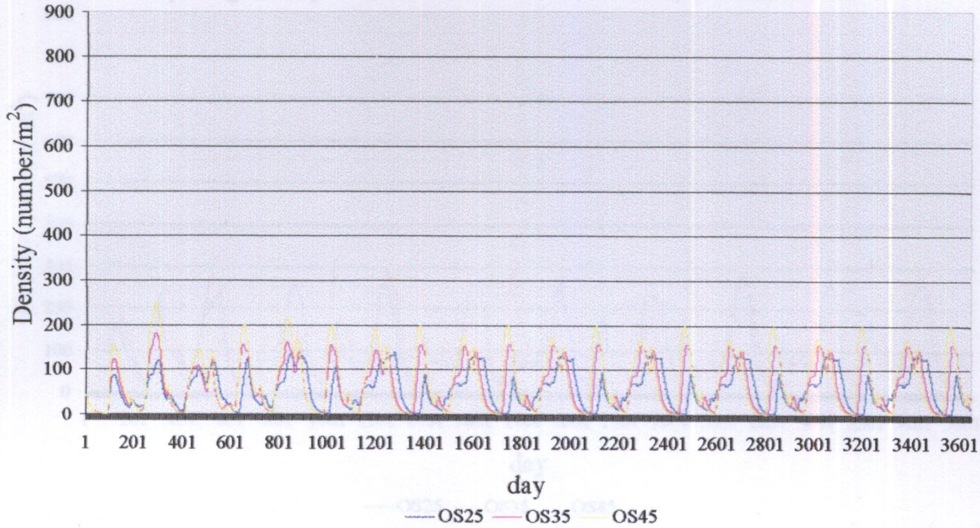
Comparing density os razor clam at K = 40, M = 0.03, OS = 25, 35, 45



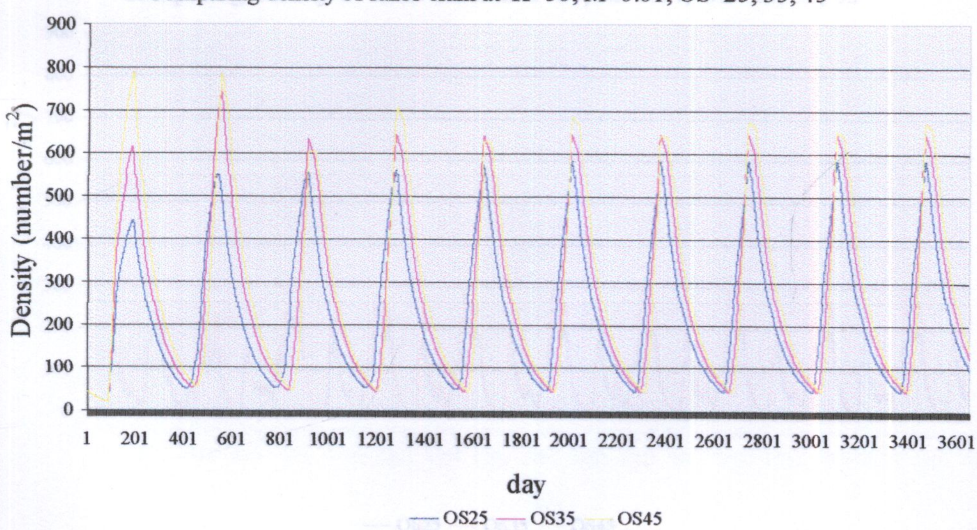
Comparing density of razor clam at K = 40, M = 0.04, OS = 25, 35, 45



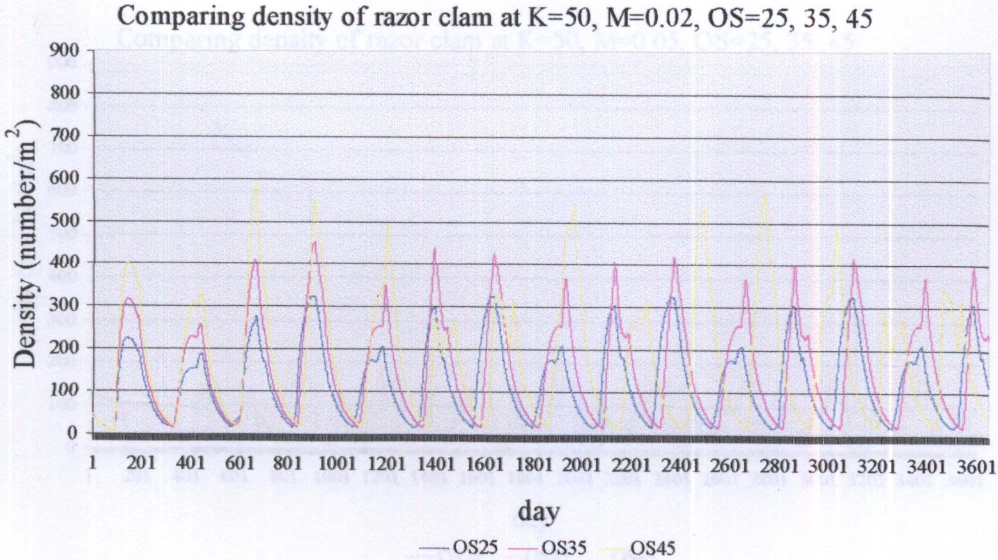
Comparing density of razor clam at K = 40, M = 0.05, OS = 25, 35, 45

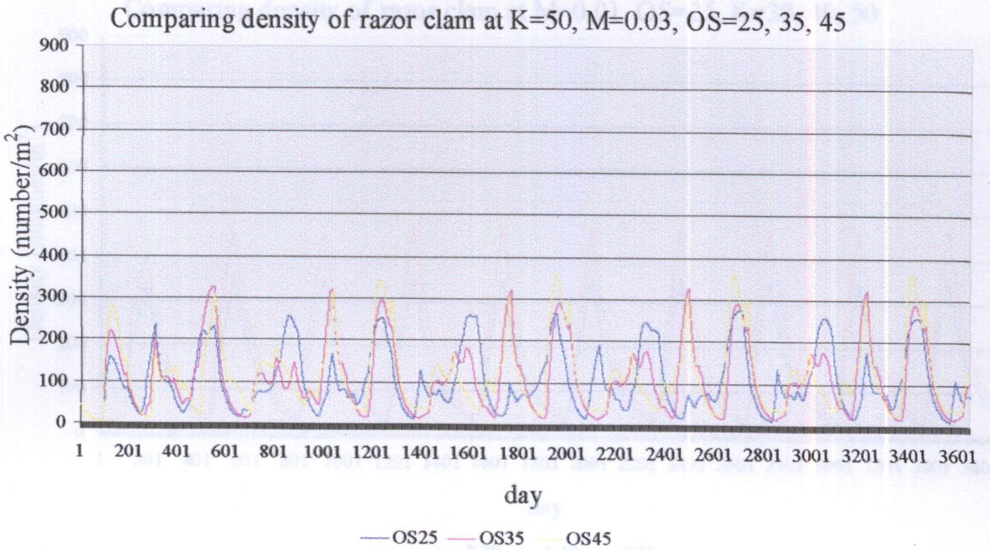


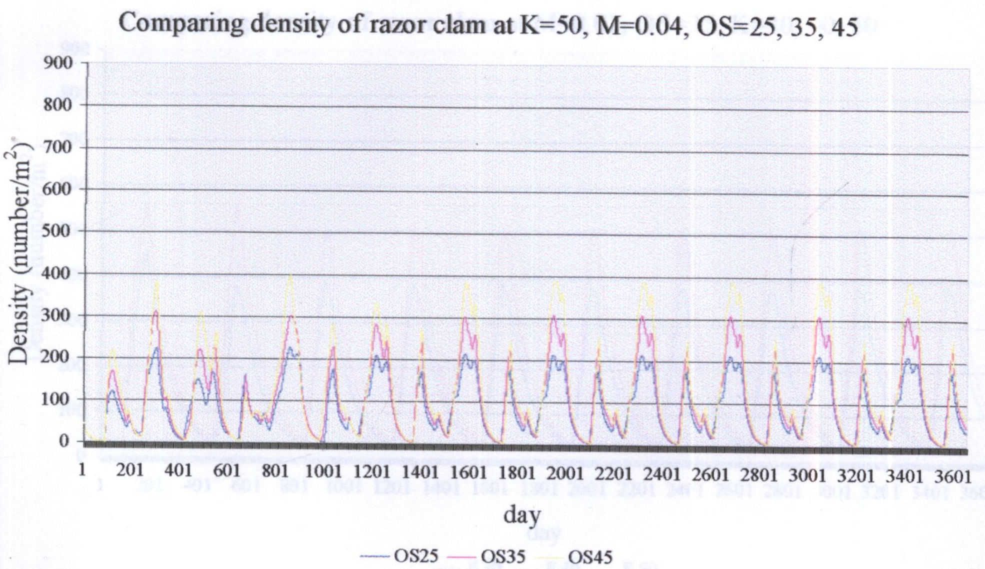
Comparing density of razor clam at K=50, M=0.01, OS=25, 35, 45

