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Bivalve Mollusc Culture Research in Thailand

Edited by

E.W. McCoy
Tanittha Chongpeepien

Department of Fisheries, Thailand

International Center for Living Aquatic Resources Management

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

Bivalve Mollusc Culture Research in Thailand

Edited by

E.W. McCoy

and

Tanittha Chongpeepien

An account of research conducted under the project:

TECHNICAL ASSISTANCE FOR APPLIED RESEARCH ON COASTAL AQUACULTURE

A cooperative Project of the Department of Fisheries, Royal Kingdom of Thailand; the International Center for Living Aquatic Resources Management (ICLARM); and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

DEPARTMENT OF FISHERIES
BANGKOK, THAILAND

INTERNATIONAL CENTER FOR LIVING AQUATIC RESOURCES MANAGEMENT
MANILA, PHILIPPINES

DEUTSCHE GESELLSCHAFT FÜR TECHNISCHE ZUSAMMENARBEIT (GTZ) GmbH
ESCHBORN, FEDERAL REPUBLIC OF GERMANY

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1988

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Cover: Steaming green mussels, Petchaburi, Thailand.
Photo by Ronald Ventilla.

ICLARM Contribution No. 455.

Contents

Annexes

Forewords

Mr. Vanich Varikul
Director General
Department of Fisheries

Fishing and aquaculture production are very important to the economy of Thailand. As the natural resources are becoming depleted, the Department of Fisheries has initiated a program of replacement utilizing cultured species. Molluscs are a very important part of aquaculture planning. The research assistance provided by ICLARM has been particularly useful in focusing attention on the constraints to development in mollusc culture.

Dr. Plodprasop Suraswadi
Deputy Director General
Development Directorate
Department of Fisheries

The Department of Fisheries has research, development and extension responsibility. The Department attempts to develop and extend applied methods of culture, product handling and marketing to the private sector. The mollusc culture Project has integrated all of these aspects, with concentration on shellfish. The Department of Fisheries has incorporated the concept into a series of centers for combined effort on specific products.

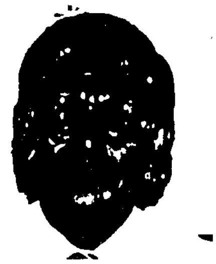
Ms. Bung-Orn Saisithi
Deputy Director General
Technology Directorate
Department of Fisheries

New product development and product quality are crucial in expanding demand for fisheries products. The Project has incorporated these aspects within the biological and economic framework. A series of new forms of mollusc products have been developed by the Department of Fisheries and particular attention is given to product preservation. Applied research, as illustrated by the Project, must give consideration to suitability for local conditions. The long-term nature of the research assistance has allowed this consideration.

Mr. Urubhan Boonprakop
Deputy Director General
Administrative/
Marine Directorate
Department of Fisheries

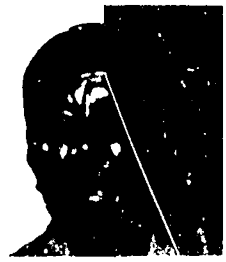
As the economy and population of Thailand expand, the task of the Department of Fisheries becomes more complex. Land and freshwater become increasingly valuable for multiple purpose use. The marine and coastal waters may become the most suitable locations for aquaculture expansion. As data from the mollusc culture Project indicate, the same conflicts can arise in the coastal zone if careful advance planning is not performed.

The Brackishwater Fisheries Division has responsibility for development of coastal aquatic resources. The Division has instituted a special section devoted to shellfish research and development. Project assistance has provided technical staff training and allowed Division staff to interrelate with senior scientists from ICLARM on a day-to-day basis. The staff thus have gained the capability to produce high-level applied research which will continue beyond the termination of the Project.

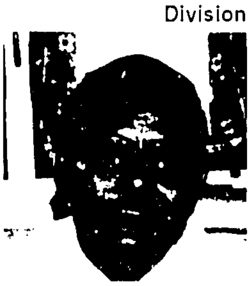


Mr. Pairoj Brohmanonda
Project Director
Brackishwater Fisheries Division

The operating units of the Department of Fisheries must respond to current problems and plan information collection to respond to problems that may arise in the future. The decision to expand mollusc culture in the coastal zone was made a matter of governmental policy. Implementation of the policy is the responsibility of the Brackishwater Fisheries Division. Appraisal of the feasibility of the various means of implementation is the responsibility of the Planning and Policy Division. The mollusc culture Project was conducted within both Divisions. The technical, biological and economic feasibility of each system was carefully appraised. The Co-Project Leaders interrelated with each other and with Project staff to assist the Project Director in assuring beneficial results to the people of Thailand.



Kosol Mutarasint
Chief
Coastal Investigation Section
Brackishwater Fisheries Division



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Fisheries Economics Section
Department of Fisheries

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Dr. Anant Saraya


Ms. Tanittha Chongpeepien


Dr. Yont Musig


Ms. Yajai Charoenvittayakul


Ms. Vanida Anaman


Mr. Yudh Hansopa


Ms. Sunan Tuaycharoen


Ms. Sabaithip Amornjaruchit


Ms. Kwanruethai Thanomkiat


Ms. Arunee Chindanond


Mr. Songchai Sahavacharin


Mr. Khom Silapajarn


Mr. Kachornsak Wetchagarun


Mr. Pongpat Boonchuwong


Ms. Panipa Hanvivatanakit


Ms. Pongpen Rattagool


Dr. Ruangrai Tokrisna


Mr. Somkit Tugsinavisuitti

Preface

Bivalve molluscs feed low in the food chain and are an attractive source of protein-rich products for human consumption. Most bivalve culture operations, however, depend upon collection of seed from the natural environment and many are adversely affected from time to time by pollution and environmental fluctuations. Therefore, bivalve culture is usually a form of extensive aquaculture in which little or no control is possible over broodstock management, hatchery/nursery procedures and feeding. Moreover, the public health aspects of bivalve consumption and the need to ensure adequate financial returns to bivalve culturists are important considerations.

Against a background of seemingly high potential for bivalve culture and the complex biological, economic and social issues that affect its development, ICLARM was asked to assist the Department of Fisheries of Thailand in efforts to develop coastal aquaculture, with a special focus on bivalve culture.

In Southeast Asia, Thailand has an unrivalled diversity of coastal aquaculture and fisheries practices that produce a vast range of marine products for human consumption. The objective of this technical assistance project was to explore new biological and socioeconomic perspectives on bivalve mollusc culture to increase production and to improve the livelihood of farmers. This required an interdisciplinary approach concerned as much with profit margins, product handling and the socioeconomic conditions of producers and others involved in the industry as with biological and ecological factors.

In many respects, the project results pose more questions than were answered. The feasibility of commercial hatchery production of tropical bivalves still remains unproven and the effects of deteriorating environmental quality still threaten coastal aquaculture development. However, the project worked extremely well as a partnership between the Government of Thailand, Thai institutions and ICLARM as a nongovernmental research organization. It produced a large amount of useful information and advances in research and training.

This technical report contains results of some of the studies performed and describes all the other outputs of the project. It is offered as an example of the progress that can be achieved through such interagency partnerships in aquaculture research and development. ICLARM was very pleased to have had the opportunity to cooperate on this project with the Thailand Department of Fisheries. This was all made possible by the generous support and constant advice and encouragement of the agency that funded the project, the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

I.R. Smith, Director General
R. S.V. Pullin, Director-Aquaculture Program

Introduction

The Project, **Technical Assistance for Applied Research on Coastal Aquaculture,** was initiated on 14 December 1980 with an agreement between the Departments of Fisheries (DOF) and Technical and Economic Cooperation, Government of Thailand, and the International Center for Living Aquatic Resources Management, Manila, Philippines.

The Project was based on a specific request from the DOF to ICLARM. Adequate research information was not available to DOF to implement programs to increase mollusc culture in Thailand. ICLARM was requested to provide research assistance to identify constraints to development and to suggest means to overcome the identified constraints.

The German Agency for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit) (GTZ) GmbH arranged funding to ICLARM to provide the requested research assistance to DOF.

Prior to initiation of the Project, ICLARM provided a site survey team to assist DOF in selection of a lead station for mollusc culture research. The team surveyed a series of sites selected by the DOF and recommended development of the Brackishwater Fisheries Station at Prachuap Khiri Khan as the lead station for biological activities of the Project.

The first Phase, at the request of DOF, concentrated on research in four areas. Each of these areas had been identified as a potential source of constraints in increasing mollusc culture in the coastal zone. The Project was to provide expertise in each of the problem areas.

- Postharvest handling
- Pollution in mollusc production areas
- Shellfish economics and marketing
- Shellfish culture and hatchery technology

DOF staff were assigned to conduct research and ICLARM and GTZ personnel assisted in an advisory capacity.

In addition, special arrangements were made with the Department of Agricultural Economics, Kasetsart University, to conduct economic studies. The National Inland Fisheries Institute (NIFI) personnel and facilities were involved in analysis of some samples collected for the postharvest handling research. The mollusc culture and hatchery technology subprojects were conducted by staff of the lead station at Prachuap Khiri Khan.

During the first phase of the Project (reported in various documents of the Phase I Project Report), some very useful information emerged, as follows:

- All mollusc culture areas were polluted with fecal bacteria. This constituted a health hazard for human consumption.

Acknowledgements

The editors and authors wish to acknowledge gratefully the assistance provided by Mr. Pairoj Lipikorn (retired), Director of the Brackishwater Fisheries Division, during the initial phases of the Project. Thanks are also due to Mr. Ariya Sidthimunka (retired), Deputy Director General, Department of Fisheries, during Phase I of the Project. Without their support and assistance the Project could not have attained the desired level of success. Dr. Anant Saraya, Head of the Environmental Studies Subsection of the Coastal Investigation Section, Brackishwater Fisheries Division, ably served as Co-Team Leader during Phase I.

Many individuals, both in the Thai Department of Fisheries and ICLARM, contributed to the research conducted under the auspices of the Project. Grateful thanks are also given to the junior staff, technicians and office personnel. Without their willing assistance the Project activities could not have been conducted.

Special mention should be given to the fisheries personnel of Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. Their interest in the Project transcended provision of funds for Project activities. Dr. F. Shodjai and Dr. M. Bilio personally conducted Project appraisals and made important suggestions for Project implementation; Mr. H. Nehez of the office of Bundesministerium für Wirtschaftliche Zusammenarbeit (BMZ) also visited the Project and was instrumental in arranging additional funding assistance.

The Project is indebted to Dr. Richard A. Neal, former Director General of ICLARM. The Project was initiated with Dr. Neal as Project Coordinator. Throughout the remainder of his tenure at ICLARM he retained very close ties with and a high interest in Project activities.

The editors and authors hope that this compilation of Project-related documents will serve as an illustration of a successful attempt at cooperative efforts in research. All research under this Project was conducted by Department of Fisheries staff. ICLARM staff and consultants served as technical advisors. ICLARM was uniquely suited to provide advisory services because of its status as an independent nongovernmental agency.

E. W. McCoy
Tannittha Chongpeepien

Aspects of Mussel Culture in Thailand

1. Growing green mussels on ropes, Phangnga.
2. Harvesting mussels grown on wooden poles, Chumphon
3. Steaming green mussels
4. Shucking mussels.
5. Mussels sun-drying on plastic cloth.
6. Bottled mussels on sale, Ang Sila

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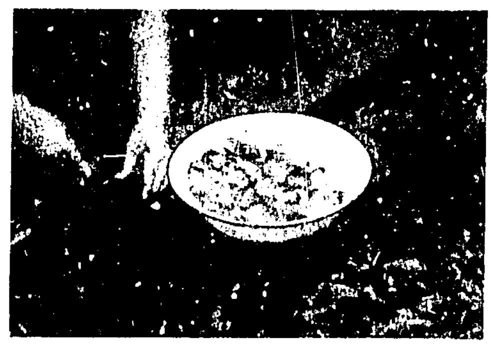

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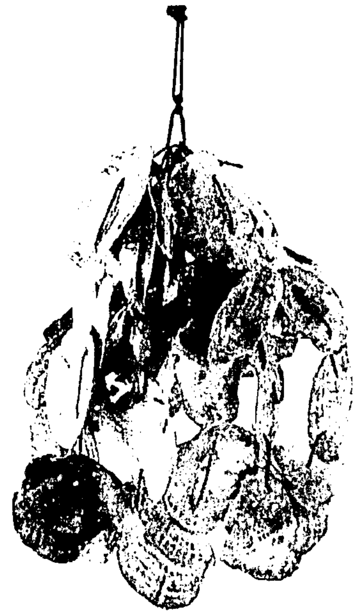
Aspects of Oyster Culture in Thailand

1. Spat collectors made from oyster shells.
2. Culture of oysters on rocks.
3. Cement pole collectors (foreground) with extensive rock culture behind.
4. Oyster culture, Surat Thani.
5. Oyster culture on cement poles, Trat
6. Large oysters in hanging culture, Phangnga
7. Cement pipes used for oyster culture.



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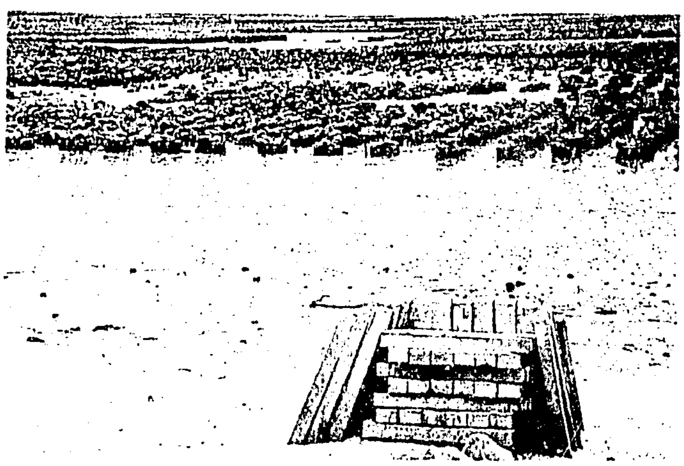

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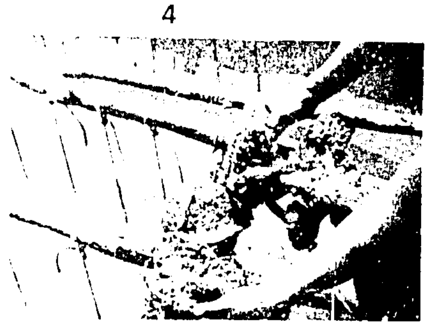

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Economically Important Molluscan Shellfish of Thailand*

SABAITHIP AMORNJARUCHIT
Coastal Resource Survey Section
Brackishwater Fisheries Division
Department of Fisheries
Bangkhen, Bangkok 10900
Thailand

AMORNJARUCHIT, S. 1988. Economically important molluscan shellfish of Thailand, p. 1-18. *In* E.W. McCoy and T. Chongpeepien (eds.) Bivalve mollusc culture research in Thailand. ICLARM Technical Reports 19, 170 p. Department of Fisheries, Bangkok, Thailand; International Center for Living Aquatic Resources Management, Manila, Philippines; and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn, Federal Republic of Germany.

Abstract

A survey of markets and interviews with villagers in the 22 coastal provinces of Thailand revealed 39 species of commercial molluscan shellfish and 13 additional locally-consumed species. The species are illustrated and local names are provided, with comments on distribution.

Introduction

Economically important shellfish, as listed in this report, are those species marketed for human consumption. The abundant numbers of species with shells used solely for ornamental purposes are excluded. Some species are utilized both as food and for ornamental purposes.

Survey Methods

There are 22 marine coastal provinces in Thailand. The total coastline length is 2,696 km (Fig. 1). For this report, the coastal provinces were subdivided into 6 areas:

Area 1 : Chon Buri, Rayong, Chanthaburi, and Trat. Coastline is 502 km long.
Area 2 : Chachoengsao, Samut Prakan, Bangkok, Samut Sakhon. Coastline is 102 km long.
Area 3 : Samut Songkhram, Phetchaburi, Prachuap Khiri Khan. Coastline is 337 km long.
Area 4 : Chumphon, Surat Thani, Nakhon Si Thammarat. Coastline is 603 km long.
Area 5 : Ranong, Phangnga, Krabi, Trang, Phuket. Coastline is 677 km long.
Area 6 : Songkhla, Satun, Pattani, Narathiwat. Coastline is 475 km long.

*Translated by Tanittha Chongpeepien and E.W. McCoy.