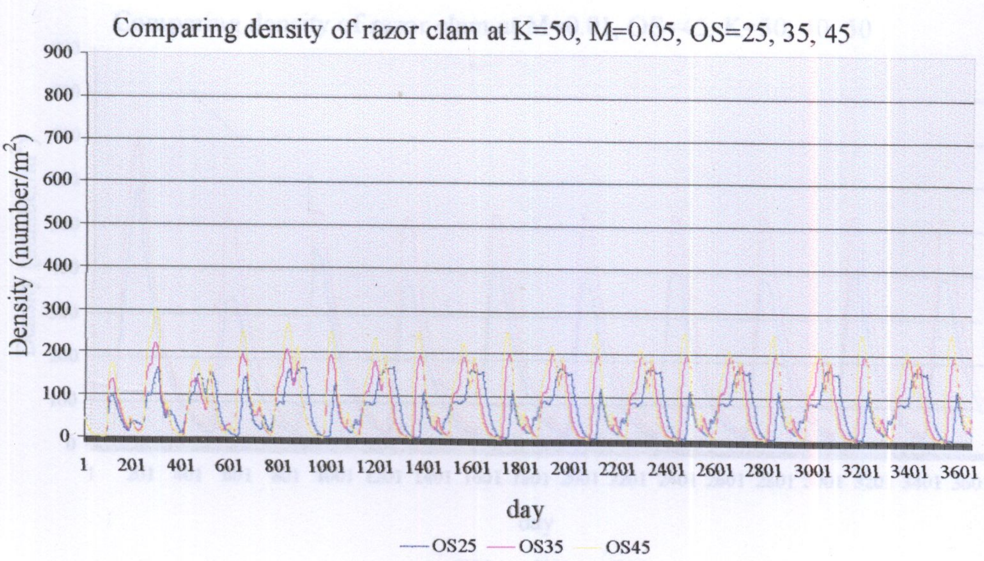


Comparing density of razor clam at K=50, M=0.02, OS=25, 35, 45

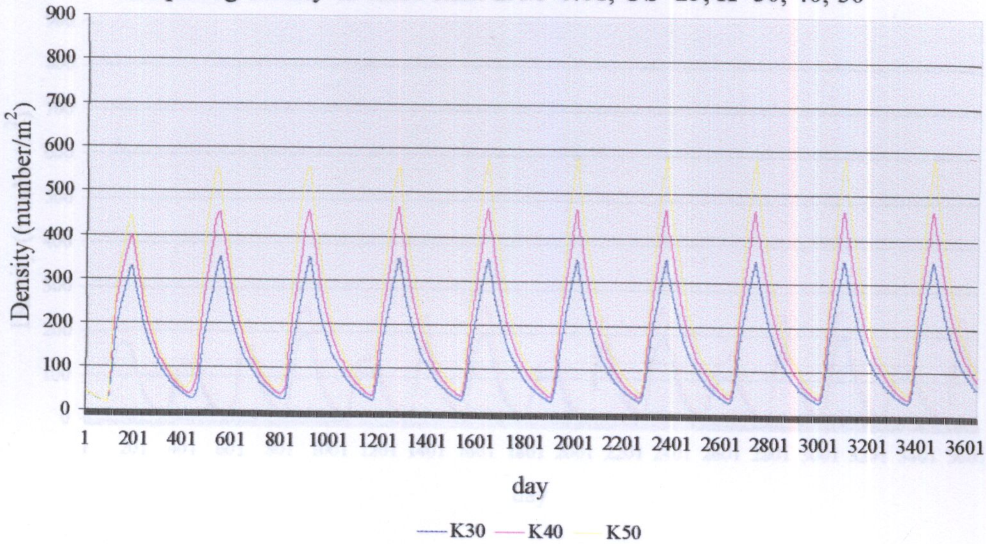



Comparing density of razor clam at K=50, M=0.03, OS=25, 35, 45
Density (number/m2)
day
OS25
OS35
OS45

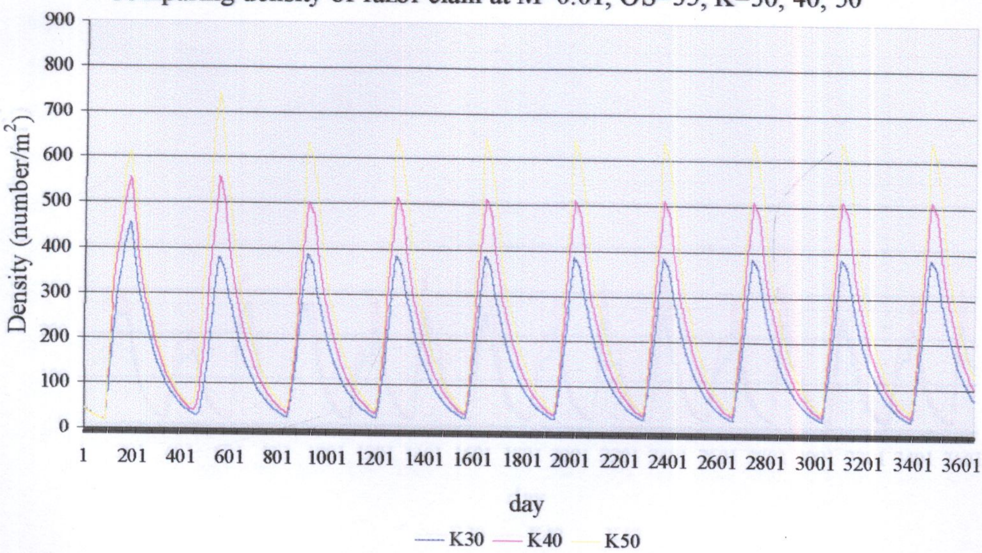

Comparing density of razor clam at K=50, M=0.04, OS=25, 35, 45
Density (number/m2)
day
OS25
OS35
OS45


Comparing density of razor clam at K=50, M=0.05, OS=25, 35, 45
Density (number/m2)
day
OS25
OS35
OS45

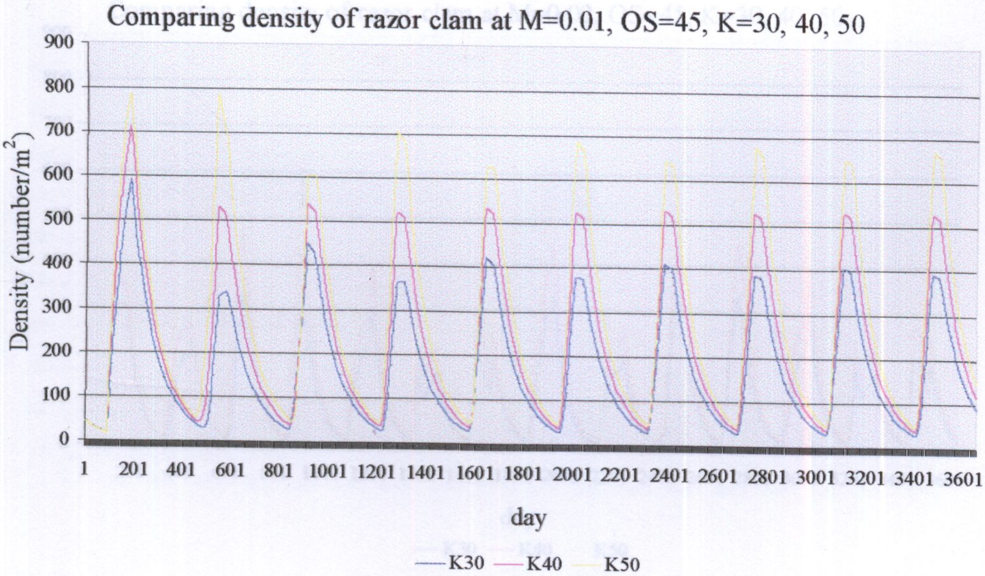
Comparing density of razor clam at M=0.01, OS=25, K=30, 40, 50