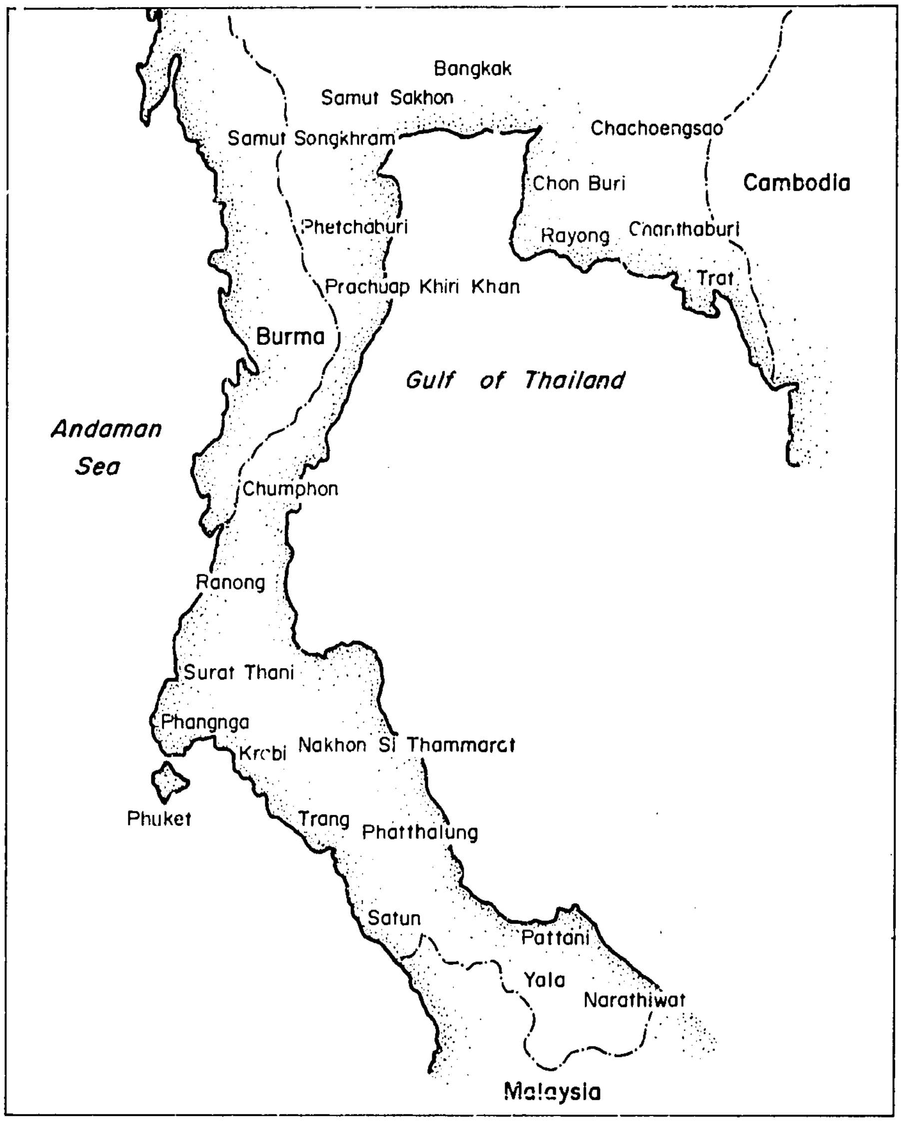

Fig. 1. Map of coastline of Thailand.

A market survey for shellfish was conducted in all of the coastal areas between July 1984 and November 1985. In Area 5, Phatthalung Province was also surveyed since this Province has a brackishwater coastline on Songkhla Lake.

Shellfish samples were collected from local markets. Vendors were interviewed regarding price and source of supply (location). Identifications were verified at the Brackishwater Fisheries Division.

Commercial and Locally Consumed Species

The survey revealed 39 species of shellfish sold in the markets of Thailand (Table 1). In addition, 14 species were identified from village interviews (Table 2). The 14 species were consumed at the village level and normally did not enter market channels. One nonmolluscan shellfish is included in view of its similarity *(Lingula).* Specimens collected in the survey were classified as follows:

Table 1. Scientific and common Thai names for species of shellfish purchased from markets, by location and market.

Scientific name	Thai name	Location 1				2				3			4			5						6				Total
		1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	4	5	6	1	2	3	4	
1 *Turbo argyrostomus*	Ta Wua		•																							1
2 *Nerita insculpta*	Nam Prik																•	•								2
3 *N. lineata*	Non, Tanon		•**																							1
4 *Cerithidea obtusa*	Jup Jaeng													•		•	•	•	•							4
5 *C. quadrata*	Jup Jaeng					•																				1
6 *Strombus canarium*	Chak Tin																	•								1
7 *S. decorus*	Chak Tin																			•**						1
8 *Babylonia areolata*	Waan			•								•														2
9 *Anadara antiquata*	Kraeng Biaw		•																							1
10 *A. granosa*	Kraeng	•	•	•	•				•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	20
11 *A. nodifera*	Kraeng Kluy	•			•													•		•						4
12 *A. trocheli*	Kraeng Mun															•										1
13 *Scapharca inaequivalvis*	Krang		•		•						•	•	•	•	•									•		8
14 *S. subcrenata*	Kraeng Ling Krasun Met Khanun	•		•									•*			•										3
15 *Perna viridis*	Malaeng Phu	•	•	•	•				•		•	•	•	•	•	•	•	•			•	•			•	16
16 *Modiolus metcalfei*	Kapong Kapang																	•		•						2
17 *Arcuatula arcualata*	Kapong		•	•										•	•											4
18 *Isognomon ephippium*	Waen										•															1
19 *Crassostrea* sp.	Ta Krom													•												1
20 *Saccostrea cucullata*	Nang Rom Lek Pak Jip	•	•	•	•						•						•								•	7
21 *Elongaria* sp.	Kraeng Fung													•												1
22 *Corbicula* sp.	Tal																							•	•	2
23 *Arctica* sp.	Gun																	•								1
24 *Gafrarium divaricatum*	Laay, Khao		•																							2
25 *Meretrix lusoria*	Waan, Talap													•			•	•								3
26 *M. meretrix*	Waan, Talap													•			•	•								3
27 *M. lamarckii*	Waan, Talap													•			•	•								3
28 *M.* sp.	Waan, Talap Paa													•			•	•	•	•			•			6
29 *Dosinia biscocta*	Khao, Waan																•									1
30 *Callista* sp.	Laay																							•		1
31 *Paphia* sp.	Khao				•																					1
32 *Paphia undulata*	Laay	•	•	•	•				•		•	•		•	•	•	•				•					12
33 *Katelysia hiantina*	Khao																							•		1
34 *Mercenaria* sp.	Yam													•						•						2
35 *Mactra* sp.	Pit												•													1
36 *Solen strictus*	Lot										•	•														2
37 *Donax faba*	Siap			•										•	•								•			4
38 *Gari* sp.	Kathi, Ni Thi Yoa, Kap		•								•			•*											•	3
39 *Lingula anatina*	Raak, Pak Pet												•	•		•		•	•							5

*Not found in market, information from interview.
**Purchased in market by BWFD personnel and brought to research taxonomist for identification.

Locations:

1. East Coast
   - 1.1: Chanthaburi
   - 1.2: Chon Buri
   - 1.3: Rayong
   - 1.4: Trat
2. Upper Inner Gulf
   - 2.1: Bangkok
   - 2.2: Chachoengsao
   - 2.3: Samut Prakan
   - 2.4: Samut Sakhon
3. Upper Western Gulf
   - 3.1: Samut Songkhram
   - 3.2: Phetchaburi
   - 3.3: Prachuap Khiri Khan
4. Middle Western Gulf
   - 4.1: Chumphon
   - 4.3: Nakhon Si Thammarat
5. Andaman Sea Coast except Satun
   - 5.1: Ranong
   - 5.3: Krabi
   - 5.4: Phuket
   - 5.5: Trang
   - 5.6: Phatthalung
6. Lower Southern Gulf and Satun
   - 6.1. Songkhla
   - 6.3: Pattani
   - 6.4: Narathiwat

Table 2. Scientific and common Thai names for species of shellfish identified from village interviews and collection, by location and market.

	Scientific name	Thai name	1				2				3			4			5						6				Total
			1	2	3	4	1	2	3	4	1	2	3	1	2	3	1	2	3	4	5	6	1	2	3	4	
1	*Tectus niloticus*	Nomsao												•													
2	*Neohaustator* sp	Muan Pu												•													
3	*Melo melo*	Taan, Kong																		•							
4	*Modiolus* sp.	Kapong													•												
5	*Pinctada chemnitz*	Muk																	•								
6	*Pinna bicolor*	Kap, Jop												•													
7	*Atrina pectinata*	Kap, Jop			•									•													
8	*A. vexillum*	Kap, Jop												•													
9	*Amusium pleuronectes*	Shell			•																						
10	*Ensidens ingallsianus*	Met Khanun																		•							
11	*Tridacna squamosa*	Muu Sua												•													
12	*Cultellus attenuatus*	Siap												•													
13	*Donax scortum*	Pow, Taay Tapow																			•						
14	*Pholas orientalis*	Pim											•*														

*Not found in market, information from interview.

Locations:

1. East Coast
   - 1.1: Chanthaburi
   - 1.2: Chon Buri
   - 1.3: Rayong
   - 1.4: Trat
2. Upper Inner Gulf
   - 2.1: Bangkok
   - 2.2: Chachoengsao
   - 2.3: Samut Prakan
   - 2.4: Samut Sakhon
3. Upper Western Gulf
   - 3.1: Samut Songkhram
   - 3.2: Phetchaburi
   - 3.3: Prachuap Khiri Khan
4. Middle Western Gulf
   - 4.1: Chumphon
   - 4.2: Surat Thani
   - 4.3: Nakhon Si Thammarat
5. Andaman Sea Coast except Satun
   - 5.1: Ranong
   - 5.2: Phangnga
   - 5.3: Krabi
   - 5.4: Phuket
   - 5.5. Trang
   - 5.6: Phatthalung
6. Lower Southern Gulf and Satun
   - 6.1: Songkhla
   - 6.2: Satun
   - 6.3: Pattani
   - 6.4: Narathiwat

Phylum Mollusca

(i) Class Gastropoda

Family Trochidae

Tectus niloticus Linnaeus, 1767
Nom Sao (Fig. 2)

Family Turbinidae

Turbo argyrostomus Linnaeus, 1758
Ta Wua (Fig. 3)

Family Neritidae

Nerita insculpta, Recluz, 1841
Nam Prik (Fig. 4)

Nerita lineata Gmelin, 1791
Non, Tanon (Fig. 5)

Family Turritellidae

Neohaustator sp.
Muan Plu (Fig. 6)

Family Potamididae

Cerithidea obtusa (Lamarck, 1822)
Jup Jaeng (Fig. 7)

Cerithidea quadrata Sowerby, 1866
Jup Jaeng (Fig. 8)

Family Strombidae

Strombus canarium Linnaeus, 1758
Chak Tin (Fig. 9)

Strombus decorus Roding, 1798
Chak Tin (Fig. 10)

Family Buccinidae

Babylonia areolata Link, 1807
Waan (Fig. 11)

Family Volutidae

Melo melo Lightfoot, 1786
Taan, Kong (Fig. 12)

(ii) Class Pelecypoda

Family Arcidae

Anadara antiquata (Linnaeus, 1758)
Kraeng Biaw (Fig. 13)

A. granosa Linnaeus, 1758
Kraeng (Fig. 14)

A. nodifera (Von Martens)
Kraeng Kluy (Fig. 15)

A. trocheli (Dunker, 1882)
Kraeng Mun (Fig. 16)

Scapharca inaequivalvis (Bruguiere, 1789)
Krang (Fig. 17)

S. subcrenata (Lischke, 1869)
Kraeng Ling, Krasun, Met Khanun
(Fig. 18)

Family Mytilidae

Perna viridis (Linnaeus, 1758)
Malaeng Piu (Fig. 19)

Modiolus metculfei (Hanley, 1843)
Kapong, Kapang (Fig. 20)

Arcuatula arcualata (Hanley, 1843)
Kapong (Fig. 21)

Family Isognomonidae

Isognomon ephippium (Linnaeus, 1758)
Waen (Fig. 22)

Family Pteriidae

Pinctada chemnitz (Philippi, 1849)
Muk (Fig. 23)

Family Pinnidae

Pinna bicolor Gmelin, 1791
Kap, Jop (Figs. 24 25)

Atrina pectinata (Linnaeus, 1767)
Kap, Jop (Fig. 26)

A. vexillum (Born, 1778)
Kap, Jop (Fig. 27)

Family Pectinidae

Amusium pleuronectes (Linnaeus, 1758)
Shell (Fig. 28)

Family Ostreidae

Crassostrea sp.
Takrom (Figs. 29, 30)

Saccostrea cucullata (Born, 1778)
Nang Rom Let, Pak Jip (Fig. 31)

Family Unionidae

Elongaria sp.
Kreng Fung (Fig. 32)

Ensidens ingallsianus (Lea, 1852)
Met Khanun (Fig. 33)

Family Corbiculidae

Corbicula sp.
Tal

Family Arcticidae

Arctica sp.
Gun (Fig. 34)

Family Tridacnidae

Tridacna squamosa Lamarck, 1819
Muu Sua (Figs. 35, 36)

Family Veneridae

Gafrarium divaricatum (Gmelin, 1791)
Laay, Khao (Fig. 37)

Meretrix lusoria (Roding, 1798)
Waan, Talap (Fig. 38)

M. meretrix (Linnaeus, 1758)
Waan, Talap (Fig. 39)

M. lamarckii Sowerby, 1874
Waan, Talap (Fig. 40)

Meretrix sp.
Waan, Talap, Paa (Fig. 41)

Dosinia biscocta (Reeve)
Khao, Waan (Fig. 42)

Callista sp.
Laay (Fig. 43)

Paphia sp.
Khao (Fig. 44)

P. undulata (Born, 1778)
Laay (Fig. 45)

Katelysia hiantina (Lamarck)
Khao

Mercenaria sp.
Yam (Fig. 46)

Family Mactridae

Mactra sp.
Pit (Fig. 47)

Family Solenidae

Solen strictus Gould, 1861
Lot (Fig. 48)

Family Cultellidae

Cultellus attenuatus Dunker, 1861
Siap (Fig. 49)

Family Donacidae

Donax faba Gmelin, 1791
Siap (Fig. 50)

Donax scortum Linnaeus, 1758
Pow, Taay Tapow

Family Psammobiidae

Gari sp.
Kathi, Ni, Thi, Yoa, Ikap (Fig. 51)

Family Pholadidae

Pholas orientalis Gmelin, 1790
Pim (Fig. 52)

Phylum Brachiopoda
Order Inarticulata
Family Lingulidae

Lingula anatina Lamarck
Raak, Pak pet (Fig. 53)

Occurrence and Habitat

Kraeng *(Anadara granosa)* was found in 20 provinces. The shellfish is cultured and/or captured in many provinces. Culture areas exist in Samut Songkhram, Phetchaburi, Surat Thani, Nakhon Si Thammarat, Phangnga, Trang and Satun.

Malaeng Phu *(Perna viridis)* was found in 16 provinces. This species also is widely cultured. Most of the samples collected originated from culture areas in Chon Buri, Chachoengsao, Phetchaburi, Prachuap Khiri Khan, Chumphon and Phangnga.

Laay *(Paphia undulata)* was found in all areas except 6. All Laay came from capture. The capture areas were not fixed from year to year but usually were located at Samut Songkhram and Surat Thani. Laay capture areas existed in Area 6 but none were found in the market.

Krang *(Scapharca inaequivalvis)* was frequently found and normally was mixed with Kraeng in sacks sold to retailers in the markets in the south (Areas 2 and 3). Most was marketed in shucked form when sold separately from Kraeng.

In addition, Nang Rom Lek *(Saccostrea cucullata)* was abundant in Area 1 because of an extensive culture area in Chon Buri.

Jup Jaeng *(Cerithidea obtusa)* and Talap (*Meretrix* spp.) were found in Areas 4 and 5.

Other shellfish were found in some provinces only. For example, Chak Tin *(Strombus canarium)* was only found in Phangnga Province. Full details are given in Tables 1 and 2.

Distribution of shellfish in each area

Area 1, Chon Buri Province, included the biggest shellfish market in the eastern part of Thailand. Some shellfish species not found in other markets were available in Chon Buri Market; Non, Ta Wua, Kraeng Biaw and Kho *(Gafrarium divaricatum)*. The last three species were available in very limited quantities. Villagers collected them from the coastal area and sold them in the Satahip market. Ni, in this Province, is the same species as Kathi in Prachuap Khiri Khan Province and Kap in Surat Thani. Khao (*Paphia* sp.) was found only in Trat Province.

In Area 2, there were 3 important species of shellfish in Samut Sakhon; Kraeng, Malaeng Phu and Laay.

Area 3, Prachuap Khiri Khan Province, had many species of shellfish in the markets. In addition to the major species, the markets had Waen in shucked form, not seen in any other market during the study.

Area 4, Surat Thani Province, was the major shellfish market for the southern part of the middle Gulf of Thailand. Many species, both in shell and processed, were available in the markets. Jup Jaeng, Pak Pet *(Lingula anatina)*, Waan (*Meretrix* sp.), Yam (*Mercenaria* sp.), Kap (*Gari* sp.), Kraeng Fung (*Elongaria* sp.) were among the minor species found.

In Area 5, Phuket had the largest market. Phangnga and Krabi had many species different from other Provinces, for example, Kapong *(Modiolus metculfei)*, Chak Tin *(Strombus canarium, S. decorus)*.

Area 6, Pattani Province, had two species of shellfish different from other provinces; Laay (*Callista* sp.) and Khao *(Katelysia hiantina)*.

Common Names

The study indicated much confusion regarding local names for species. The same species often had different local names or the same local name might refer to different species. Identification of species by scientific name is important in determining the feasibility of culture of the species. Below are lists of species with common local names and of local names that refer to more than one species of shellfish.

A. Shellfish with common local names

Local Name	Scientific Names	Province
Nam Prik (น้ำพริก)	*Nerita insculpta*	Phuket, Phangnga
	N. lineata	Chon Buri
Jup Jaeng (จุ๊บแจง)	*Cerithidea obtusa*	Surat Thani, Rangon, Phuket, Phangnga, Krabi
	C. quadrata	Trat
Chak Tin (ชักตีน)	*Strombus canarium*	Phangnga
	S. decorus	Krabi
Waan (หวาน)	*Babylona areolata*	Rayong
	Meretrix lusoria	Prachuap Khiri Khan Surat Thani, Phuket, Phangnga
	M. meretrix	Surat Thani, Phuket, Phangnga
	M. lamarckii	Surat Thani, Phuket, Phangnga

	Meretrix sp.	Surat Thani, Phuket, Phangnga, Krabi, Trang
	Dosinia biscota	Phuket
Kapong (กะพง)	*Modiolus metculfei*	Phangnga, Trang
	Arcuatula arcualata	Chon Buri, Rayong, Surat Thani, Nakhon Si Thammarat
Khao (ขาว)	*Gafrarium divaricatum*	Chon Buri
	Dosinia biscocta	Phuket
	Paphia sp.	Trat
	Katelysia hiantina	Pattani
Laay (ลาย)	*Gafrarium divaricatum*	Pattani
	Calista sp.	Pattani
	Paphia undulata	Chanthaburi Chon Buri Rayong Trat Samut Sakhon Samut Songkhram Prachuap Khiri Khan Surat Thani Nakhon Si Thammarat Ranong, Phuket
Met Khanun (เม็ดขนุน)	*Scapharca subcrenata*	Chumphon, Ranong
	Ensidens ingallsianus	Krabi
Siap (เสียบ)	*Donax faba*	Rayong Surat Thani Nakhon Si Thammarat Songkhla
	Cultellus attenuatus	Chumphon
Kap (กาบ)	*Gari* sp.	Surat Thani
	Pinna bicolor	Chumphon
	Atrina pectinata	Chumphon
	A. vexillum	Chumphon

B. Species with varying local names

Scientific Name	Local name	Province
Scapharca subcrenata	*Krasun* (กระสุน)	Chanthaburi
		Rayong
	Met Khanun (เม็ดขนุน)	Chumphon
		Ranong
	Kreang Ling (แกรงลิง)	Ranong
Gari sp.	*Ni* (นิ)	Chon Buri
	Kathi (กะทิ)	Prachuap Khiri Khan
	Kap (กาบ)	Surat Thani

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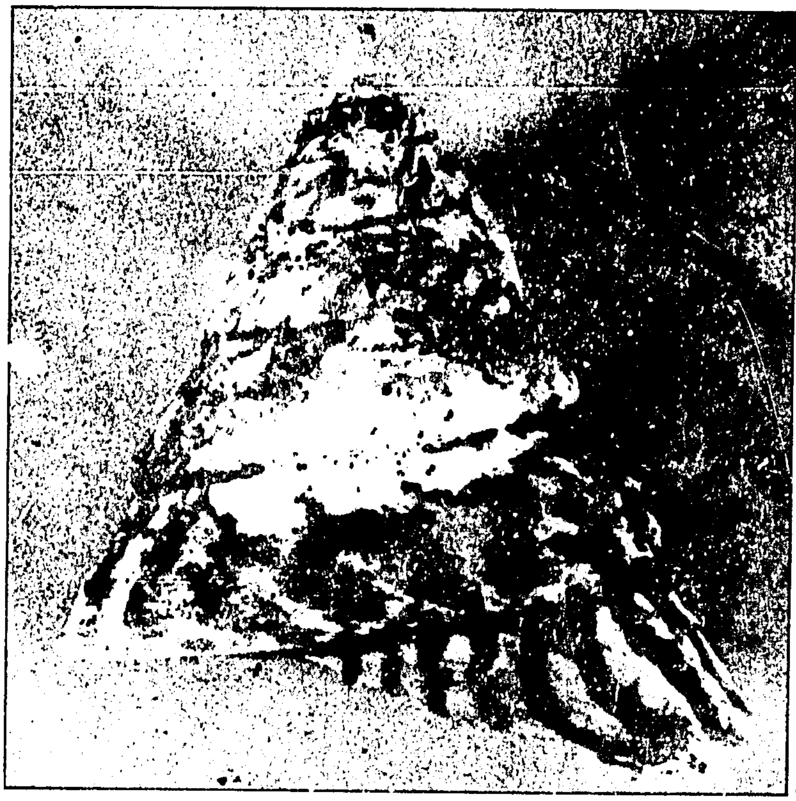

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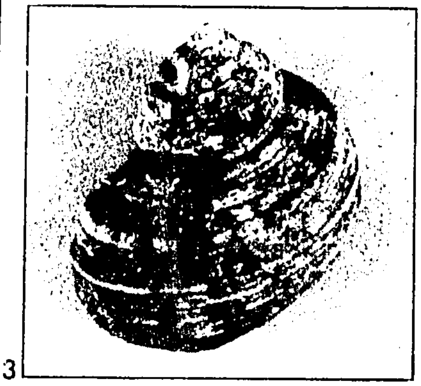

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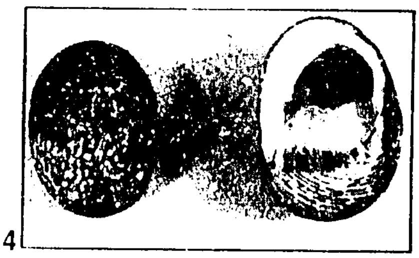

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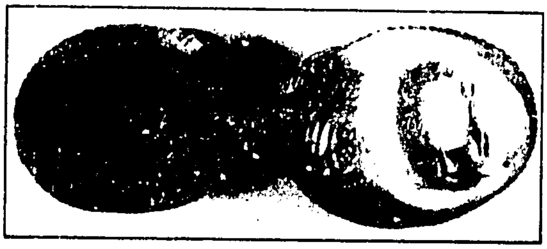

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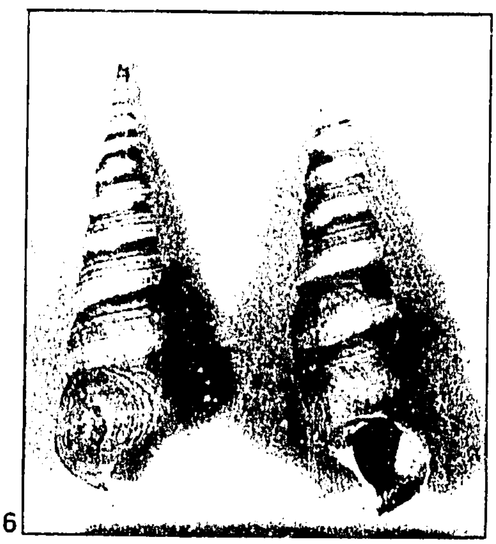

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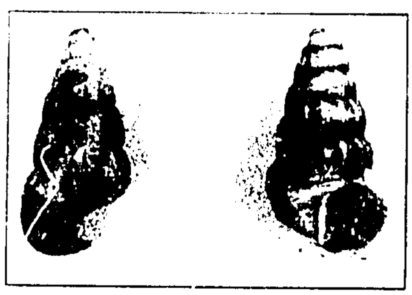

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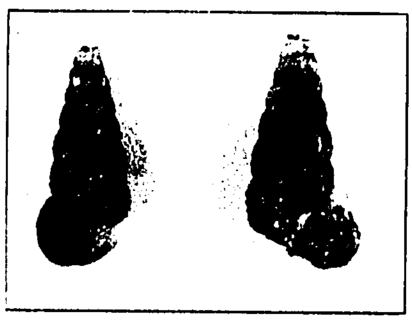

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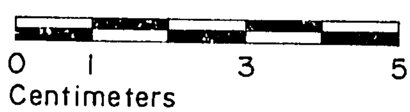

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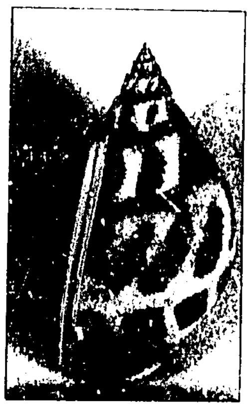

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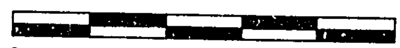

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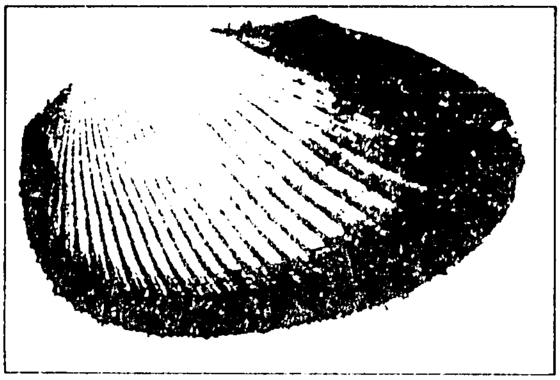

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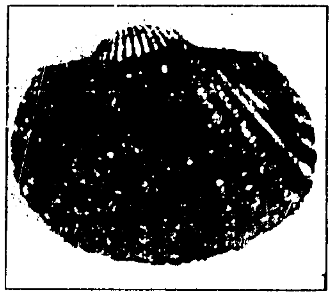

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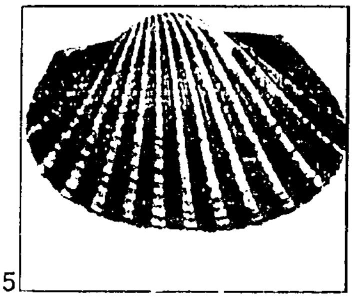

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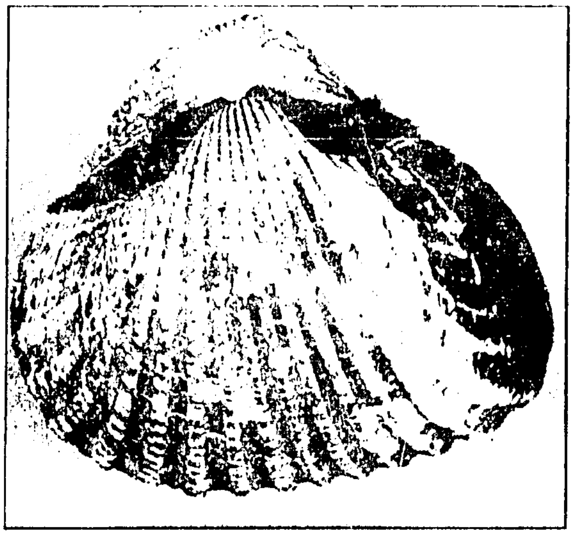

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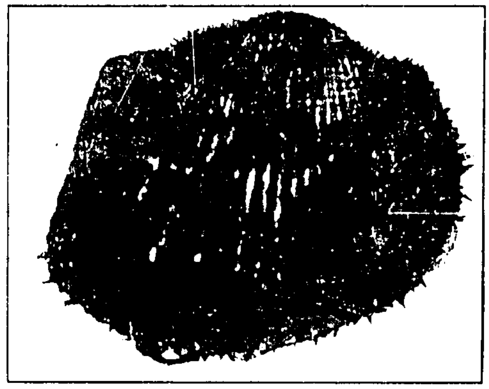

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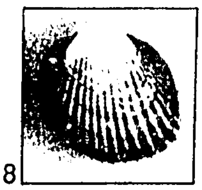

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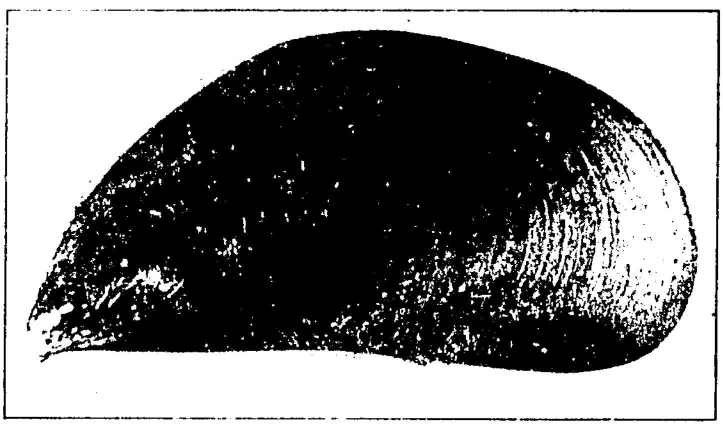

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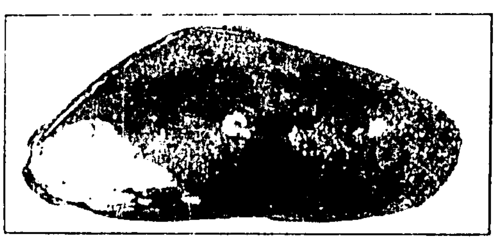

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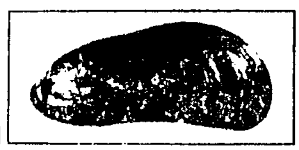

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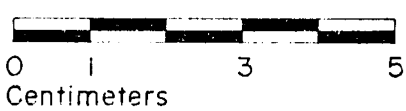

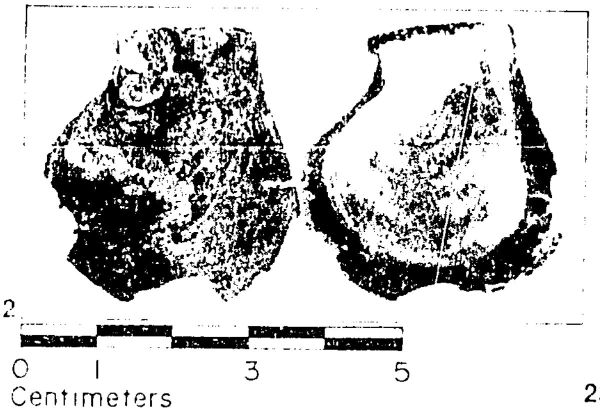

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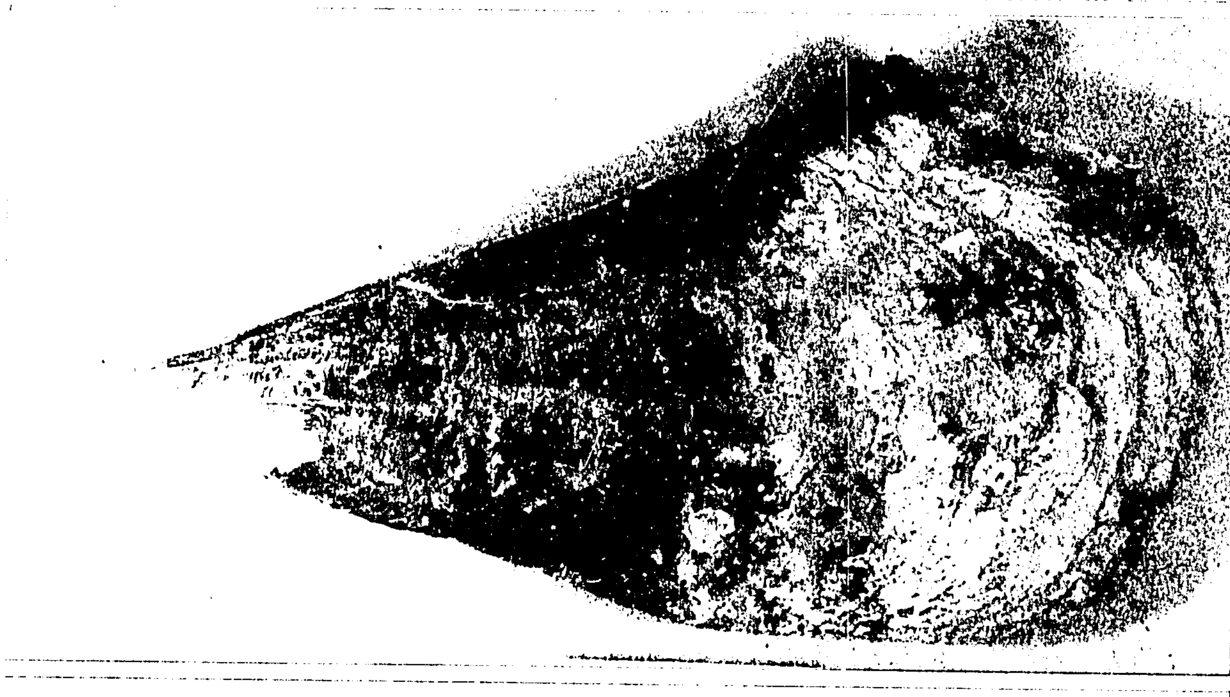

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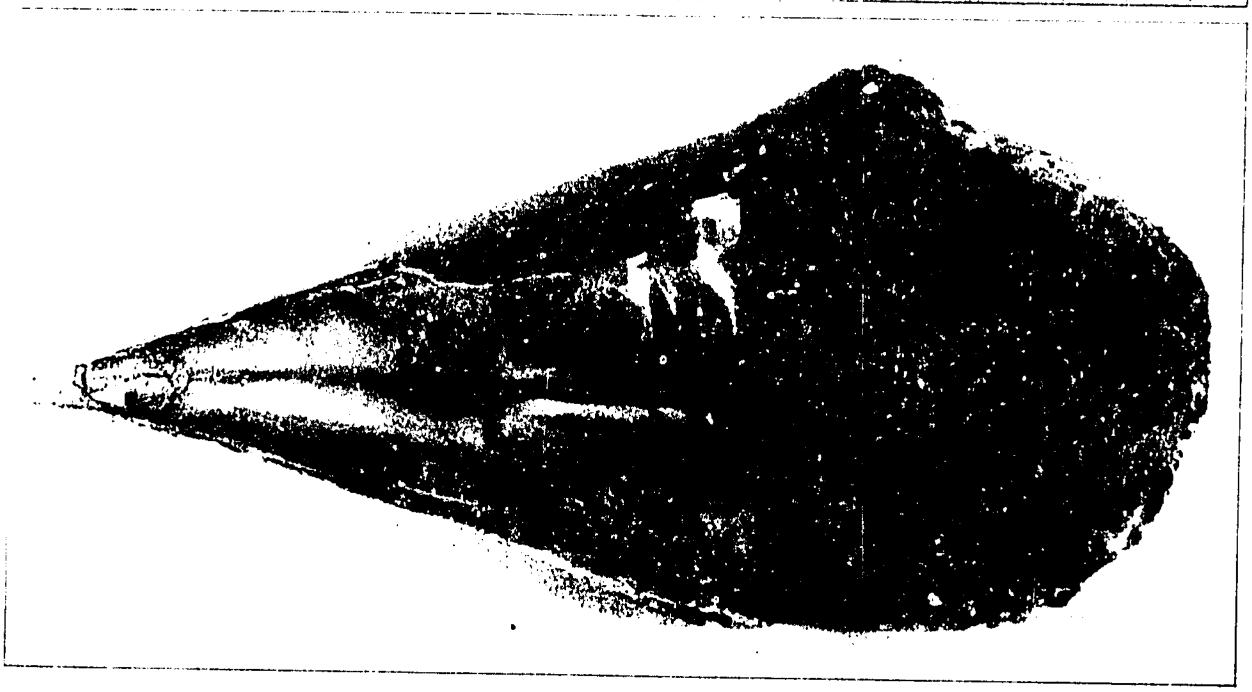