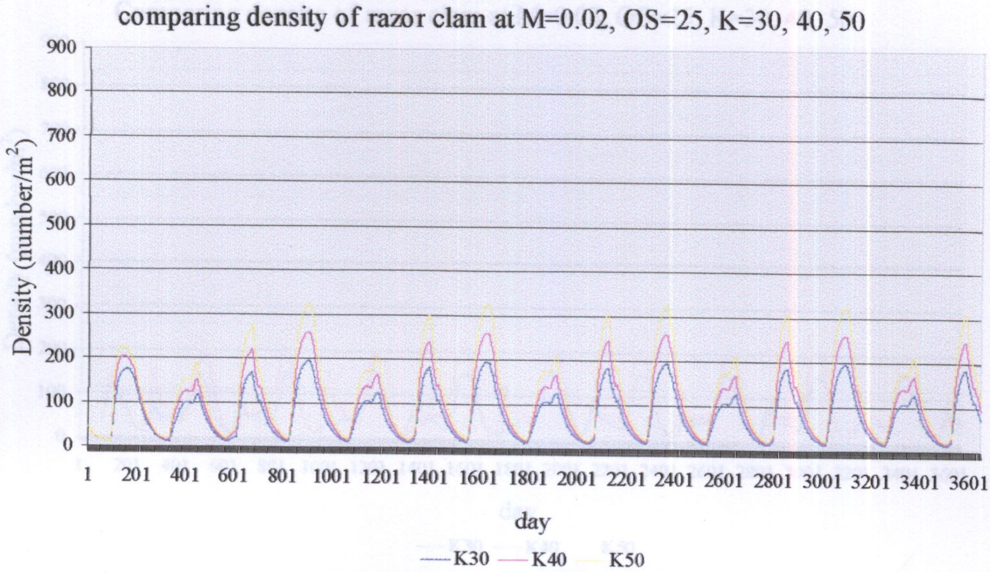


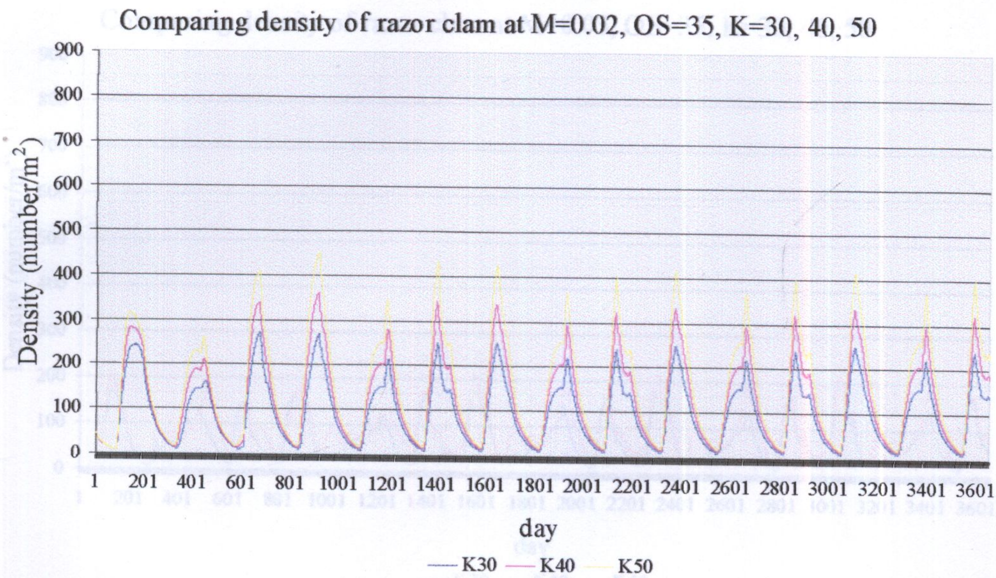
Comparing density of razor clam at M=0.01, OS=35, K=30, 40, 50

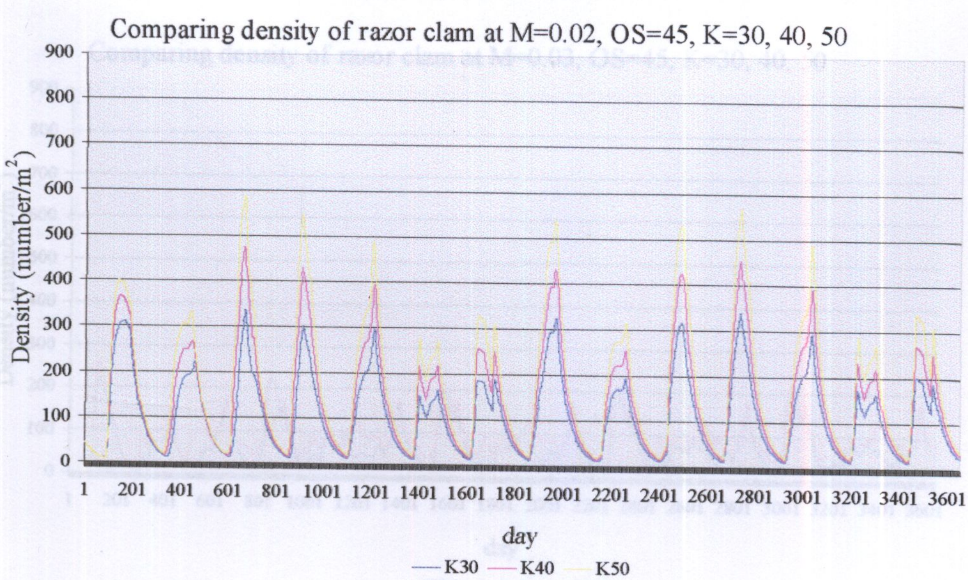


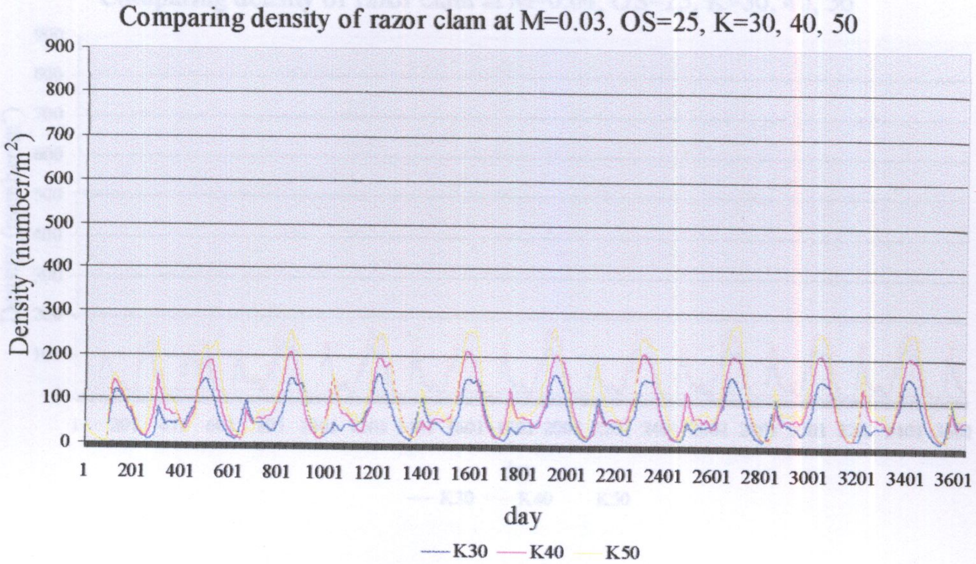
Comparing density of razor clam at M=0.01, OS=45, K=30, 40, 50

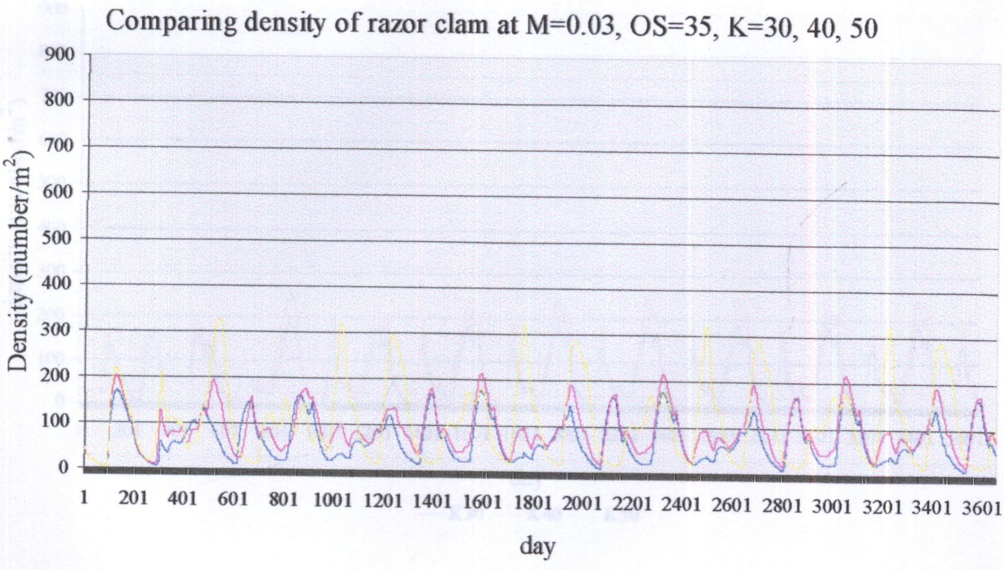


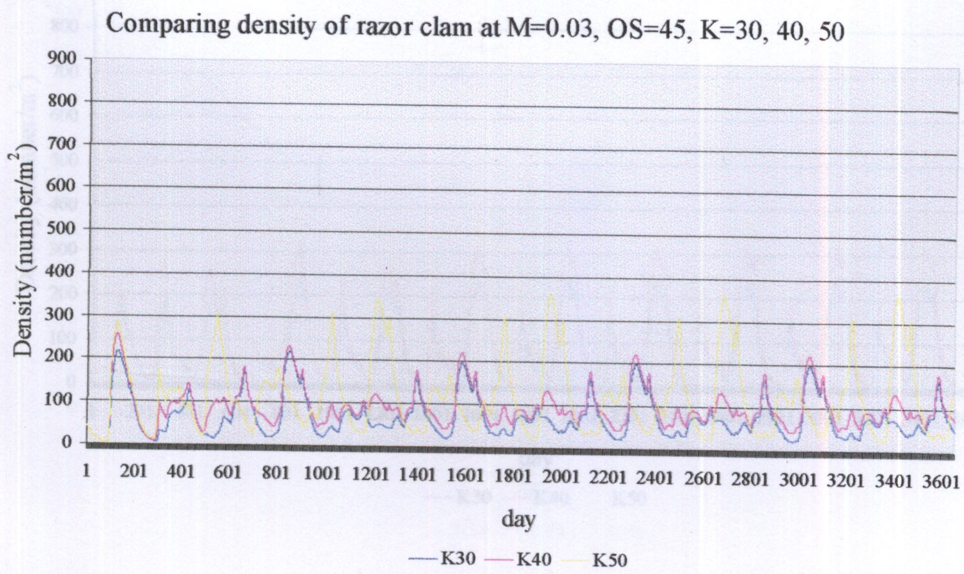

comparing density of razor clam at M=0.02, OS=25, K=30, 40, 50
Density (number/m2)
900
800
700
600
500
400
300
200
100
0
1 201 401 601 801 1001 1201 1401 1601 1801 2001 2201 2401 2601 2801 3001 3201 3401 3601
day
K30 K40 K50


Comparing density of razor clam at M=0.02, OS=35, K=30, 40, 50
Density (number/m2)
900
800
700
600
500
400
300
200
100
0
1 201 401 601 801 1001 1201 1401 1601 1801 2001 2201 2401 2601 2801 3001 3201 3401 3601
day
K30 K40 K50