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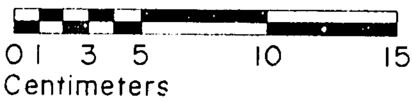

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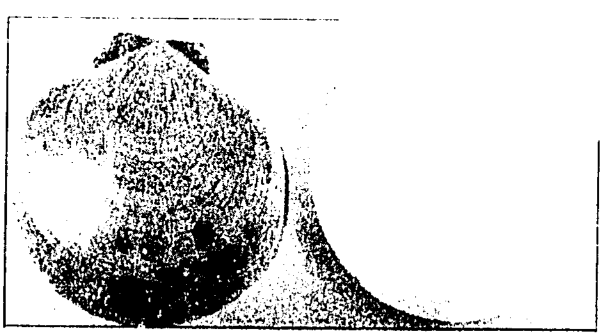

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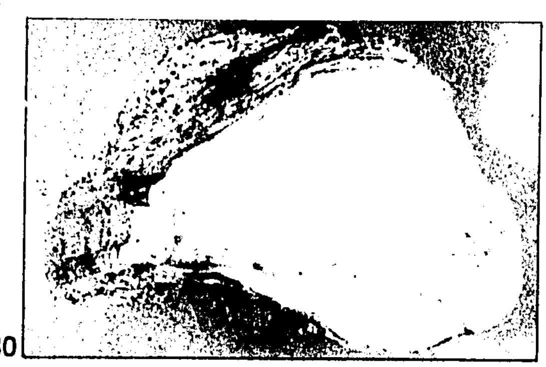

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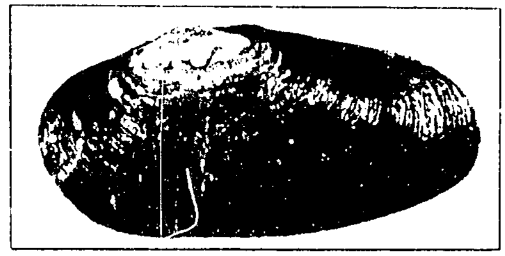
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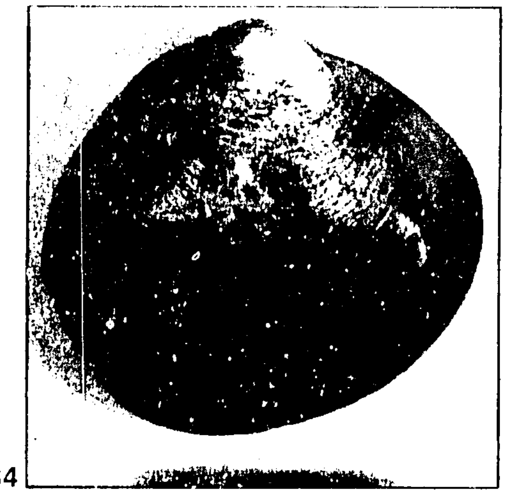
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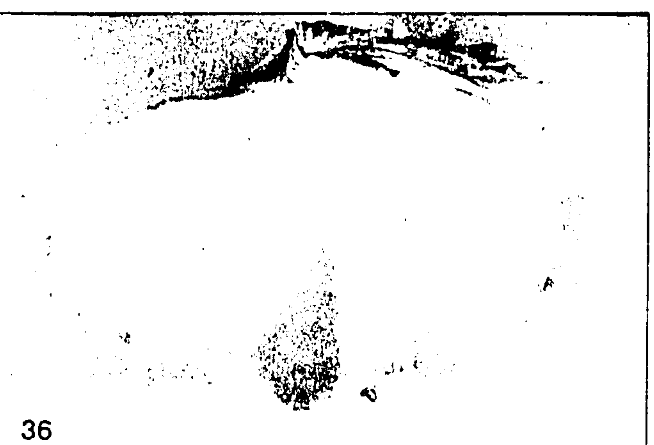
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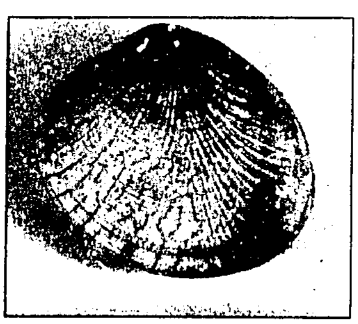
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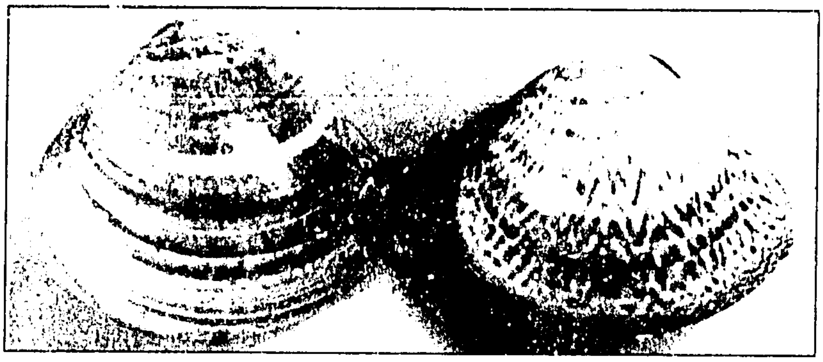
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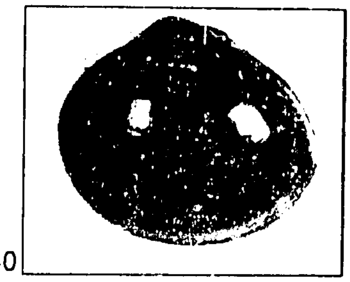
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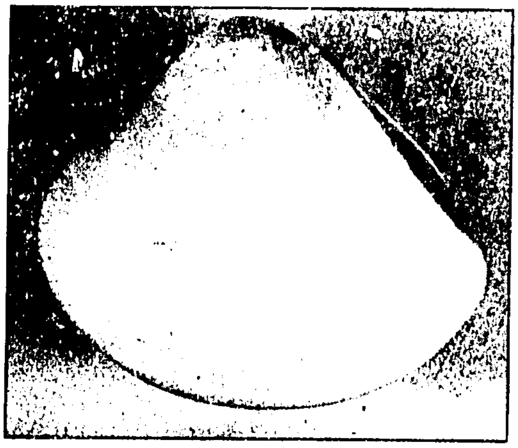
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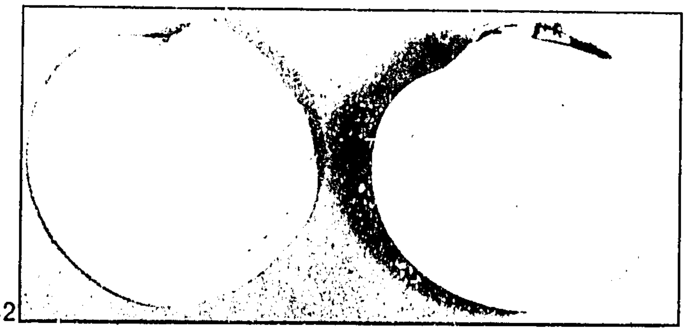
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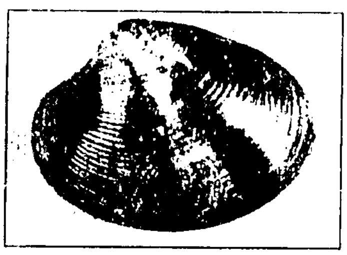
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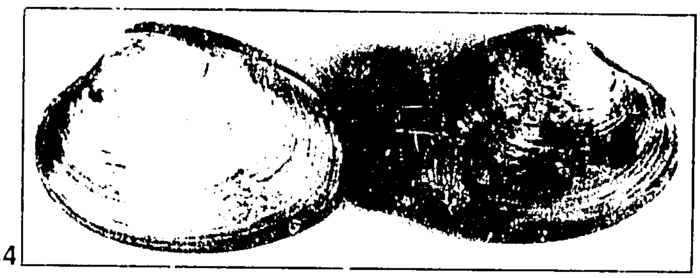
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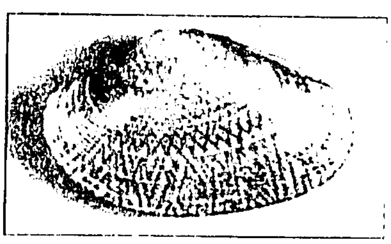
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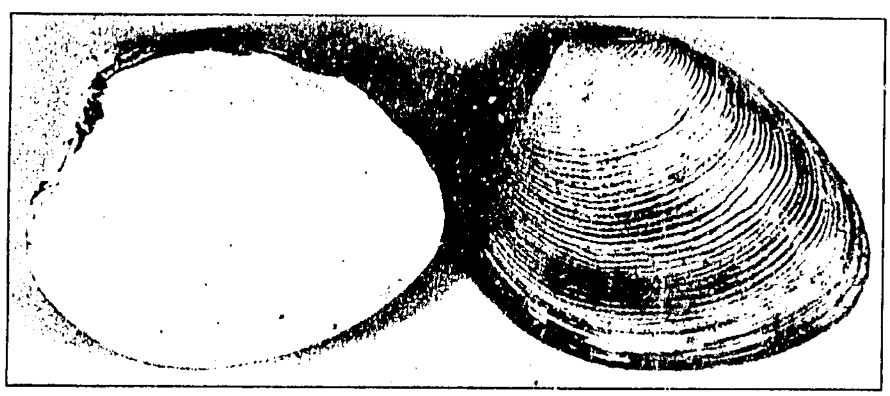
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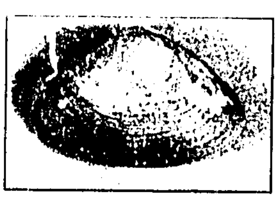
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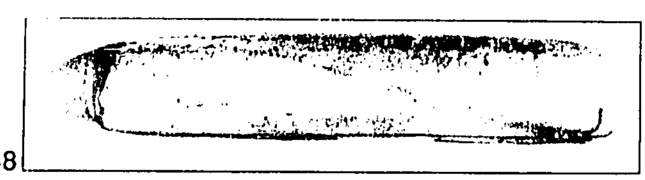
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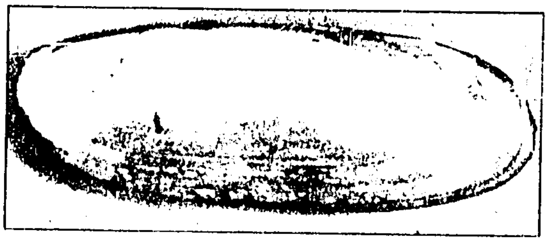
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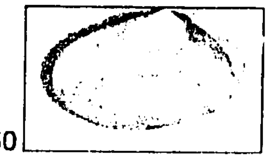
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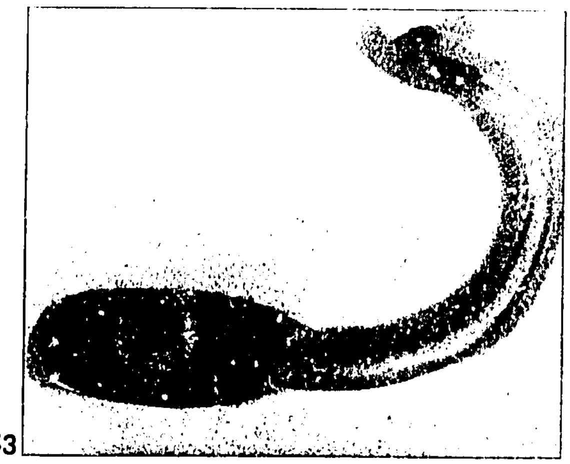
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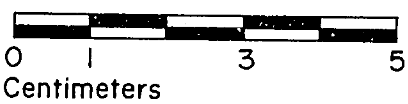

Hatchery Techniques for Tropical Bivalve Molluscs*

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Abstract

Thirteen species of bivalve molluscs were induced to spawn at the Prachuap Khiri Khan Brackishwater Fisheries Station, Thailand. The facilities and techniques used are described including water supply; four induced spawning methods (hydrogen peroxide; ammonium hydroxide; thermal shock and flowing water/drying treatments); larval rearing and spat collection and handling. Detailed accounts are given for cockles (*Anadara* spp.), large oysters (*Crassostrea belcheri* and *Saccostrea lugubris*) and fan shell *(Pinna bicolor)*. Despite water quality limitations and variable results, the techniques described are a useful step towards assessing the feasibility of rearing tropical bivalves in hatcheries. At present, hatchery production of large oyster spat appears the best possibility.

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Introduction

Overfishing of stocks of fish and shellfish has created a shortage of fisheries products for the domestic market in Thailand. The problem is particularly acute for fish. The establishment of Exclusive Economic Zones (the 200-mile limit) restricted the range and activity of the Thai commercial fishing fleet.

The Department of Fisheries established a policy of increasing production of marine animals through aquaculture to attempt to alleviate the decline from capture fisheries. One of the priority types of marine animals for expanded culture activities was shellfish.

Thailand has many species of shellfish suitable for culture. Current culture activities have been restricted to green mussel *(Perna viridis)*, cockle *(Anadara granosa* and *A. nodifera)*, horse mussel *(Arcuatula arcualata)*, and three species of oyster, small oyster *(Saccostrea commercialis)*, and large oysters *(Saccostrea lugubris* and *Crassostrea belcheri)*.

Culture activities have been constrained for cockles and large oysters by lack of natural seed supplies. Seed supplies from nature have been reduced due to pollution and detrimental fishing activities in natural production areas. The fishing activities include harvest of immature species, thus reducing the potential spawning population.

The Project had a primary goal of increasing seed production for mollusc culture activities. Seed production increases were planned from establishment of natural seed beds, from production of hatchery seed by induced spawning activities and from increasing seed survival in transport. The Department of Fisheries, with assistance from a survey team provided by the Project, selected the lead station for mollusc culture activities at the Prachuap Khiri Khan Brackishwater Fisheries Station.

Prior research on mollusc spawning has been conducted at several locations in Thailand but with limited success. The efforts were not concentrated on a single species nor was there continuity in the research.

During the hatchery project, induced spawning of many species was attempted. With completion of the Prachuap Khiri Khan hatchery in late 1985, pilot-scale experiments were conducted on promising species. This paper describes the facilities and methods used at the hatchery.

Facilities and Methods

Water supply

Water was temporarily stored in a 1,000-l tank and pumped to the larval rearing tanks via two cartridge filters and a UV lamp. The cartridge filters (20 and 5 µm pore sizes) replaced a gravity sand filter which could not be used with a pressure system. The installation of the pump and pressure system enabled a bioassay to be done using seawater as a control and lagoon water as the experimental treatment. The water was transported to the station by truck; the pump provided easy transfer of stored ocean water into the hatchery. The sterile water is used for algae culture in large carboys.

Addition of 1 and 0.25 µm filters to the system is planned to test the feasibility of cold sterilization of large (20 l) carboys used for algae culture. If feasible, this will considerably reduce the cost of algae culture, as heating with propane gas will no longer

determining the suitability of broodstock for induced spawning. Different species have different spawning seasons. The spawning season for an individual species may also vary depending on location. Wherever possible, large specimens (e.g., hard clams, 5-7 cm) should be selected to increase the probability of mature gonads and high fecundity. Sizes and ages preferred for cockle and oyster broodstock are given below. Gonad development is determined by killing several specimens, dissecting the gonads and viewing a smear under the microscope. When the gonads are ripe, the eggs are round and fully formed. When the gonads are unripe, the eggs are elongated and no nucleus is visible.

Spawning seasons for various species in Thailand as determined in the course of the Project are:

Large oysters *(C. belcheri, S. lugubris);* Surat Thani	February-April September-October
Small oyster *(S. commercialis)*	April-May October-November
Cockle *(Anadara granosa)* Malaysia (Broom 1985)	September-November May-June
Cockle *(A. nodifera)* Phetchaburi	March-August October-December
Hard clam *(Meretrix meretrix)* Trat	June-August November-February
Green mussel *(Perna viridis)* Trat	June-August November-February
Green mussel *(P. viridis)*	July-September November-February

Studies of gonad development in natural populations and cultured stocks of shellfish during the Project indicated that some species spawn every month. The proportions in the ripe stage vary and the probability of finding a set of successful candidates for induced spawning is increased if selection is made at the peak of the spawning season.

Green mussels and small oysters were spawned at the Prachuap Khiri Khan station in February 1984. Large oysters were spawned in March 1985 and subsequently on numerous occasions.

Before induced spawning, the outer surface of the shell should be thoroughly cleaned with freshwater before placing the shellfish in a flowing water tank. They will then eject materials from the shell cavity and gut. Removal of these materials will reduce the probability of bacterial contamination in the spawning vessels.

In this project, four methods of induced spawning were tried: hydrogen peroxide, ammonium hydroxide, temperature shock and flowing water.

Hydrogen peroxide

The pH of sea water was raised to 9.1 by addition of 10% sodium hydroxide. Reagent grade hydrogen peroxide was added to form a 150 ppm solution. The shellfish were placed in the solution for 8 hours. After that they were placed in a shallow raceway with clean flowing seawater. After 1 to 4 hours those with ripe gonads spawned. This method was successful with green mussel, cockles and fan shell.

Ammonium hydroxide

One cm^3 of 0.1 N ammonium hydroxide was injected into the body cavity of the shellfish. The shellfish was then replaced in the tank. After 30 minutes a shellfish with ripe gonads spawned. This method was successfully used for hard clam.