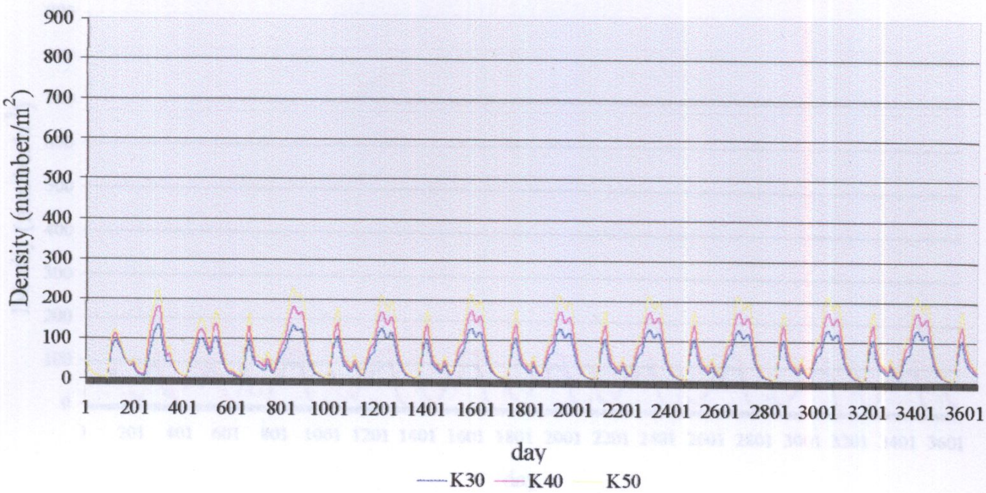

Comparing density of razor clam at M=0.02, OS=45, K=30, 40, 50
Density (number/m2)
900
800
700
600
500
400
300
200
100
0
1 201 401 601 801 1001 1201 1401 1601 1801 2001 2201 2401 2601 2801 3001 3201 3401 3601
day
K30 K40 K50


Comparing density of razor clam at M=0.03, OS=25, K=30, 40, 50
Density (number/m2)
0
100
200
300
400
500
600
700
800
900
1 201 401 601 801 1001 1201 1401 1601 1801 2001 2201 2401 2601 2801 3001 3201 3401 3601
day
K30 K40 K50

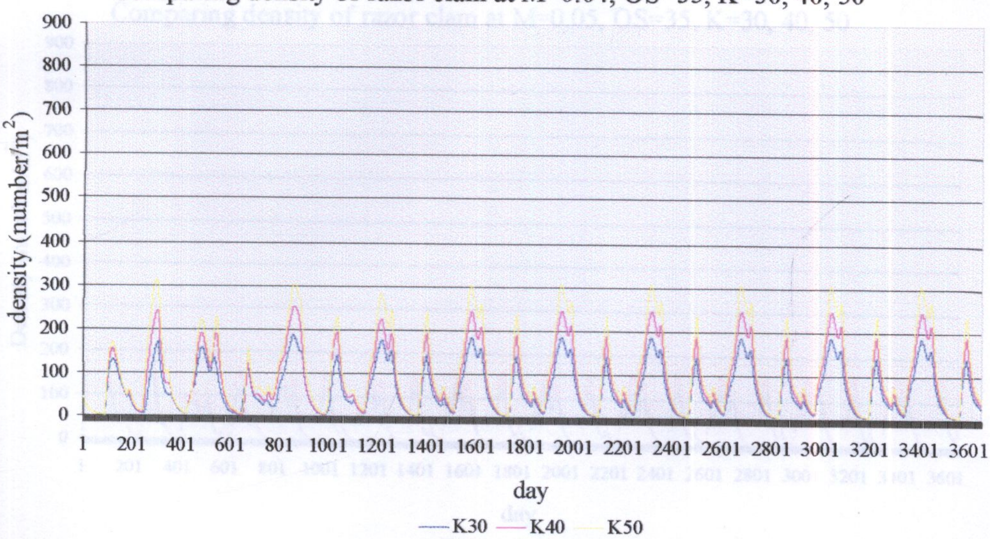

Comparing density of razor clam at M=0.03, OS=35, K=30, 40, 50
Density (number/m2)
0
100
200
300
400
500
600
700
800
900
1 201 401 601 801 1001 1201 1401 1601 1801 2001 2201 2401 2601 2801 3001 3201 3401 3601
day
K30 K40 K50


Comparing density of razor clam at M=0.03, OS=45, K=30, 40, 50
Density (number/m2)
0
100
200
300
400
500
600
700
800
900
1 201 401 601 801 1001 1201 1401 1601 1801 2001 2201 2401 2601 2801 3001 3201 3401 3601
day
K30 K40 K50

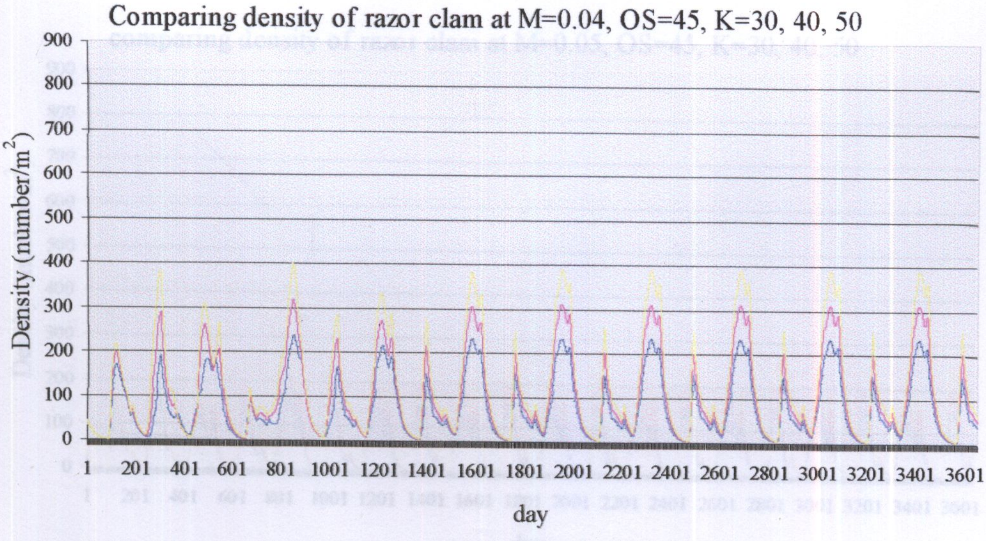
Comparing density of razor clam at M=0.04, OS=25, K=30, 40, 50



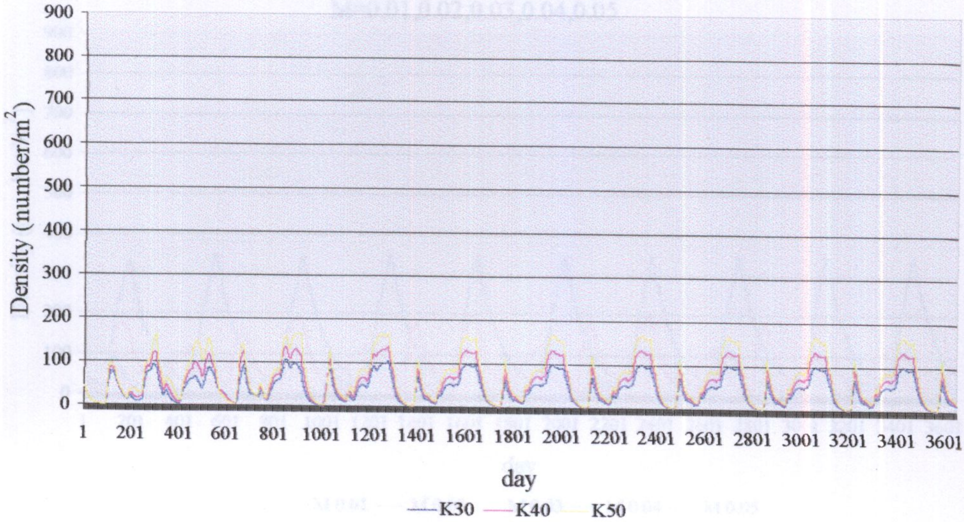
Comparing density of razor clam at M=0.04, OS=35, K=30, 40, 50



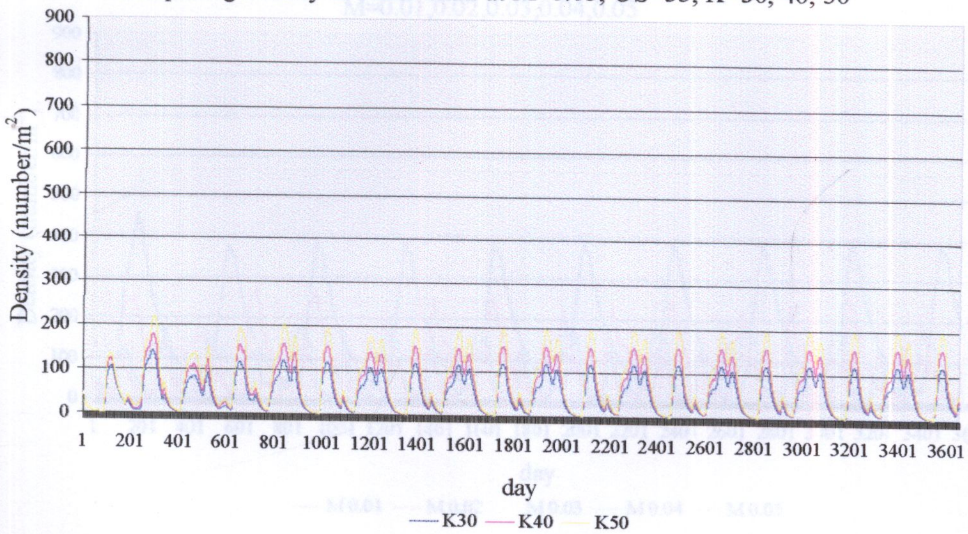
Comparing density of razor clam at M=0.04, OS=45, K=30, 40, 50