Temperature shock

The temperature of the seawater in the tank used for temperature shock treatment was increased from ambient to 34-35°C. After checking the temperature the shellfish were transferred abruptly to this high temperature, held for up to 3 hours and then decreased gradually to ambient temperature or below (e.g., 20°C) for 1-2 hours. A simple heating coil can be used for raising the temperature and ice in plastic bags used for cooling to ambient or below. However, it is better to use flowing water for the heat treatment supplied from a simple flowthrough system. Cooling may be done in a stagnant system such as an aquarium or bucket. If the shellfish do not spawn after one heat shock-cooling cycle, the cycle is repeated. This method worked well for shellfish with ripe gonads. Adding a solution of gonadal products to the water also stimulated spawning. This method is easy to implement and normally successful. It is time consuming, but labor requirements are low. It was successfully used for small oyster, large oysters, cockle, hard clam and other species. Details are given below of the different treatments for different species.

Flowing water with intermittent drying

This method is described in the section on large oysters (below).

Thirteen species of bivalve were spawned at the station (Table 2), but only the results with cockles, large oysters and fan shell are presented here in detail.

Larval rearing - general methods

Conway medium was used to culture unicellular algae of 6-8 mm diameter (*Isochrysis galbana, Pseudoisochrysis paradoxa* and *Chaetoceros costatum*) in a controlled temperature room at 24-27°C. Light intensity was 1,200-1,500 Lux; air was mixed with CO_2 at 3% by volume. The addition of CO_2 increased production 2-5 times, reducing labor and the requirement for culture vessels. All containers used in the algae

Table 2. Shellfish species used as spawners.

Scientific name	Thai Common name	English common name
Perna viridis	Hoy maeng pu	Green mussel[1]
Anadara granosa	Hoy kraeng	Cockle
Anadara nodifera	Hoy kraeng	Cockle
Saccostrea commercialis	Hoy nang rom	Small oyster[2]
Saccostrea lugubris	Hoy takrom	Large oyster
Crassostrea belcheri	Hoy takrom	Large oyster
Paphia undulata	Hoy laay	Short-necked clam
Pholas orièntalis	Hoy pim	Angel wing
Pinna bicolor	Hoy jop	Fan shell
Atrina pectinata	Hoy jop	Fan shell
Atrina vexillum	Hoy job	Fan shell
Meretrix meretrix	Hoy talap	Hard clam[3]
Scapharca inaequivalvis	Hoy krang	Hairy cockle

[1]Spat set on bamboo or rope; fecundity about 3.4 million eggs/spawning pair.
[2]Fecundity about 1.1 million eggs/spawning pair.
[3]Spat set on 200-µm mesh nylon screen at tank bottom; fecundity about 0.7 million eggs/spawning pair.

room were thoroughly cleaned then sterilized with heat treatment. The seawater was pasteurized to destroy harmful bacteria.

Larvae were first fed with algae one day after fertilization. Feeding was normally twice daily, morning and evening. Pulse feeding was also used for cockle and oyster larvae. In contrast to batch feeding, in which a fixed amount is given once per day. pulse feeding begins with a small amount and is continued throughout the day as the water becomes cleared of food: i.e, four or five feedings per day. Pulse feeding gave better larval growth. For oysters and green mussels stocked at 5-10 larvae cm^{-3}, *Isochrysis* was initially fed at 5,000-7,000 cell cm^{-3}/day. For large oysters, cockles and hard clams, 7,000-30,000 cm^{-3}/day were fed depending on size of the larvae.

Feeding rates were, however, largely determined by observing the rate of consumption. If the water became clear very quickly the feeding rate was increased. Microscopic inspection of the intestines of the larvae was also used in determining rate of feeding. If the intestines were dark after feeding the rate was deemed sufficient. *Tetraselmis suecica*, 10-14 µm in diameter, was given when larvae reached 200 µm. Other species of algae fed at various times were *Thallasiosira pseudonana*, *Monochrysis lutheri* and *Dunaliella* sp. *Chlorella* sp. was not used since it is toxic to larvae at high concentration.

Spat larger than 5 mm were moved to rearing ponds since sufficient food supply could not be provided from hatchery algal cultures.

Methods and Results Obtained for Different Species

Cockles (Anadara *sp., probably* A. nodifera)

Cockle broodstock were washed thoroughly in freshwater to ensure they remained closed. The washed cockles were bathed for 15 minutes in about 10 ppm sodium hypochlorite. The treatment was given prior to induced spawning by thermal shock in order to kill any potentially harmful organisms on the outer surface of the shell. The thermal shock treatment was 34°C water followed by cold shock at 20°C, then a second heat shock at 34°C. The first two treatments were for two hours each. The last treatment continued until spawning occurred, usually within one hour of initiating the second heat shock. The fecundity of cockles was about 500,000 eggs per spawner.

Cockle larvae were reared at 10/ml in 50-l fiberglass tanks at ambient salinity (around 32 ppt). EDTA was added to the tank water after each daily water change to maintain a concentration of 5 ppm. Each batch was separated into two groups when larvae were 11 days old and had reached 140 to 165 µm.

The larvae was exclusively fed on Tahitian strain Isochrysis galbana, beginning feeding with about 5,000 cells cm^{-3}. This was increased according to the size of the larvae.

Table 3 gives the terminology and descriptions of the various stages of larval development.

Table 3. Stages of larval development of bivalve shellfish.

Fertilized egg	45-60 µm for all species in Table 2; except hard clam 70 µm; has a gelatinous outer membrane about 130 µm diameter; stage lasts 20-30 minutes at 26-28°C.
Trochophore	55-65 µm. Cilia develop and motility starts: lasts 8-20 hours after fertilization
D-hinge Veliger	65-95 µm. Begins to develop a ciliated velum; D shaped; begins to consume food 1 day after fertilization in small oyster and green mussel, 1-3 days in cockle, hard clam and large oyster.
Umbo	150-165 µm. Begins to develop umbo which becomes clearly visible; 5-7 days after fertilization in small oyster and green mussel and 7-15 days in cockle, hard clam and large oyster.
Pediveliger	Larger than 200 µm. Eyespot development begins; eyespot enlarges and becomes clearly visible; 12 days in green mussel and small oyster. After eyespot develops the larvae can seek substrate for settlement by protusion of the foot.
Settlement stage	280-320 µm. Very clear eyespot. Green mussel can attach to substrate in 17 days; small oyster attach at 22-24 days; large oyster and cockle require 21-35 days and hard clam 10 days.

The setting technique used for cockle spat differs from that used for oysters. Cockle larvae go through a prolonged metamorphosis once setting begins. Moreover, cockles do not require a special setting substrate; they can set on the bottom of the rearing tank. Growth is very rapid after setting and within a few days it is relatively easy to screen off cockle spat with a 280 µm or larger screen for transfer to an upwelling nursery, returning unset larvae to the rearing tank. Cockles grew better when reared on a mud bottom than in a tray without mud.

The best size of cockle broodstock for induced spawning is 3-4 cm (1.0-1.5 years old). Cockles were spawned on two occasions. The first, on 21 March, was probably only a partial spawning by one individual and yielded 124,000 eggs. The eggs were

Large oysters (Crassostrea belcheri *and* Saccostrea lugubris)*

Broodstock

Oyster broodstock were maintained in a station pond. Each oyster was numbered to insure adequate records of individual spawning. Multiple spawnings frequently occurred. It was demonstrated that ponds can be utilized for broodstock maintenance, provided that they have adequate water exchange.

Broodstock of the proper size (11-15 cm; 1.5 to 2.0 years old) and at the proper stage of gonad development should be selected for induced spawning. If possible 60-70% of the stock should have ripe gonads. If not, needed to ensure successful induced spawning.

Induced spawning

Oyster broodstock were removed from the pond the evening before spawning and allowed to dry overnight. The following morning the oysters were placed in flowing seawater at ambient temperature for 2 hours. The oysters were removed from the water and allowed to dry for 30 minutes, then replaced in flowing water. Spawning usually occurred shortly after the second immersion. If not, a second drying period was required. Heat shock (34°C) successfully induced spawning on one occasion when oysters treated as described above failed to spawn. This heat shock was given in a flowing water system (Fig. 6). If static water is used for induced spawning of oysters, polyspermy often occurs and the eggs fail to develop normally.

After fertilization, the eggs were cleaned and filtered from other materials using sieves: 180 µm, to remove larger waste; 80 µm, to remove smaller waste and 32 µm, to collect the eggs. The eggs were transferred to 50-500 l fiberglass tanks, normally stocked at 10-20 eggs/ml, with EDTA added to maintain a concentration of 5 ppm. The salinity ranged from 30 to 32 ppt and pH from 7.5 to 7.8.

Setting and spat collection and handling

Three methods were used:

1) Setting on large shells, 15 cm in diamater - the shells were cleaned; a hole was drilled in the center of the shell; the shells were attached to a line and suspended in the tank.

2) Setting on ground shells of (cultch) green mussel or oyster, 300 µm in diameter spread on a screen in the tank, with water passed through the screen by upwelling: this method can be used for large and small oysters *(Saccostrea commercialis)*. Pearl oyster shell was also used as a substrate for setting large oyster larvae.

3) Setting on the tank bottom and then spreading fine sand on the bottom of the tank after 1-2 days. The spat, mixed with the sand, are then removed from the bottom. The mixture of sand and spat are placed on a screen and the screen mesh size increased as the spat increase in size. Sand falls through the larger mesh screens and

*Small oyster spat *(S. commercialis)* were also produced at the station and transferred to a local farm, but all died due to pollution from a pineapple cannery.

only spat remain. If the spat are allowed to remain attached to the tank bottom for more than 2 days they are difficult to remove without damage to the shell. The ground shell method (2 above) and this sand method produce single spat.

For any given brood of oyster larvae (larvae spawned at the same time), setting may occur over an extended period of time, often many days. This is due to the wide range of developmental stages found at a particular age. Larvae that are ready to set can be screened from the rearing tank, placed in the setting tank and allowed to set. Alternately, the setting size larvae can be maintained in a separate tank until they begin to set, as indicated by the appearance of new spat on test shells.

Oyster larvae of both species were successfully set on both shell cultch and as single seed on ground shell. When spat appeared on a test shell immersed in the rearing tank, cultch was prepared and larvae introduced into the setting tank. After about 6 hours, setting was considered completed. Swimming larvae were maintained in the setting tank overnight and then the cultch was transferred to a nursery tank. This procedure resulted in high mortality of larvae that had not completed setting. Since initial setting densities were low, larvae which had been returned to the rearing tanks were reset on the same cultch until an adequate set was obtained. These shells were then transferred to 200-l aquaria and the spat fed *Tetraselmis*.

Larvae which have not set in the setting tank can be removed by siphoning and returned to the rearing tank. These larvae can then be reset using again a test shell as an indicator. Depending on the degree of development, they may be reset the following day, or it may take several days for development to proceed to the extent that resetting can be attempted. Removing larvae and resetting can be continued until the majority of the brood have set.

An attempt was made to screen larvae for setting the mesh sizes available at the station, 280 and 270 µm. The larger size was too large and the smaller retained too many underdeveloped larvae; a 275 µm screen may be the appropriate size for oyster larvae.

Because the appropriate screen size was not available, the siphoning technique described above was used. Unset larvae were siphoned from the setting tank and returned to the rearing tank for later resetting. The system worked well for shell cultch but proved difficult for single seed because the larvae tended to accumulate on the screen with the result that shell was siphoned out with the larvae.

Setting size larvae are negatively phototactic. This attribute was used to attempt to separate eyed larvae from those set on shell particles. The procedure appears to have possibilities. The light source must be mounted below the setting screen so that light is directed toward the water surface. Here the 270 µm screen was slightly too small, and also many of the larvae did not have the eye spot and could not respond to the light stimulation. Use of a slightly larger screen size to collect larvae for setting should improve separation by negative phototaxis.

Spat were moved from the tanks to open waters on the station. Single seed spat were reared in nylon lantern nets (16 mesh per inch) in the canal or in ponds. Spotted cultch was also suspended in the canal from a small dock. The net containers were 40 cm in diameter. Spat remained in the net until reaching 1 cm. The spat were then moved to another net container 50 x 90 x 10 cm (mesh size, 5 x 5 mm). A suitable size for transplantation to culture areas was judged to be more than 2 cm. Seed were cemented to concrete posts or placed in trays for growout.

Spawning and rearing results

Several broods of larvae of *C. belcheri* and *S. lugubris* and two broods of reciprocal hybrids of *C. belcheri* with *S. lugubris* were reared, using 50- and 500-l tanks at densities ranging from 0.5 to 1.8/ml. Growth and survival were very variable, probably due to water quality problems. The outlet of the canal has become badly silted up and water exchange with the sea has suffered. Problems with larval shrimp and sea bass *(Lates calcarifer)* rearing have also occurred at the station. Some of the inconsistency of results may also have been due to the inexperinece of the station staff. Therefore studies on the effects of density and salinity on rearing were inconclusive. All that can be said is that reduction of salinity from 32 to 15 ppt helped to stimulate setting and appeared to improve growth and survival of older larvae. Similarly, attempts to demonstrate the benefits of using 5 ppm EDTA in larval rearing were also frustrated by mortalities (sometimes total). More controlled experiments with good water quality are needed. The treatment of larvae with Sulmet (see above) to control bacteria was generally effective, whether used as a hatching treatment or added to tank water (for severe infections). However more tests should be made with a range of antibiotics and antifungal compounds under better controlled conditions.

Some of the induced spawnings were partial. Two *C. belcheri* females yielded 35 and 53 million eggs but fecundity was usually measured at about 10 million/eggs/ spawning pair.

C. belcheri and *S. lugubris* and larvae were reared to setting on whole shell and as single seed on crushed and graded shell.

For *C. belcheri*, the onset of setting varied from 17 to 25 days and mortality was high for some broods. Survival of spat after removal from the hatchery to natural waters was about 78%. Reduction of salinity from 30 to 32 pt to 15 ppt stimulated setting and may improve growth and survival of older larvae.

Reciprocal crosses between *C. lugubris* and *C. belcheri* had higher larval survival than larvae of either parental species. Female *C. belcheri* x male *S. lugubris* hybrids seemed to be the more vigorous, but good data are lacking.

Considering the high demand for large oyster seed in Thailand and the high value of oysters, the development of commercial hatcheries is well worth investigating.

Fan shell (Pinna bicolor)

Bivalves of the genera *Pinna* and *Atrina* are of commercial interest because of their export potential. These are presently underutilized in Thailand. *P. bicolor* and *Atrina vexillum* were collected from Hua Hin District of Prachuap Khiri Khan Province. *Pinna bicolor* was induced to spawn using hydrogen peroxide at 100, 150 and 200 ppm in seawater at pH 9.1. *Atrina vexillum* was not tested.

P. bicolor began to spawn 2 to 3 hours after immersion in all three concentrations of hydrogen peroxide. As soon as spawning was detected the fan shells were transferred to clean seawater. Spawning continued for another 4 hours. However, only the eggs that were released during the first 3 hours had a high rate of normal development. A total of 1,820,000 eggs were obtained during the first 3 hours and an additional 90,000 eggs during the last hour. The latter were discarded due to their low rate of fertilization.

The earlier group was placed in a 500-l tank. The larvae survived for 3 days in water taken from a lagoon at the station, not ocean water.

The larvae were large, the D-hinge measuring 80 x 60 µm at 24 hours and 90 x 70 µm by the second day. The D-hinge appeared normal and at 24 hours there were an estimated 1,090,000 larvae. By the second day there were only an estimated 440,000 veligers and total mortality occurred by the third day.

It was not possible to determine here the number of fan shells that spawned. They were placed vertically in a bucket with the anterior (pointed) end down. As far as could be determined, eggs and sperm were released from a point just above the byssus. It is likely, in natural conditions, that the gametes are conveyed by some means to the posterior region and expelled into the sea since the anterior end is buried in the sand.

In future attempts to spawn this species, individuals could be held in a vertical position in a rack in a glass aquarium to enable determination of the number of spawners. The experiment indicated the fanshell must be placed in a vertical position for induced spawning. Controls placed horizontally in an aquarium did not spawn. Heat shock treatment did not induce spawning.

As a method to induce spawning for this species has been described here, continued experimentation would be useful. It would be advisable to use ocean water and to rear the larvae in small 50-l tanks. Stocking and feeding rates and setting techniques must be established.

Oyster Culture in Thailand

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Abstract

Thai oyster culture began about 50 years ago using stones to collect and grow spat in shallow waters. Present culture methods also include use of cement poles, cement pipes and wooden poles as substrates. Dead shell is also hung or spread out to collect spat. The shells are then placed in trays or hung on or from poles. The major species are *Saccostrea commercialis, S. lugubris* and *Crassostrea belcheri.*

Introduction

Oysters marketed in Thailand are harvested from natural and culture beds along the coastline. Thailand has more than 2,500 km of coastline in the Gulf of Thailand and the Andaman Sea. Much of the area has natural oyster beds and the potential for expansion of culture activities is very high. Domestic and international demand is sufficient to absorb increased expansion in production.

Distribution

The Thai coastal area includes three major species, *Saccostrea commercialis,* a small oyster, and *Saccostrea lugubris* and *Crassostrea belcheri,* which are large oysters. The Thai names vary by location but are generally descriptive of the appearance of the shell. Fig. 1 shows the general distribution of Thai oyster beds.

Different species of oysters can grow in waters from full sea strength to intertidal streams. The oysters are found abundantly in shallow water along rocky coastlines and

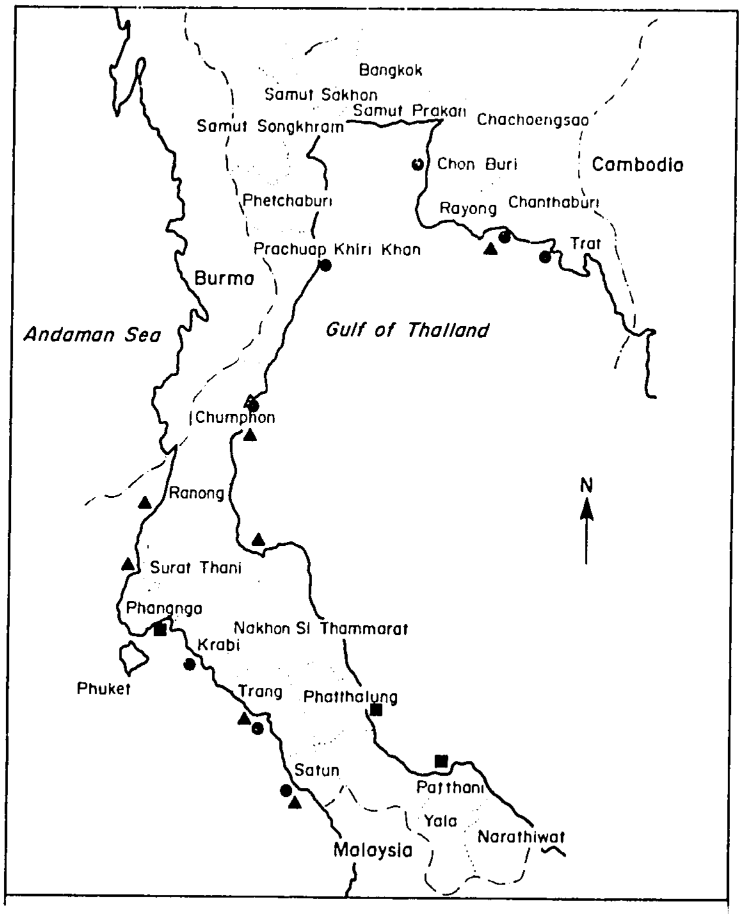

Fig. 1. Location of oyster beds in Thailand. Small oyster (*Saccostrea commercialis* - ●); big oyster (*Crassostrea belcheri* - ▲ ; *Crassostrea lugubris* - ■).

in intertidal mangrove areas. Oysters have been found attached to rocks and other substrate in intertidal streams in Thailand. In the mangrove area the oysters attach to roots or other vegetative substrate. They are found attached to coral or rocks around islands and are found both along the shoreline of the Gulf of Thailand and the Andaman Sea coast.

Saccostrea commercialis, a small oyster, is widely distributed throughout the coastline but is very abundant in Chon Buri, Chanthaburi, Prachuap Khiri Khan, Chumphon, Trang and Krabi. In the previous paper by Sabaithip Amornjaruchit (this vol., p. 1-18), this species is referred to as *Saccostrea cucullata.*

The large oysters, *S. lugubris* and *C. belcheri,* are distributed along the estuarine and coastline of Chanthaburi, especially at the mouth of the Chanthaburi River, Laem Sing, Perid Island, the mouth of the Wellu River. In Surat Thani, large oysters are abundant at Prab Island, Tatong River, the coastline of Kanjanadit, and Klong Phumreing (Amphoe Chaiya). In Songkhla the large oysters are abundant at Klong Natap (Amphoe Chana), and Klong Lagom (Amphoe Thepha) and in Pattani, at Klong Maruat (Amphoe Panarae). On the Andaman sea coast, large oysters are found at Klong Puyu, Klong Sakhon, Sarai Island and Ta Ru Tao Island in Satun Province. The large oysters are also found at other places including Klong Wungwon (Amphoe Kantang) Trang Province.

Development of Oyster Culture in Thailand

Formerly Thailand had abundant resources of oysters from natural beds. The oyster beds were located in shallow coastal water near river mouths and in the enriched water of the intertidal mangrove areas. Increased population and demand for oysters reduced the natural oyster populations to a level insufficient to supply local demand. It is believed that immigrants from China first began culturing oysters in Chon Buri, Rayong and Chanthaburi Provinces about 50 years ago. The culture method was placement of stones on the bottom in shallow areas. The stones served as spat collectors and as a growout surface for the oysters. The system is similar to that used in the southern part of China. In the eastern coast of Thailand oyster farming is a full-time family occupation.

Oyster culture developed later in the southern part of Thailand. Production was at Prachuap Khiri Khan, Surat Thani, Songkhla and Pattani. Only recently culture activities have increased in the southern region. Most culture there is a part-time activity for the operator.

Suitable Locations for Oyster Culture

The Coastal Survey Section of the Brackishwater Fisheries Division conducted an intensive survey of the current production and potential areas for expansion of oyster culture in the coastal provinces of Thailand. The Department of Fisheries has an established policy to increase culture of aquatic products to compensate for the reduction in natural harvest. The market demand is sufficient to sustain increased production of oysters. Increased production will increase employment and income for coastal villagers and increase the food supply for the Thai people. The current and potential production areas by coastal province are shown in Table 1.

Table 1. Existing oyster farms and potential area (1983).

Province	Existing area (ha)	Potential area (ha)	Total
Chon Buri	1,714	1,000	2,714
Rayong	520	1,500	2,000
Chanthaburi	2,922	3,000	5,922
Phetchaburi		1,000	1,000
Prachuap Khiri Khan	21	2,000	2,021
Chumphon	538	940	1,478
Surat Thani	494	1,562	2,056
Nakhon Si Thammarat		1,875	1,875
Songkhla	1	550	551
Pattani	200	2,500	2,700
Narathiwat		3,125	3,125
Ranong	625	3,125	3,750
Phangnga	1	6,250	6,251
Krabi	10	1,256	1,266
Trang		3,125	3,125
Satun		3,125	3,125
Total	7,046	35,933	42,979

Physical parameters are the most crucial factors in choosing a site. The physical selection parameters are as follows:

1. Intertidal brackish- or seawater for 7-8 months of the year. No influx of freshwater sufficient to reduce salinity for long periods during the rainy season.
2. Natural seed supply present or in a nearby area for acquisition of seed to keep seed costs low and for convenience in stocking.
3. Limited effects of current and strong winds. Substrate for culture will be difficult to maintain. Suitable areas would be enclosed bays or shorelines.
4. No external sources of pollution that can release substances harmful to the oysters or to humans who consume the oysters. Located away from mining activities that reduce water transparency. Turbidity reduces growth rate because of low natural nutrients and can cause mortality in spat.
5. An ideal current speed in the area would be 5-8 km/hour. The water should contain ample nutrients for plankton growth. The water should be moderately clear with low turbidity and good light penetration.
6. The area should have shallow water and be located in a mud flat or on soil with sandy loam composition. The mud layer should be shallow or located over a hard bottom to support the substrate for culture depending on the method of culture. The coastal region of Thailand has many sites that meet this criterion.
7. Substrate material can be found at low cost in the local area. For example, rock, wood, empty shells or other materials, depending on availability.
8. Limited number of oyster predators.
9. Area that can be guarded with a minimum cost.
10. Developed infrastructure with roads and markets for ease of transport and sale of the oysters.

Methods of Culture

There are various methods for culturing oysters. Each method is suitable for biological and climatic conditions at specific locations.

Rock culture

Rocks are used as substrate for oyster spat settlement. Oysters remain on the rocks until harvest. The area should be close to a supply of natural rock materials. The rocks are piled in groups of 5-10 and spaced in rows approximately 50 cm apart. The maximum rock surface should be exposed for spat settlement. The area can be an open bay with clay or sandy clay bottom firm enough to support the rocks. The area must be intertidal to facilitate harvest of the oysters.

For areas with soft bottom mud a platform or mat of bamboo can be used to prevent the rocks from sinking. Rocks with spat attached are placed on the bamboo structure. The method is used near the mouth of rivers or other muddy areas.

Culture on cement poles

This method is suitable for the same conditions as for rock culture. The pole system can be used in combination with rocks by placing poles between the piles of rocks leaving a pathway for walking. The conditions at Ang Sila and Laem Tan, Chon Buri Province, are suitable for this type of culture system.

The cement poles are constructed especially for oyster culture and withstand wind and wave action. They are constructed with a wooden rod in the center to add strength. The lower end of the cement pole has an opening for insertion on a wooden pole placed in the bottom of the culture area. The pole can be removed from the wooden stake for ease of harvesting. The cement pole has a very long life.

Length of the cement pole is dependent on water level and the preferences of the producer. Experiments indicated that poles should be 50-70 cm in length and 12 x 12 cm square. The wooden support pole should be at least 1 m in length with 50 cm enclosed in the cement pole and 50 cm below the cement pole.

Culture on cement pipe

Culture on cement pipe is similar to culture on cement posts. However, cement pipes can be acquired from local dealers and do not have to be specially built for oyster culture. The cement pipes are fitted on strong wooden stakes driven into the bottom of the culture area. Pipes are placed in rows with approximately 1 m between pipes in each direction. About 1,600 pipes can be set per rai (= 1,600 m^2).

Culture on wooden poles

This system is suitable for areas with strong but not destructive currents and wave action. Poles are set in the soft or muddy bottom similar to the system used for green mussel culture. Some producers allow spat to settle on the poles and use the initial spat set for growout to market size. Other producers collect or purchase spat that has set on oyster or other shell. Spat 1-2 months old is transferred to the poles for growout to market size. The shell is attached loosely to the pole to allow freedom of growth for the oysters. Bamboo or other locally available wood with a low price is used for the poles.

The oyster shell is attached to the poles and the poles then are stacked in rows with sufficient area between poles for good water circulation. The poles should be firmly driven into the bottom. The depth will depend on the bottom composition but will approximate 30-40 cm for firm bottom and more for softer bottom.

Tray culture

Tray culture can be used in muddy bottom areas near the mouth of rivers where the water remains brackish year-round. Trays can be built in any convenient size but a popular size is 80-100 cm with an upright side of 2.5 cm in height. The trays are often constructed from strong wood although bamboo can be used. The tray is mounted on stakes approximately 30 cm above the bottom.

Oysters are placed in the tray for growout. Small oysters are removed from rocks at about 6-7 months of age and 3.5-4.5 cm in length for placement in the trays. For oysters that have been collected on shell, the entire shell is placed in the tray. Growout to market size is about one year when the oysters are 18 months old.

Large oysters are placed in trays at about 3-4 months of age and 3-4 cm in length. The growout period for large oysters is about 4 months to market size. The oysters are then 7-8 months old.

Culture by suspension

This method is also known as hanging culture. The method is widely used in Japan and South Korea because the oysters grow fast and high yields can be obtained. Suitable sites are in deep water sheltered from high winds and waves. The Department of Fisheries of Thailand has conducted many experiments on hanging culture. The growth rate is very high but many problems are encountered. The type of materials available in experiments would not sustain wind and wave action and the structures were rapidly destroyed in some seasons. In addition, the initial investment for this type of culture is high compared to that for other types of culture materials. The daily labor and management requirements are higher than for other methods. Applicability of this method to Thailand conditions would require careful consideration.

Width and length of the raft structure is dependent on the individual producer. Gasoline tanks of 200 l can be used as floats after painting with anti-rust material. The raft must be secured by anchors. Depth of water should be approximately 10 m.

Spat collection is by the same procedure as described above. The spat, attached to shells which were used as cultch, are placed on the lines for suspension. Galvanized wire, No. 10 size, is used as the suspension line with 15-20 cm intervals between the shells with spat attached. A small section of bamboo cut to length is inserted between the shells with the wire passing through the bamboo. Each shell normally has 2-4 oyster spat. The complete system is then hung from the raft. The system remains in place until the oysters reach market size. The time required for growth to market size is dependent on the type of oysters.

Other culture methods

In addition to types of material listed above, other strong and durable materials are used in oyster culture, e.g., cement blocks, car tires, asbestos roof tiles, brick and broken earthen vessels.

For large-scale operations as practiced in some countries a survey of possible culture areas is first made. A wide flat area with a firm bottom is selected near an estuary or mud flat. The sites are usually rich in nutrients and suitable for oyster culture. Small oysters are collected and spread on the culture bed. High yields can be obtained from this method.

Spatfall Season

The spawning season and seasonality of spatfall were studied at various locations along the coast of Thailand. At Lam Tan, Tambol San Suk, Amphoe Muang, Chon Buri Province, the small oyster *Saccostrea* sp. spawned all year with seasonal peaks of spat settlement in April-May and October-November. Similar patterns of spat settlement for this oyster occur elsewhere in the eastern Provinces of Thailand, as illustrated in Figs. 2 and 3 for Tumbon Laem Taen, Chon Buri Province.

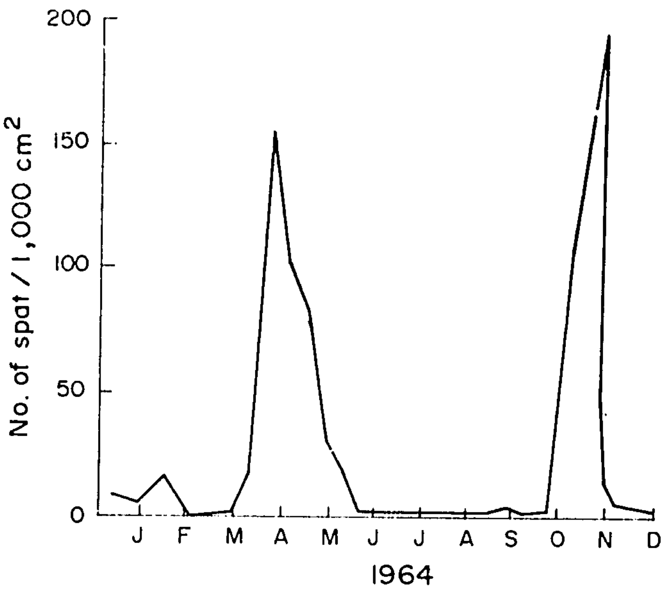

Fig. 2. Average number of oyster spat of *Saccostrea commercialis* per 1,000 m^2 of surface area of asbestos roof tile collector at the study site, Tumbon Laem Taen, Chon Buri Province, 1964.

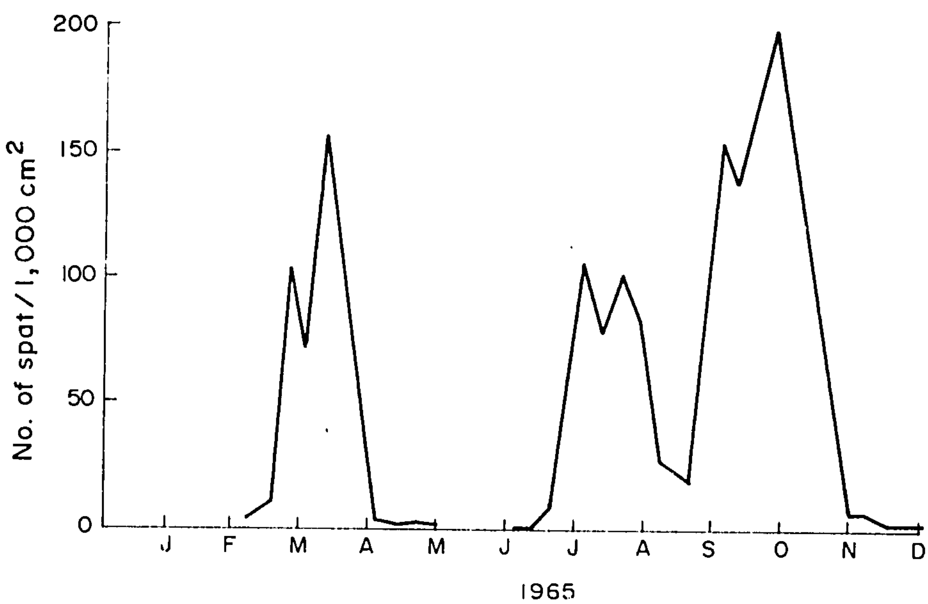

Fig. 3. Seasonal change in average number of oyster spat of *Saccostrea commercialis* per 1,000 m^2 of collector surface at the study site, Tumbon Laem Taen, Chon Buri Province, 1965.

Spawning season and spatfall for large oyster *Crassostrea lugubris* at Klong Natap, Songkhla Province, indicated two periods of spat settlement. The first was from January to April. Spat were very abundant during this period. A second may sometimes occur in September-Novernber. This spatfall pattern (Fig. 4) is assumed to occur for all Gulf coast southern Provinces.

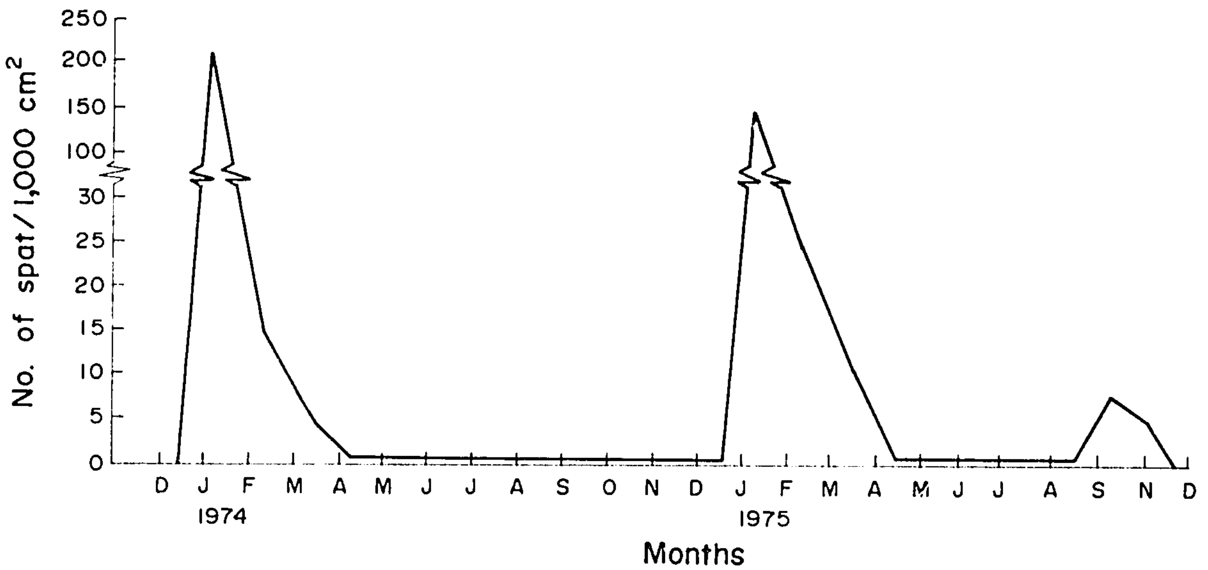

Fig. 4. Monthly average number of oyster spat of *Saccostrea lugubris* per 1,000 cm^2 of surface area of collectors at the study site, Klong Ban Natub, Chana District, Songkhla Province, 1974 and 1975.