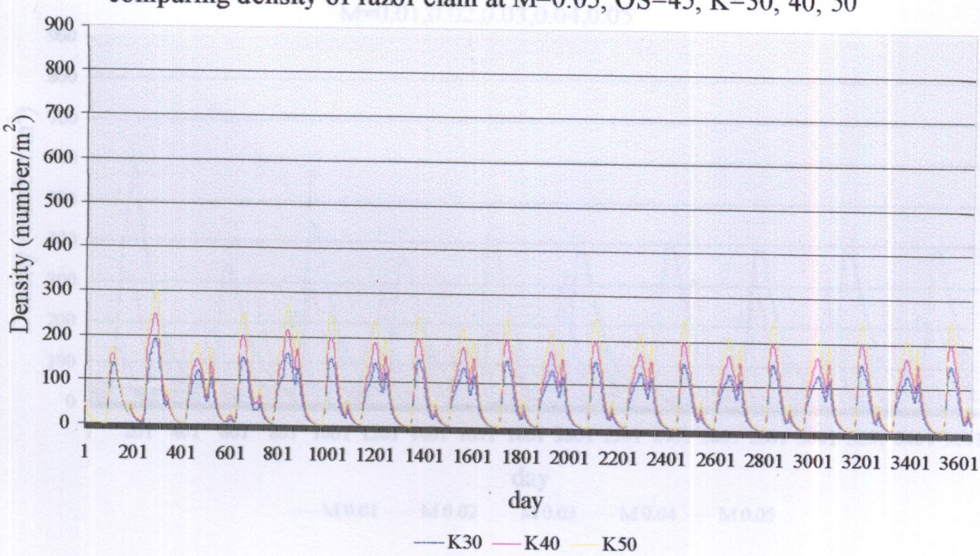
Comparing density of razor clam at M=0.05, OS=25, K=30, 40, 50



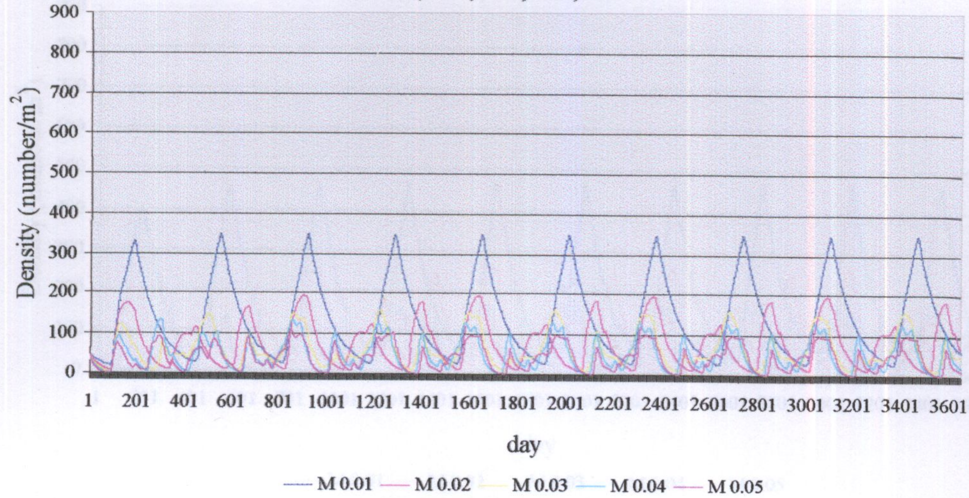
Comparing density of razor clam at M=0.05, OS=35, K=30, 40, 50



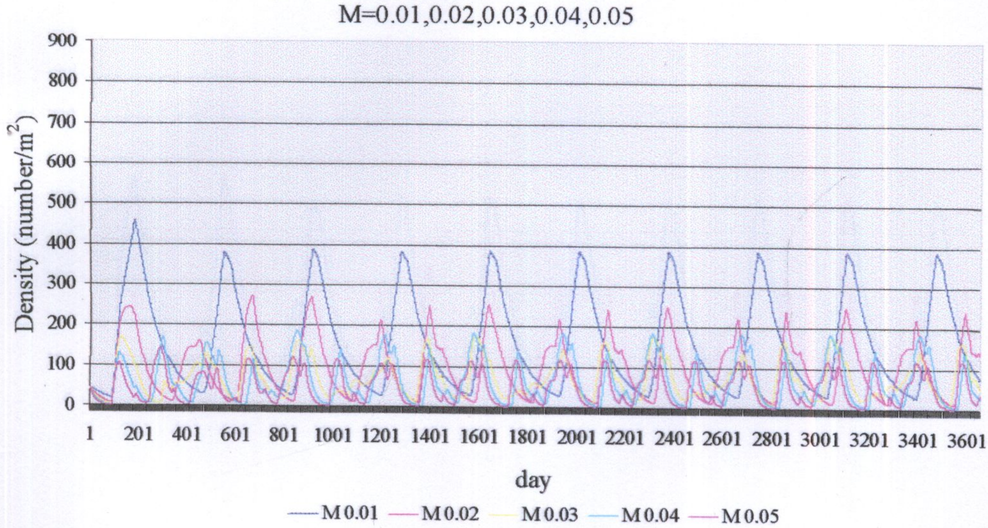
comparing density of razor clam at M=0.05, OS=45, K=30, 40, 50



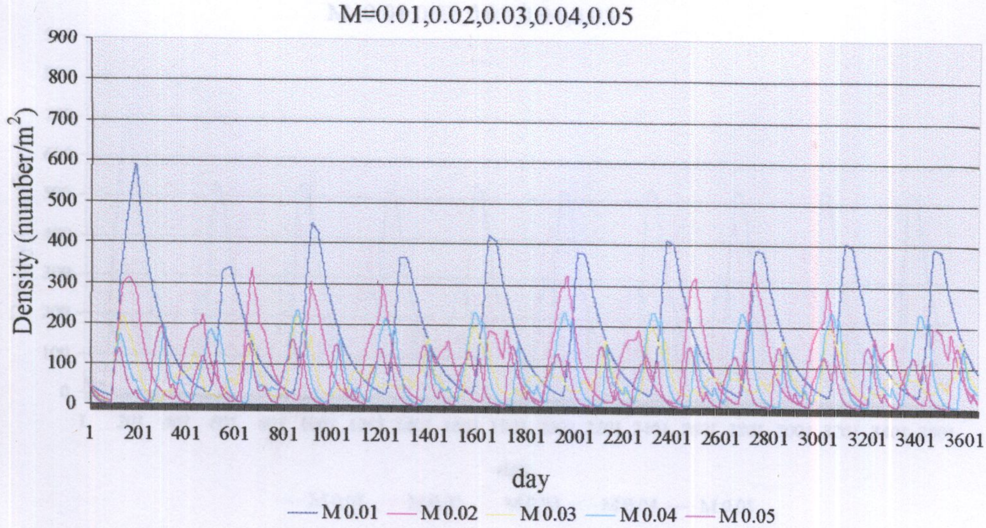
Comparing density of razor clam at K=30 OS=25
M=0.01,0.02,0.03,0.04,0.05



Comparing density of razor clam at K=30 OS=35
M=0.01,0.02,0.03,0.04,0.05



Comparing density of razor clam at K=30 OS=45
M=0.01,0.02,0.03,0.04,0.05



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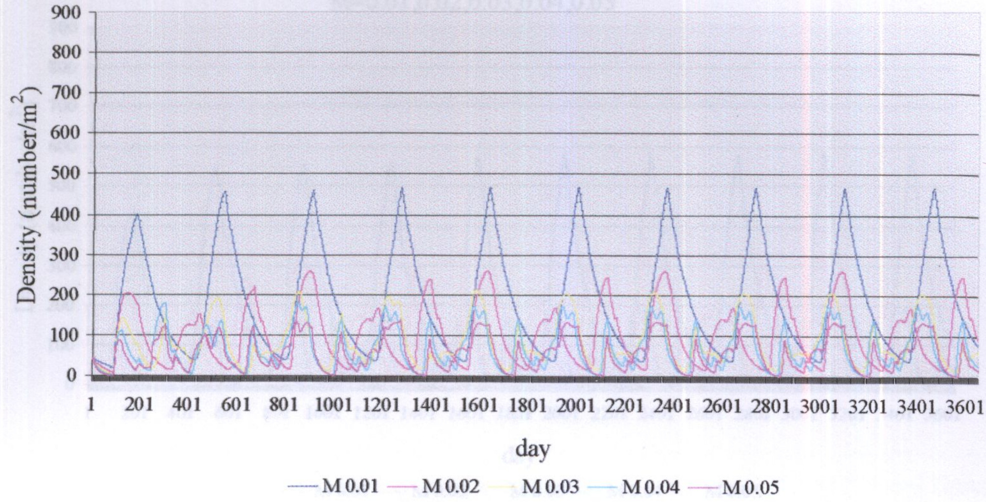