Spat collection in Chumphon, Nakhon Si Thammarat, Songkhla, and as far south as Narathiwat occurs in January. For the eastern coast of the Gulf of Thailand and the Andaman Sea coast, the spat collectors should be set out in October. The spat season occurs after the rainy season and there is no danger from freshwater flow. With a suitable environment, a fast growth rate and high survival should be obtained.

Maintenance

About 15-20 days after setting, the spat will be visible on the collectors. Frequent inspection of the collectors must be made to eradicate predators and competitors. A crucial factor is security of the collectors and the production area.

Predators and Competitors

The main predators of oysters consist of various types of aquatic animals including gastropods, *Thais* spp. and *Melongina* spp. In addition, starfish and many fish feed on molluscs. Competitors include green mussels, horse mussels and other bivalves which live in the oyster beds.

Natural disasters can occur which cause fatalities to oysters. Included are freshwater influx from rivers and streams during the rainy season, which lower salinity. If the condition persists for an extended period the oysters will die. At the end of the dry season and prior to onset of the rainy season, an abrupt change in air temperature may cause sudden mortality of algae which can cause decrease of oxygen in the water. If the polluted water moves into the production area serious losses of oysters can occur. Polluted wastes from industrial plants can also damage oyster production.

Yields

S. lugubris has been experimentally cultured at the Songkhla Brackishwater Fisheries Station on concrete culverts. The oysters reached a market size of 7 cm in 7-8 months (Table 2). The growth rate was relatively even and harvesting could commence

Table 2. Growth rate of oysters *(Saccostrea lugubris)* at the experimental site at Klong Natub, Songkhla Province, in 1974 and 1975.

Age (months)	Average Length (cm)	
	1974	1975
1	1.38	2.01
2	2.31	2.40
3	3.91	3.48
4	5.13	4.49
5	5.84	5.91
6	6.84	6.76
7	7.57	7.45
8	8.68	8.11
9	9.27	8.47
10	9.36	8.63

from 6 months onward. The study result indicated that 1,600 culverts in one rai would yield 40,000-70,000 oysters. An experiment using wooden trays indicated a tray area of 132 m^2 would produce 9,000-10,000 marketable oysters.

Culture of small oyster *Saccostrea* sp. was experimentally conducted using cement culverts in the eastern coastal area. Yield of in-shell weight was 3,000 kg per rai. The culture period was 1-2 years.

A Bioeconomic Longitudinal Processing and Marketing Study of Green Mussels in Thailand*

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Abstract

This paper summarizes the findings of a longitudinal marketing-processing study carried out in 1984-1985 as part of a bioeconomic study of the green mussel culture industry in Thailand. The operations of mussel producers and processors in Samae Khao and Ban Laem were monitored for various periods

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from July 1984 to June 1985 in order to obtain information on the production of green mussels and mussel products as well as the economic and technical conditions of production and processing. There were some difficulties in collecting data over such an extended period of time with an interdisciplinary team.

Larger mussels for human consumption are processed into dried butterfly form or are boiled and dried, the latter product largely produced by large-scale operators and the former by families. The study showed operating losses to the processors of boiled dried mussel and positive returns to the smaller producers of butterfly forms; however, the returns to the latter group are low.

Introduction

The main objective of the cooperative project between the Department of Fisheries, Royal Kingdom of Thailand (DOF) and the International Center for Living Aquatic Resources Management (ICLARM) funded by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH was to identify constraints to expansion of mollusc culture in the coastal areas of Thailand. Preliminary research indicated that the project should concentrate on the green mussel *(Perna viridis)*. The green mussel was the mollusc of greatest immediate economic importance to Thailand but the industry was facing many serious biological and economic constraints. The project initiated a major bioeconomic study to identify the major constraints on the efficiency and further development of the industry.

This report draws on the longitudinal marketing-processing study of the green mussel in order to demonstrate the interrelationship of biological and economic information.

The green mussel is the most important shellfish in Thailand, comprising more than one-half of total commercial production (Table 1). The industry has quite a long history.

Table 1. Production and value of bivalves in Thailand, 1979-1983.

Year	Green mussel Weight (t)	Green mussel Value ('000 B)	Cockle* Weight (t)	Cockle* Value ('000 B)	Oyster Weight (t)	Oyster Value ('000 B)
1979	49,397	65,698	23,741	61,727	9,876	91,452
1980	31,386	129,633	17,666	77,735	6,015	60,105
1981	36,746	78,469	23,354	81,373	8,429	85,951
1982	65,509	128,263	8,636	29,302	5,671	39,598
1983	43,130	106,983	16,575	56,095	5,322	38,689

*Includes Hoy Krang (Hairy cockle *Scapharca inequivalvis*).

Source: DOF Annual Statistical Reports, 1979-1983.

Green mussels were always collected from the stakes of stationary fishing gear but for more than 60 years farmers along the coastlines of Thailand have specialized in green mussel culture using simple methods adapted from this whereby strong lengths of bamboo or palm are driven into the muddy bottom of the shallow water zone specifically as collectors of mussel spat. Another adaptation is to extend the wings of fish traps to collect green mussels. The attached mussels are allowed to grow for 6 to 8 months before harvesting for the market.

Most green mussel production has been located near the mouths of major rivers such as the Bang Pakong, Chao Prya, Mae Klong and Tha Chin in the inner Gulf of Thailand. However, with increased urbanization and industrialization these areas have become increasingly polluted and efforts have been made to introduce green mussels in other areas such as Sawi Bay in Chumpon Province, Phangnga Bay in Phangnga Province, and Nakhon Bay in Nakhon Si Thammarat Province (see Fig. 1). The transplantation was successful in Sawi Bay where production exceeded 8,000 tonnes in 1983 making this the second largest production area in the country in that year.

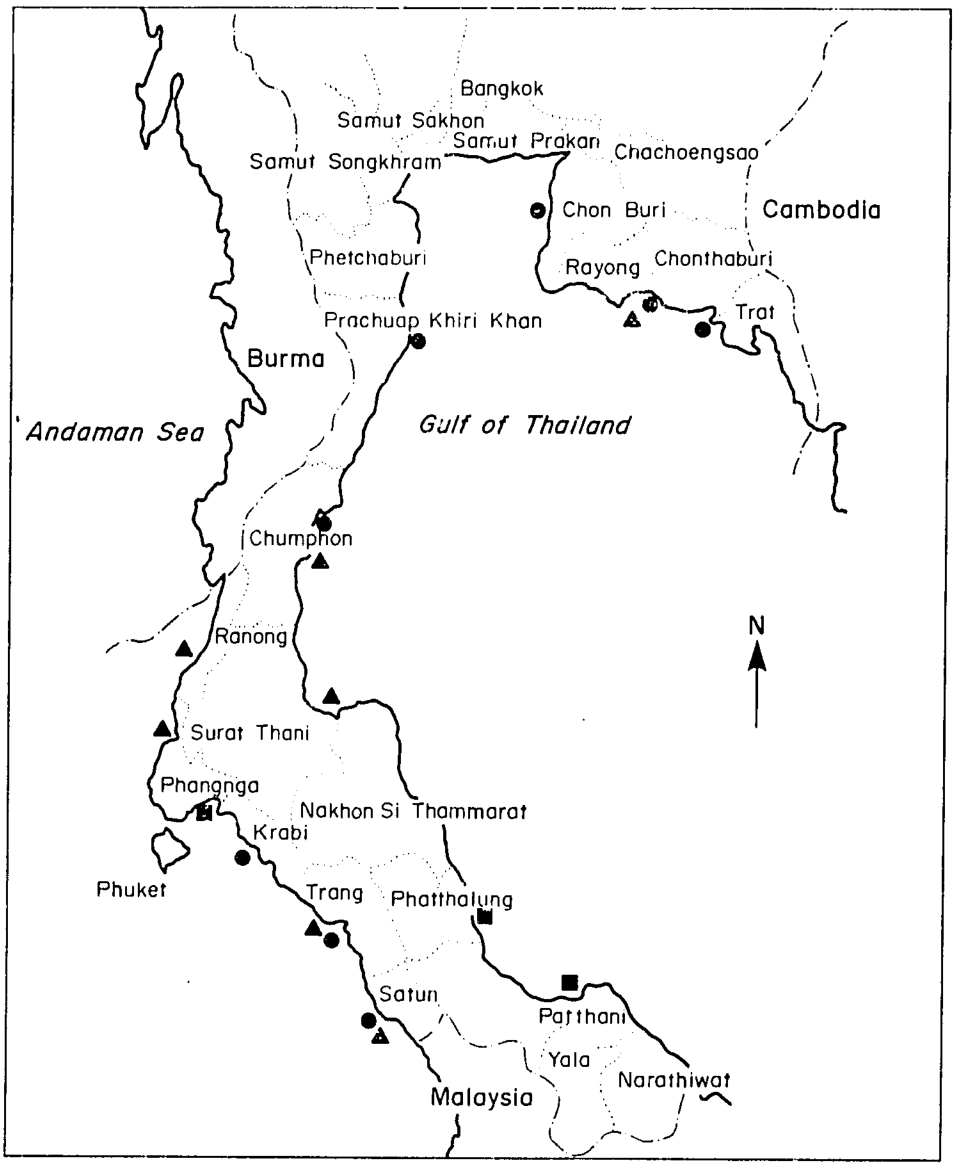

Fig. 1. Map of Thailand, showing areas mentioned in the text.

Department of Fisheries data show that green mussel production has fluctuated widely from year to year without an apparent trend, either in both total production and production in each province (Table 2). From the official statistics it is difficult to identify the contribution made to total production by mussel farming. The same data give the areas of green mussel farms and the numbers of farmers in the six contributing provinces (Table 3), while another publication indicates that virtually all production in twelve provinces is from green mussel farms (Table 4). The confusion appears to be one of definition. Another table in the second publication shows that the output from "farming" includes production from "stakes" and "fish traps" (Table 5). It appears that the output from fish traps is counted as green mussel culture, but fish trap operators are not counted as fish farmers (because they do not have a license for green mussel) nor are

Table 2. Green mussel production in tonnes by province, Thailand, 1975-1983.

Province	1975	1976	1977	1978	1979	1980	1981	1982	1983
Trat						0	85	0	345
Chon Buri	15,950	28,319	34,708	18,447	11,595	2,200	2,491	7,147	1,393
Chachoengsao	11,800	16,129	16,854	10,733	11,339	4,500	11,685	8,377	3,543
Samut Prakan	1,170	1,920	1,602	1,080	748	1,680	5,100	3,059	6,501
Samut Sakhon	5,850	9,000	9,591	6,531	8,405	3,472	3,523	13,710	1,496
Samut Songkhram	6,646	10,652	11,204	9,398	10,644	15,390	8,879	21,529	5,801
Phetchaburi	5,320	6,480	5,846	2,579	3,150	252	840	2,553	15,740
Chumphon	180	2	2,000	1,100	2,349	217	4,144	7,485	8,152
Prachuap Khiri Khan		40				0		1,649	130
Trang								0	3
Ranong								0	26
Total	46,916	72,542	81,805	49,868	48,230	27,711	36,747	65,509	43,130

Source: DOF Annual Statistical Reports, 1975-1983.

Table 3. Farms and area of green mussel culture by province, Thailand, 1975-1982.

Province	1975		1976		1977		1978		1979		1980		1981		1982	
	Farms No	Area Rai	Farms No	Area Rai	Farms No	Area Rai	Farms No	Area Rai	Farms No	Area Rai	Farms No	Area Rai	Farms No	Area Rai	Farms No	Area Rai
Chachoengsao	113	664.50	169	1,348.90	160	1,380.10	163	1,524.20	156	1,426.70	136	1,299.00	117	1,124.30	119	1,093.90
Chon Buri	134	5,025.30	134	6,017.30	132	3,584.90	130	4,785.80	121	4,696.10	80	3,731.00	48	1,375.20	43	1,011.70
Prachuap Khiri Khan																
Chumphon															56	18.10
Phetchaburi					22	66.00	22	66.00	13	39.00	22	50.70	51	268.70	64	318.00
															63	12.80
Total	247	6,689.80	303	7,366.20	314	5,031.00	315	6,376.00	290	6,161.80	238	5,080.70	216	2,768.20	345	2,454.50

Source: DOF Annual Statistical Reports, 1975-1982.

Table 4. Quantity in tonnes of green mussels harvested from farming and capture by province, Thailand, 1980-1983.

Province	1980			1981			1982			1983		
	Farming	Capture	Total	Farming	Capture	Total	Farming	Capture	Total	Farming	Capture	Total
Trat			0	85		85	1,500		1,500	345		345
Chon Buri	2,200		2,200	2,491		2,491	7,147		7,147	2,412		2,412
Chachoengsao	4,500		4,500	11,685		11,685	8,377		8,377	9,025		9,025
Samut Prakan	1,680		1,680	5,100		5,100	3,059		3,059	1,496		1,496
Samut Sakhon	3,472		3,472	3,523		3,523	13,710		13,710	5,801		5,801
Samut Songkhram	15,390		15,390	8,879		8,879	21,529		21,529	7,108		7,108
Phetchaburi	252		252	840		840	2,553		2,553	10,747		10,747
Chumphon	42	175	217	4,055	90	4,145	7,479	6	7,485	6,037		6,037
Prachuap Khiri Khan			0			0	149		149	130		130
Trang											3	3
Ranong											26	26
Total	27,536	175	27,711	36,658	90	36,748	65,503	6	65,509	43,101	29	43,130

Source: DOF Annual Statistical Reports, 1980-1983.

their operational areas included in data on farmed areas (because they do not have specific areas of green mussel production).

As shown in Table 5, fish traps provide about two-thirds of total green mussel production. A study by Jinpinpet indicates that green mussels contributed a significant proportion of total earnings from fish traps (Jinpinpet 1984). In some cases green mussel production "rights" would be sold or leased by a fish trap operator; the green mussel producer would provide the stakes and harvest labor and his operation would be entirely independent of the fish trap. In other cases the fish trap operator would set the

Table 5. Production in tonnes and value in thousands of baht of green mussels from stake, fish traps and natural areas by province, Thailand, 1982-1983.

	1982								1983							
	Stake		Fish trap		Natural		Total		Stake		Fish trap		Natural		Total	
Province	Weight (t)	Value ('000 B)	Weight (t)	Value ('000 B)	Weight (t)	Value ('000 B)	Weight (t)	Value ('000 B)	Weight (t)	Value ('000 B)	Weight (t)	Value ('000 B)	Weight (t)	Value ('000 B)	Weight (t)	Value ('000 B)
Trat			1,500	4,500			1,500	4,500			345	1,263			345	1,263
Chon Buri	5,665	6,571	1,482	2,668			7,147	9,239	1,393	1,964					1,393	1,964
Chachoengsao	2,842	3,865	5,535	8,192			8,377	12,057	2,524	3,559	1,019	1,691			3,543	5,250
Samut Prakan			3,059	4,160			3,059	4,160			6,501	10,791			6,501	10,791
Samut Sakhon			13,710	22,347			13,710	22,347			1,496	2,169			1,496	2,169
Samut Songkhram			21,529	35,738			21,529	35,738			5,801	10,790			5,801	10,790
Phetchaburi			2,553	12,765	6	12	2,559	12,777	8,632	25,897	7,108	14,926			15,740	40,823
Chumphon	7,434	26,539	45	161			7,479	26,700	6,037	28,678	2,115	4,462			9,152	33,140
Prachuap Khiri Khan	149	745					149	745	130	649					130	649
Trang							0	0					3	5	3	5
Ranong							0	0					26	139	26	139
Total	16,090	37,720	49,413	90,531	6	12	65,509	128,263	18,716	60,747	24,385	46,092	29	144	43,130	106,983

Source: DOF Annual Statistical Reports, 1982-1983.

stakes and sell the harvest "rights" to a collector. Harvesting from the wings of fish traps is counted as culture since the wings would be deliberately extended specifically for the collection of green mussels.

A survey of coastal aquaculture conducted by the Brackishwater Division of the Department of Fisheries in 1983 showed green mussel culture on 660 ha, and included two provinces (Pattani and Phangnga) not in the 1982 official statistics. The potential area for green mussel culture was estimated at 9,950 ha. Assuming the production figures cited by Brohmanonda et al. (1985), the current and potential areas could produce some 650,000 t of in-shell green mussels. Unfortunately, production of 65,000 t appears to strain the present capacity of the domestic market to provide acceptable returns to producers (Natathanapat 1984; Tugsinavisuitti and Kantangkul 1983).

Fifty-one per cent of green mussel output is marketed fresh in-shell and 49 per cent is processed in some form or other (Poonsiripinyo 1984). The in-shell product has a relatively short shelf life which severely restricts its market in the north, northeast and south of Thailand (Chongpeepien et al. 1984; Rattagool et al. 1983). Spoilage is also a problem with some processed forms of green mussels. As high as 25 per cent of dried products is lost to spoilage or insect damage (Rattagool 1984). Green mussels are especially susceptible to mold since the product is only dried to 30 per cent moisture level (Chongpeepien et al. 1984). Losses of this magnitude can have a substantial impact as prices for the saleable produce increase to cover the costs of the spoiled produce.

If the losses were reduced while production remained the same, price to producers would decline because the amount of product available to the consumer would increase and the market could be cleared only through a reduction in price.

While there are few barriers to entry into green mussel production in Thailand, research evidence indicates that participation and production have already reached levels where there are no profit incentives for expansion. Production fluctuations appear to be the result, mainly due to biological factors. However, production at the economic margin does not imply efficiency in production or marketing and improvements that will increase the producers' share of the consumers' baht may be possible without increasing retail prices. One means is to increase the amount of value added to the product through processing and marketing.