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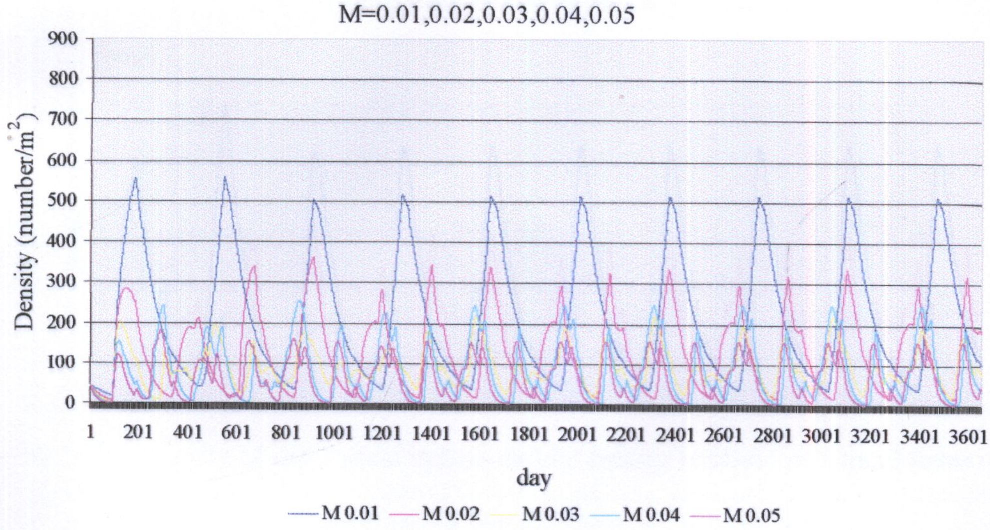
M=0.01,0.02,0.03,0.04,0.05



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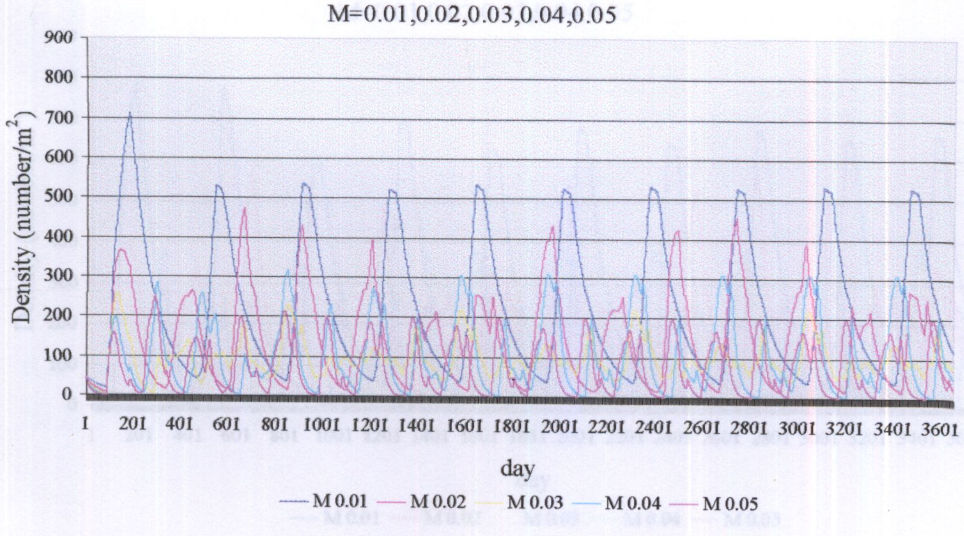
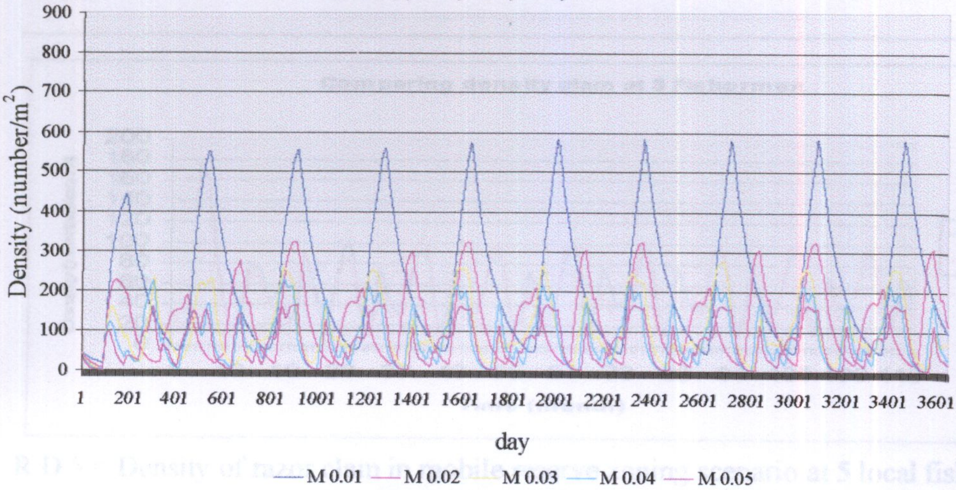
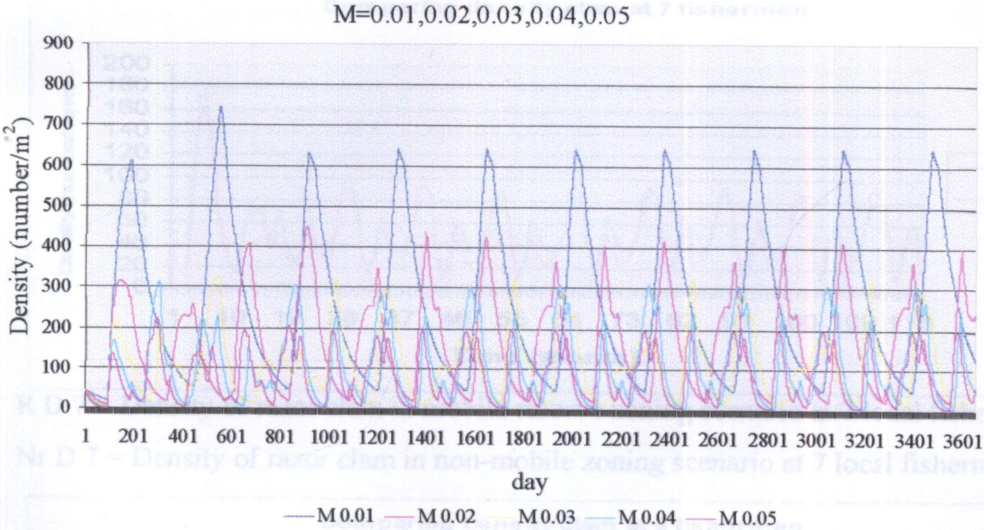
M=0.01,0.02,0.03,0.04,0.05



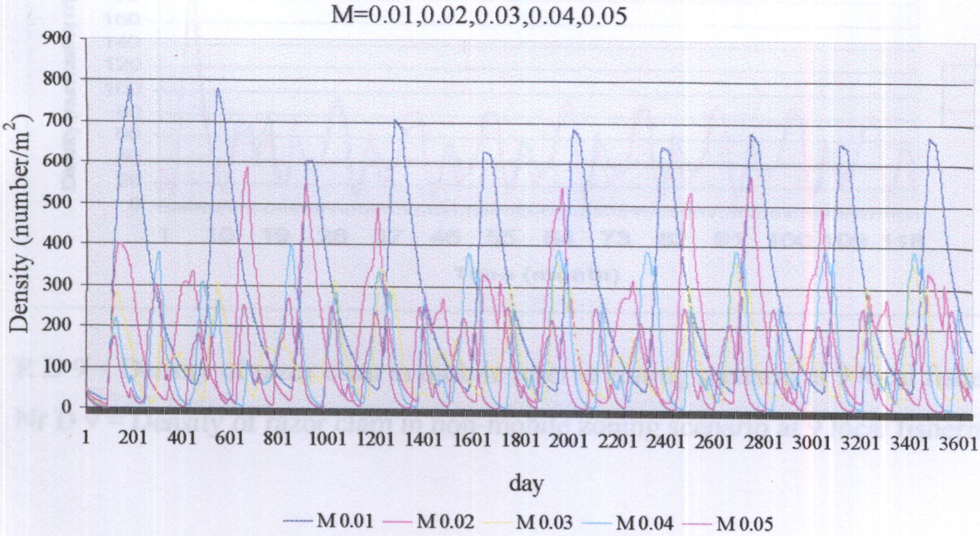
Comparing density of razor clam at K=50 OS=25
M=0.01,0.02,0.03,0.04,0.05



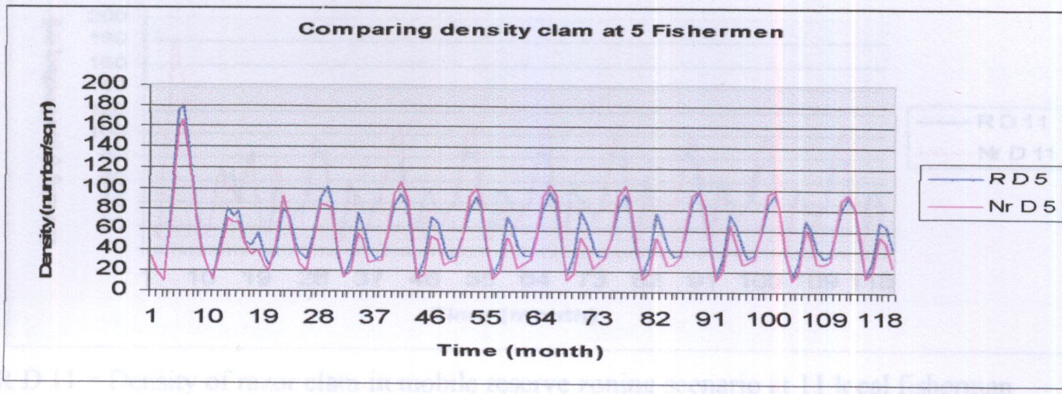
Comparing density of razor clam at K=50 OS=35
M=0.01,0.02,0.03,0.04,0.05



Comparing density of razor clam at K=50 OS=45
M=0.01,0.02,0.03,0.04,0.05

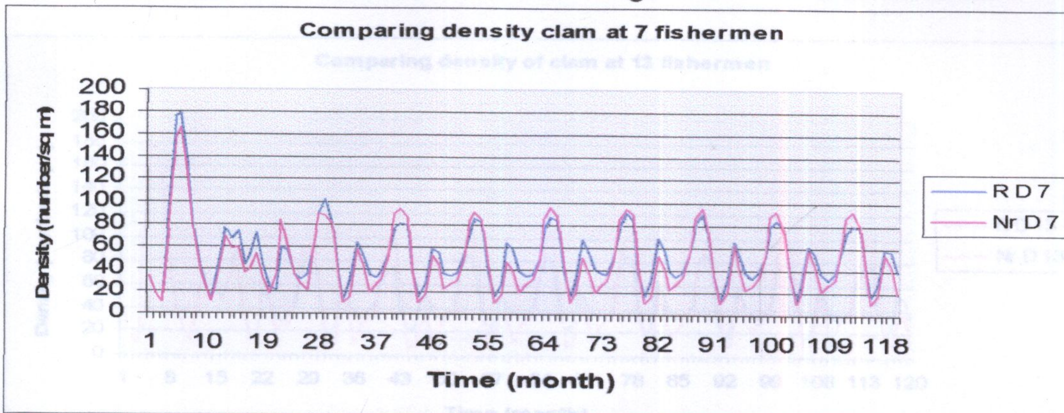


D 2 Simulation run both of two scenarios



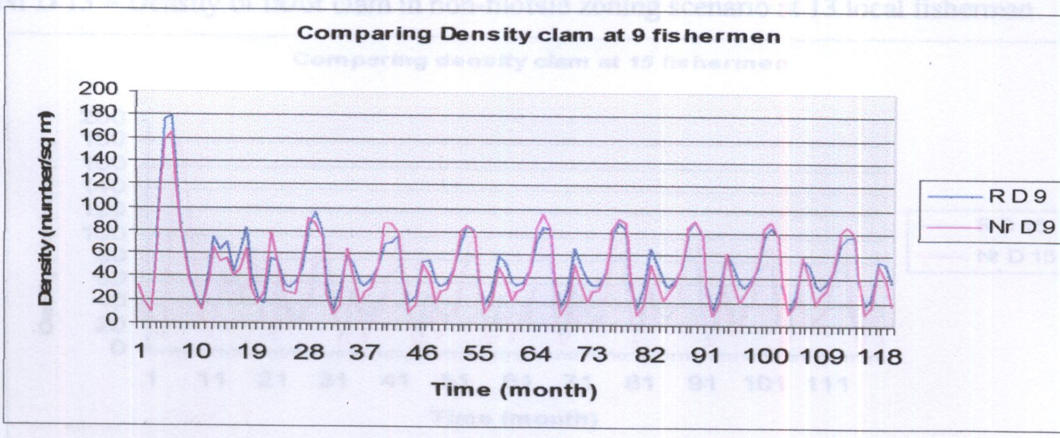
R D 5 = Density of razor clam in mobile reserve zoning scenario at 5 local fisherman

Nr D 5 = Density of razor clam in non-mobile zoning scenario at 5 local fisherman



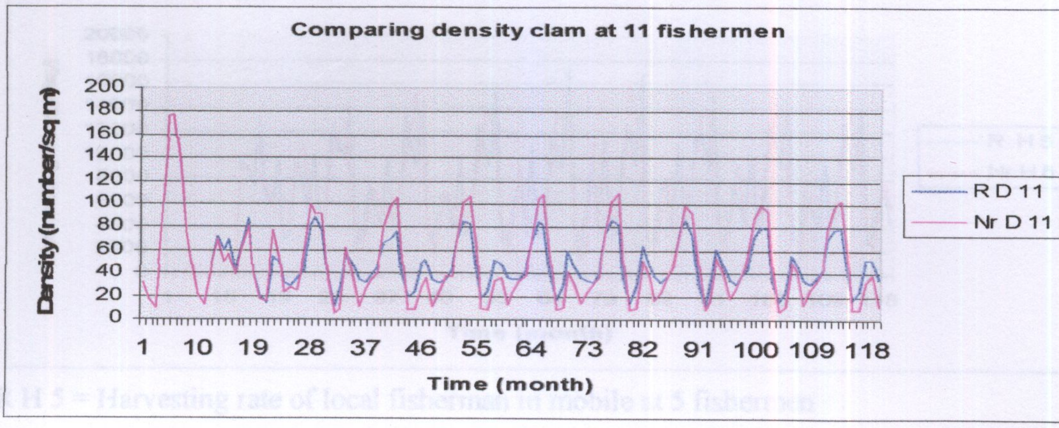
R D 7 = Density of razor clam in mobile reserve zoning scenario at 7 local fisherman

Nr D 7 = Density of razor clam in non-mobile zoning scenario at 7 local fisherman



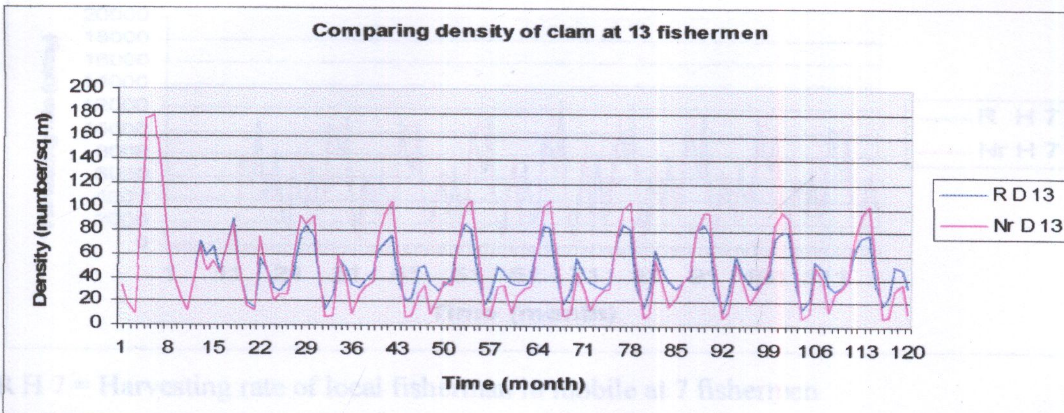
R D 9 = Density of razor clam in mobile reserve zoning scenario at 9 local fisherman

Nr D 9 = Density of razor clam in non-mobile zoning scenario at 9 local fisherman



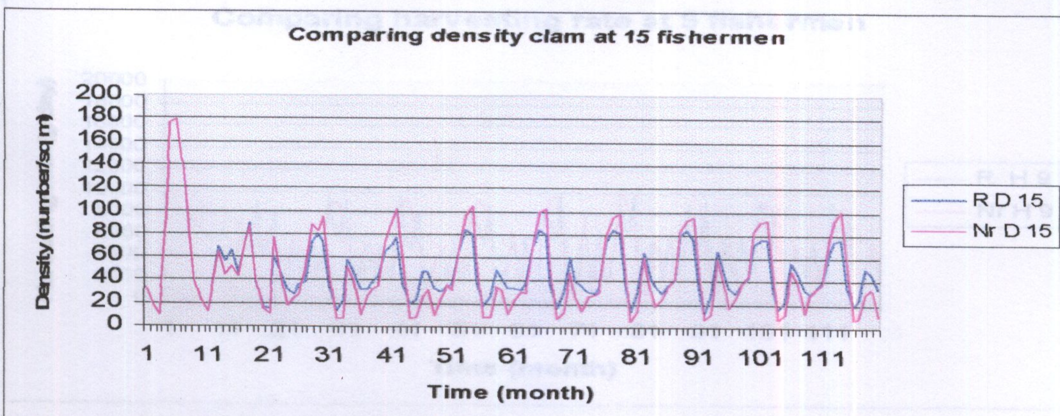
R D 11 = Density of razor clam in mobile reserve zoning scenario at 11 local fisherman

Nr D 11 = Density of razor clam in non-mobile zoning scenario at 11 local fisherman



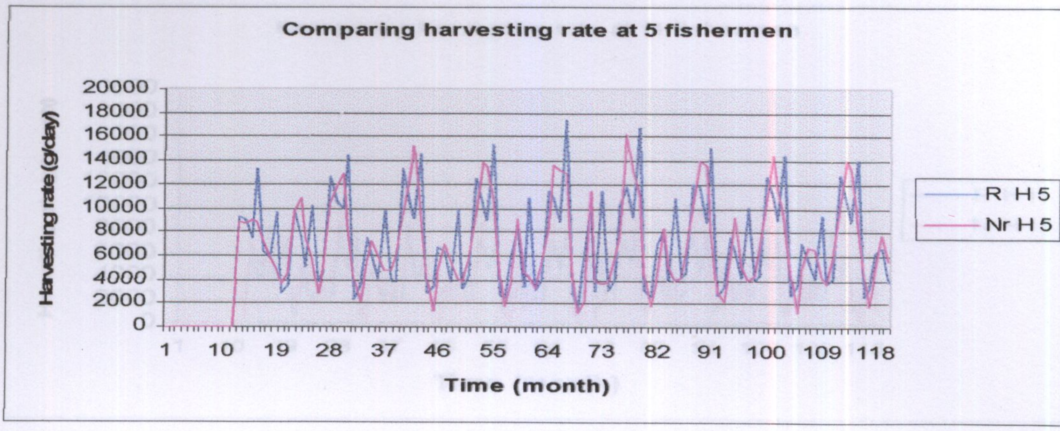
R D 13 = Density of razor clam in mobile reserve zoning scenario at 13 local fisherman

Nr D 13 = Density of razor clam in non-mobile zoning scenario at 13 local fisherman



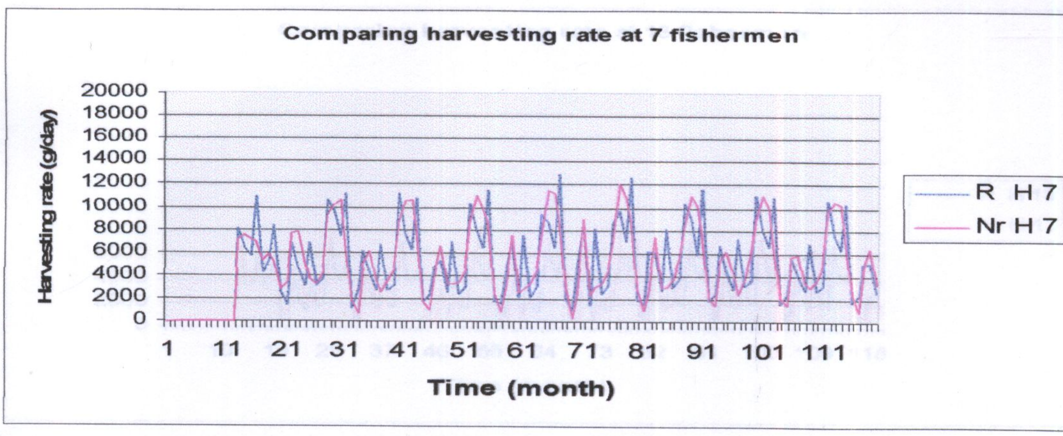
R D 15 = Density of razor clam in mobile reserve zoning scenario at 15 local fisherman

Nr D 15 = Density of razor clam in non-mobile zoning scenario at 15 local fisherman



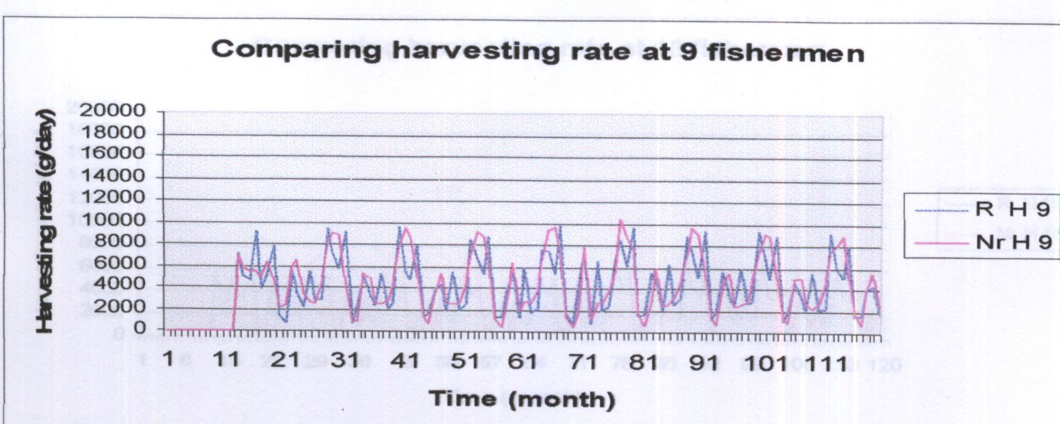
R H 5 = Harvesting rate of local fisherman in mobile at 5 fishermen

Nr H 5 = Harvesting rate of local fisherman in non-mobile at 5 fishermen



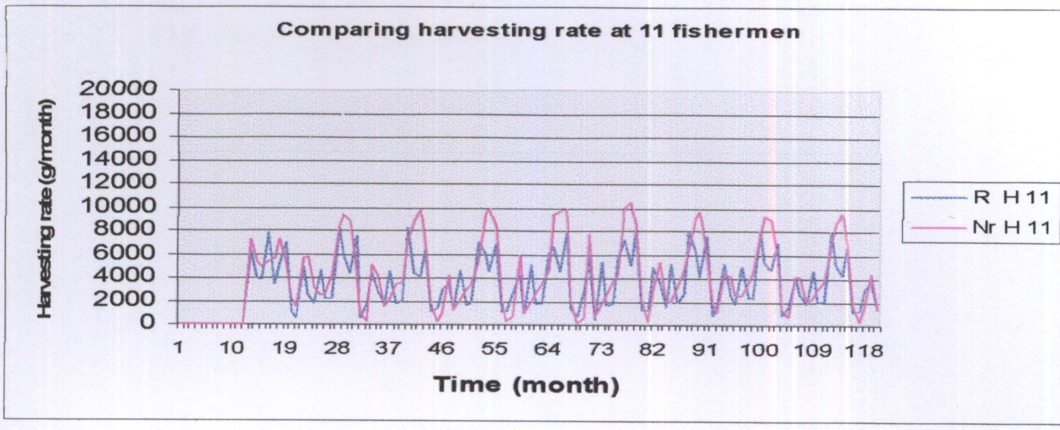
R H 7 = Harvesting rate of local fisherman in mobile at 7 fishermen

Nr H 7 = Harvesting rate of local fisherman in non-mobile at 7 fishermen



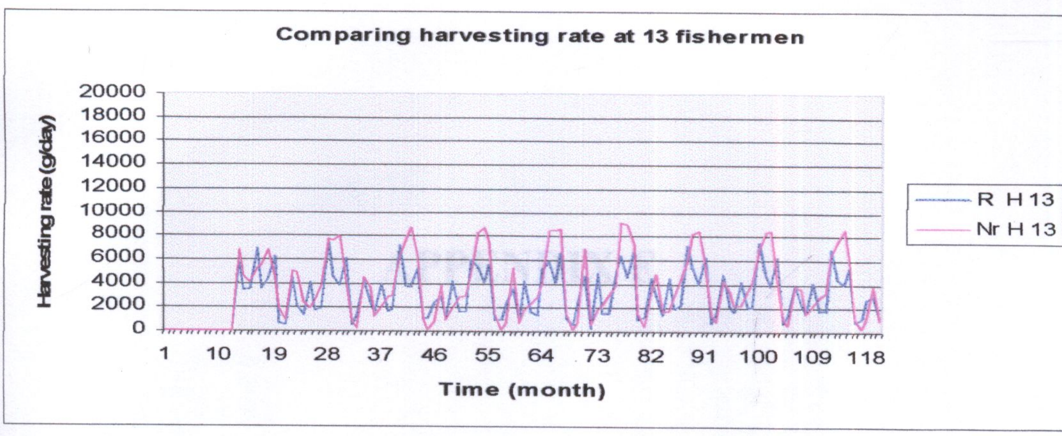
R H 9 = Harvesting rate of local fisherman in mobile at 9 fishermen

Nr H 9 = Harvesting rate of local fisherman in non-mobile at 9 fishermen



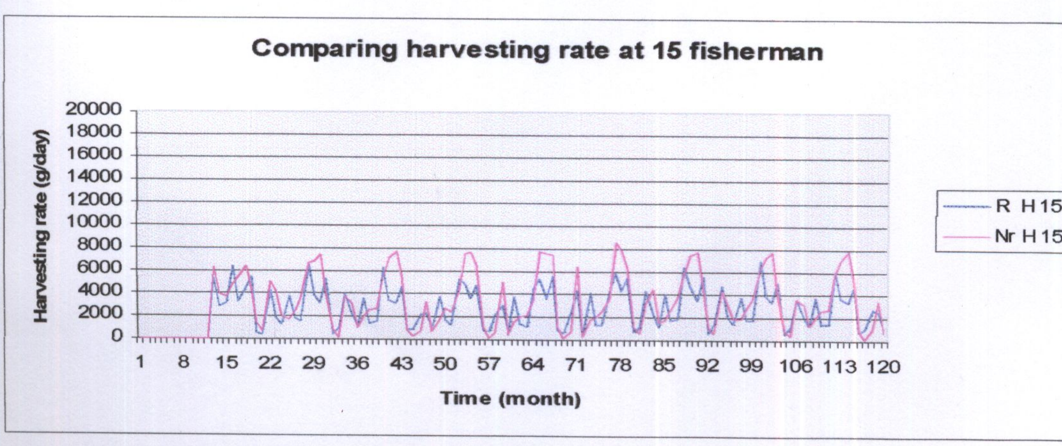
R H 11 = Harvesting rate of local fisherman in mobile at 11 fishermen

Nr H 11 = Harvesting rate of local fisherman in non-mobile at 11 fishermen



R H 13 = Harvesting rate of local fisherman in mobile at 13 fishermen

Nr H 13 = Harvesting rate of local fisherman in non-mobile at 13 fishermen



R H 15 = Harvesting rate of local fisherman in mobile at 15 fishermen

Nr H 15 = Harvesting rate of local fisherman in non-mobile at 15 fishermen

APPENDIX E

BIOGRAPHY

The author who is responded for this thesis is Mr. Kobchai Worrapimphong. He was born on April 28^{th}, 1980 at Singburi Province.

He graduated Bachelor of Science in Biology in 2001 from Chulalongkorn University, Bangkok, Thailand. Then he started his Master of Science in Zoology (Ecology) in 2002. He got scholarship from The Biodiversity Research and Training Program (BRT) for his thesis in 2003.