Green mussels are marketed in many forms of which the following are the most common:

-in-shell	- fresh shucked
-shucked and sun dried	- steamed, shucked and boiled
-steamed, shucked, boiled and dried	- shucked and brined
	- shucked and bottled with spices
-shucked and fermented	- shucked and canned in curry
-shucked, canned in soup	

In dried processing there are different forms including butterfly shape, whole ball form and dried gonad product.

The growth stage of green mussel and the spawning cycle also influence the form of processing and marketable output. The weather pattern in the production area places limits on production and on certain forms of processing. All related factors must be considered in designing research projects in processing and marketing.

Under ideal circumstances, which include freedom of entry in all components of the industry (production, processing and marketing), all forms of a product will have equal market price when differentials in processing and marketing costs are removed. Thus, dried green mussel and in-shell green mussel should result in the same raw material price if the input product is the same. Given identical initial products and freedom of entry, the product will be shifted to the form yielding the highest net returns until profits are equalized over all product forms. If these conditions are not met the profits and/or product input prices may differ between final product forms. For example, while it is possible to use small green mussels for any processed form of green mussel, they are used mainly for duck feed and the price per kilogram is about one-half that of larger mussels used for human consumption. Apparently, considering the meat yield per mussel, shucking by ducks is the most profitable use for this product. No equating of price is possible between small and larger green mussels since the products are not identical. The same situation prevails for all forms and sizes of green mussel products. There is product differentiation because of inherent biological differences.

The specific objectives of this study are:

1. To determine the monthly production of dried green mussels.
2. To estimate monthly processing costs and returns from drying green mussels.
3. To identify the constraints on increasing efficiency in processing and marketing of dried green mussels.
4. To recommend methods to eliminate the identified constraints.

Methodology

Data were collected over a 12-month period. Pretest and data analysis required an additional six months making 18 months in all for the project.

Production data were collected from a sample of producers and processors in Ban Laem, Phetchaburi Province, and Samae Khao, Chachoengsao Province. Village personnel were used to collect daily data. Monthly interviews of a sample of processors were conducted to determine the amount processed, cost of processing and labor utilization.

Biological and economic constraints were identified. Among these are seasonality of supply, which is primarily due to exogenous factors, business concentration at wholesale which is an endogenous economic factor. The lack of quality control may combine biological and economic as well as endogenous and exogenous factors.

Secondary data were obtained from the Department of Fisheries in Bangkok, and from the Provincial, District *(Amphoe)* and Sub-District *(Tambol)* Offices. The amount of detail regarding a specific location increased at the location level and only summary data were available at the higher levels.

The village head *(Phy Yai Ban),* who is elected by the villagers, is the primary contact for any village survey. He is personally acquainted with every villager and maintains records on each household including the amount of fishing gear and fishing activities. Often, the information required is already available from this official.

The household survey was designed to determine the population parameters and to identify those engaged in processing. It was conducted with the village head or his designate and this procedure removed suspicion regarding the interviewers and expedited the survey process. During the interviews visual checks on the houses and yards provided additional accuracy to the data, for example the presence of quantities of green mussel shell, drying racks and other processing equipment identified the households engaged in processing.

Immediately after completing each village household survey, a random sampling procedure was used to select a sample of households for the monitoring. The sample was then stratified by type of processing, commercial (boiling plants) or household. The sample was random to the extent permitted by the willingness of processors to provide information on a daily basis for a full year. Cooperation and agreement with the village head was crucial at this stage and very few processors refused to cooperate.

Village personnel were employed to collect daily data on quantities harvested (number of boats harvesting), quantities processed by the sample households and the numbers of collectors buying green mussels at the landings. There were logistical problems in Ban Laem where there were several major landings and many processors landed green mussels directly at their plants. The interviewers were instructed to concentrate on two landings.

The number of collectors buying green mussels at Samae Khao was assumed to be equal to the number of trucks for green mussel transport at the landing site. In Ban Laem this information was obtained from the household interviews since in this village the collectors performed the cleaning and sorting operation in the village. Earlier studies indicated that the number of collectors varied seasonally depending on the quantity and quality of green mussel available (Poonsiripinyo 1984; Tugsinavisuitti and Kantangkul

1983). Verification and quantification of the amount and timing of collector activity was sought.

Data on the number of trucks and number of collectors were obtained in Samae Khao although no follow up information on the ultimate destination or use of the product was obtained.

The number of boats landing with duck-feed size green mussels and those landing market size were separately counted at Samae Khao. No landings of duck-feed size were recorded at Ban Laem.

The price paid for green mussels was not recorded on a daily basis. In many household processor cases the green mussels were not actually purchased for a variety of reasons: the green mussels came from their own production areas or from spillage at the landings or were given to the family by the producer. In each case only one or two buckets a day were involved.

The price for the processed product was recorded daily until it was determined that price did not vary on a daily basis. Price changes were thereafter recorded as they occurred.

Data on costs and returns were obtained from monthly interviews of the sample village processors conducted by the Fisheries Economics Section, Department of Fisheries. Estimates of the quantities processed were based on the daily interview data.

The raw material input cost was determined from the technical parameters established on a monthly basis. The other costs and labor utilization were obtained from the monthly interviews.

Data Analysis

Seasonality of Harvest

To determine the level of activity in various seasons the number of boats landing mussels was recorded as was the number of buckets of mussels per boat for some locations. The process of collection and the results of the analysis of the two measures of activity are taken up below.

The numbers of boats landing in the morning and evening at Samae Khao on a daily basis for 13 months are given in Appendix Tables 1 and 2. The actual time of landing depended on the tide and in some instances only one landing a day was possible. Duck feed was landed only in the mornings. At the landing the product was moved directly from boats to trucks for transport out of the village. No sorting, cleaning or other preprocessing activity was conducted at the landing in Samae Khao.

The short shelf life of fresh green mussels and the market channel for fresh in-shell indicates that the product landed in the morning was not used for fresh in-shell (Chongpeepien et al. 1984). The period required to reach retail markets the following morning was too long. It is thought that much of the morning landings went to boiling plants (Poonsiripinyo 1984; Tokrisna et al. 1985).

Payment to producers was based on 10- or 20-liter buckets of green mussels. The buckets used for measurement belonged to the producers. The mussels were tipped from the buckets into the buyers' baskets which took two or four buckets full depending on the size of the buckets. Full baskets were then loaded into the buyers' trucks. The price for a 10-liter bucket was always exactly half that for a 20-liter bucket. In reporting and in the analytical tables all bucket weights are standardized for the 20-liter size.

The recorded number of boats landing at Samae Khao represented all landings at that location. The interviewer worked in a small shop at the landing and routinely recorded all boats as they landed green mussels. However, as there were several other landings close by which were used by Samae Khao producers the boats landing at Samae Khao did not represent all Samae Khao production.

Boat landings vary considerably throughout the year from a low of 65 in October to a high of 725 in June (see Appendix Table 5). Daily landings, even in a peak month like June, were nil on some days in 1984 although in most months there were landings every day.

Daily data for the two major Ban Laem landing sites are given in Appendix Tables 3 and 4. However as other landing places were also in use (but were not surveyed) total landings at Ban Laem cannot be determined from the data collected. Green mussels destined for processing were delivered directly to the processors in Ban Laem and, thus, were additional to the product passing through the landing sites.

Green mussel production in Phetchaburi Province was largely from fish traps. No green mussels were harvested for duck feed as was the case in Samae Khao; ducks in the area were fed trash from the cleaning operation and trash fish.

Most green mussels produced in Ban Laem underwent some form of processing for sale fresh in-shell or as dried butterfly. The area was a major producer of dried butterfly, involving many households and processing plants.

The village interviewers at the two landing sites collected data differently but comparably. At landing one the number of boats and the number of buckets unloaded from each boat were counted, while at landing two only the number of boats was recorded. At landing one the green mussels were purchased by the bucket and this was the landing where biological sampling was conducted. The biological study also provided the data for daily boat landings at a third landing in Ban Laem for the period January to June 1985 which are included in Appendix Table 4.

Some uncertainty exists regarding quantities of green mussels landed at Ban Laem. It appears possible that all buckets were counted as 20-liter buckets in arriving at the daily average figures. The possible error is quite large for, if the number of boats using each bucket size was about equal, the data expansion could have overestimated landed weight by 25 per cent.

In 1984 major monthly differences in the number of boats landing existed. The results are presented in Appendix Table 7. These differences result from changing weather conditions, tidal conditions, the size of green mussels and market prices.

The number of boats landing per month from January to June 1985 at three Ban Laem landings also varied significantly although not as much as during the June-December 1984 period. With the three landing sites it was possible to appraise differences on a monthly basis. The relationship among sites varied widely by month.

Production at Ban Laem is from fish traps but as all fish trap operators do not harvest green mussels the precise population of green mussel producers is not known. A study by Tokrisna et al. (1985) indicated that buyers have formal or informal arrangements with producers and therefore always use the same landing place and sell to the same buyer. Under these conditions a more or less constant relationship may exist between the surveyed landings and total landings.

The primary (daily) data indicated the maximum number of boats landing in any month was 888 in June. The maximum number on any day was 44 in May. The daily maximum at any one landing was 21 at landing one in May. The minimum was always 0 boats landing. The boats land green mussels during a narrow time period based on the tide and the market channel. Thus, an even distribution of boats landing during the day is not possible and all arrivals may be within a one- or two-hour period. Daily data thus have value beyond precision in estimation of total quantities harvested. The market operates on a daily time schedule that conforms to buying habits of consumers and the characteristics of the product. For example, restaurants and food shops buy fresh supplies early in the morning; fresh in-shell green mussels have a shelf life of 16 hours after harvest; water depth at low tide does not allow boat entry or exit. These diverse factors must be considered in analyzing the harvesting and marketing of green mussels.

Boat Productivity

The producers landing at Samae Khao during the monthly survey period were interviewed regarding the number and size of buckets of green mussels in the boat. The data recorded were based upon the count of buckets sold prior to the interview. In making monthly estimates of production it was assumed that the number of buckets per boat was constant during the month and equal to the number on the day of the interview. Interviews of producers established that the number of buckets might vary slightly depending on the size of the green mussels.

Analysis of the number of buckets landed monthly was conducted to determine whether the number of buckets could be used as a proxy for the number of boats. The number of buckets per boat was known only for landing site number one. Buckets harvested and landed at sites two and three were obtained my multiplying average number of buckets per boat at landing one by the number of boats at landings two and three. The number of buckets was used as a proxy variable for number of boats and differed significantly by month as did the number of boats where it was known. Appendix Table 8 summarizes the information on buckets landed by boats for Ban Laem and Samae Khao. The maximum and minimum values shown in Appendix Table 9 can be used in estimating the optimum size of facility required for processing the harvest.

The average number of buckets per boat at the sampled landings at Samae Khao is shown by month in Appendix Table 9. The monthly averages shown in Appendix Table 8 vary widely with the greatest variation at Ban Laem. Since differences in bucket size (10 or 20 liter) were not noted the data may not necessarily reflect differences in productivity or production.

Estimates of production could well be made based upon data obtained from major wholesalers on the number of buckets and/or 50-kilogram sacks they market daily. It would be more difficult to identify the source of the product but this may be unnecessary for global production estimates.

If the Ban Laem primary data are valid, then an inquiry into the causative factors for producers harvesting less than a boat load should be examined. The economic feasibility of production is strongly influenced by labor and fuel costs in harvesting.

The weight per bucket of mussels as established by the biological study group is valid for the locations and time period when samples were collected. The failure to obtain comparative values by the survey method prevents the estimation of error introduced by using producer survey data. It is possible that the producer interview method may be perfectly acceptable when estimating costs and returns in production but less acceptable in determining marketing margins where product and processing losses need to be accurately known.

The producer sells a bucket of product only part of which is saleable green mussel and the collector varies the price according to the saleable output. If the producer's perception of saleable output varies from the actual measured output, dissatisfaction with the price received can result. An interview question was included to determine whether the producer was interested in sale of buckets of green mussel products or sale of green mussels and if, in fact, the producer distinguished between the two measurements. The weight components of green mussels from different sites are shown in Appendix Tables 10 through 14.

If the differences between producers' perception of amounts and actual measured amounts were quantified effectively, the results might be used in other studies without weighing buckets of green mussels each time. For example, if producers overestimate the proportion of large green mussels and underestimate the proportion of waste, the difference between actual and perceived could be quantified. If the difference had small variation, the actual proportions of product and waste could be determined by interviewing producers. Adjustments could be made for over- and underestimated quantities. Sampling could be conducted periodically to reestablish the component proportions.

Evaluation of Estimation Procedures

It is always problematic to estimate the production of marine and fisheries products accurately. A number of approaches to the problem were considered in this study and some of these are reviewed below.

BUCKETS OF MUSSELS HARVESTED MONTHLY

Total number of buckets of green mussels harvested and landed at the sample landing sites was a simple summation of the daily numbers of boats times the monthly average number of buckets per boat. However, as has been mentioned, at one Ban Laem landing the numbers of buckets and boats were recorded on a daily basis. (See Appendix Table 15 and 16).

BUCKETS HARVESTED MONTHLY FOR DUCK FEED

The total harvest for duck feed at Samae Khao was determined from the number of boats landing only duck-feed size. There was no difficulty in distinguishing this product as the duck-feed size is much smaller and the buyers also differed. The number of buckets per duck-feed boat was not independently determined.

BUCKETS HARVESTED MONTHLY FOR MARKET

Number of boats landing market size green mussels was determined. The sum of duck-feed landings and market size landings gave the total amount landed per day. Appendix Tables 15 and 16 show the resulting estimates of marketable production.

WEIGHT HARVESTED MONTHLY

The total weight harvested monthly was calculated as the number of buckets times average weight per bucket. Overestimation of weight could occur if the bucket numbers were not standardized to the twenty-liter size since ten-liter buckets may be counted as if they were larger.

WEIGHT OF LARGE SIZE, MONTHLY

Weight of large sizes harvested monthly was a subset of the total weight harvested. Large sizes have a higher market value per unit weight. Only Ban Laem data were subdivided by size. See Appendix Table 17.

WEIGHT OF MEDIUM SIZE, MONTHLY

Medium size is the second subset of total marketable green mussels. Medium sizes commanded a lower market price per unit weight and may have had a different market channel from that of large mussels. The production of medium sized mussels has not been estimated.

SALEABLE WEIGHT, MONTHLY

The sum of large and medium sizes yields the total saleable weight. This is less than total weight purchased from producers since small sizes are not included. The proportion of saleable weight should influence the price that collectors are willing to pay producers.

While definitive data were not collected on a number of important matters, it is possible to draw some conclusions concerning areas of possible fruitful research. Some of these points are discussed below.

The proportion of large size mussels harvested should be directly related to the period of time since spat settlement. Measurements could determine the precise spat settlement period for specific stakes and provide a basis for estimating later production. Production measures could later be verified by producer interviews.

A matter of some economic importance is labor use in the harvest of mussels. It is possible that the labor required to harvest green mussels may be dependent on size. Labor use may also be linked to the weight of mussels on each stake. The amount harvested per unit time is a constant function of the size of the harvest boat. If these relationships are valid the amount of green mussels from a given area and the amount of labor required to harvest it could be estimated from biological research data.

Seasonality of Price

Seasonal price movements are related to quantity available, condition, and to external factors such as abundance of substitute goods in the market. During certain festivals the price may change temporarily. Price monitoring allows the portrayal of "what is", but analytical techniques can be used to explain "why it is", and after other bioeconomic models have been constructed, the question "what if" can be answered.

During the daily interviews conducted using village interviewers some producers were queried regarding the price received per bucket. This practice also allowed an independent measure of the size of bucket used. This practice was discontinued when it became clear that prices did not vary on a daily basis.

The price paid by one collector for in-shell product and the price received for sorted output were determined monthly by the biological study group. Not surprisingly, the size of "large" green mussel changed during the growing season and prices declined as more of the product became available. It is intersting to note, however that the size sold as "medium" later in the season had been sold as "large" early in the season. Thus, "large", "medium" and "small" meant different things at different times.

It was assumed that the mussel amounts available to the observed mussels collectors were representative of the total amounts available. The price data showed little variation while the quantity data showed very large variation, much of which was observed as the variation in the number of buckets per boat. No statistical relationship could be determined between price and availability or between the percentage of large/small size and the price received. A study that included the total amount available to the wholesaler might establish that a price quantity relationship existed but at the level of individual collectors this was not the case.

A relationship between prices paid by collectors and the prices they received could not be established statistically (this does not imply that such a relationship is non-existent). The collector could have many reasons for maintaining a relatively constant price in his dealings with producers, and he received a relatively constant price from the wholesalers regardless of the quantities he supplied. Survey price data are given in Appendix Tables 18 to 20.

Producers were paid by the bucket and the price per bucket did not vary much over the 13-month survey period. The price was adjusted to a price per kilogram of product by determining the weight per bucket. Weight of green mussels per bucket determined the saleable quantity for the collector. Thus, variations in price should be associated with variations in weight per bucket as well as variation in price received by the collector.

Regression analysis indicated prices received by collectors for small green mussels were inversely related to the price collectors paid producers. ($F = 7.79$, $R^2 = 0.41$). The relationship was not a strong one.

Price paid/bucket	=	43.46 - 8.91 • Price rec'd for small green mussels
Standard error	:	(1.11) (3.16)

The equation indicates that for every 1 baht increase in price for small size received by the collector, price per bucket paid to the producer declines by 9.81 baht. The result is contrary to logic and theory. During the entire data collection period price for small green mussels changed by exactly 1 baht with the lowest prices recorded in January and February. Price per bucket changed by 16 baht with the lowest price recorded in September and the highest in March. If a valid relationship exists between the prices it is not apparent from the primary data.

Seasonality of Processing

The daily amount and value of processed green mussels were estimated using primary data collected from a sample of household processors in three villages at Ban Laem, Phetchaburi Province (see Appendix Table 21).

Determination of Processing Costs

Economists typically use an interview technique to determine costs and returns and a longitudinal study was conducted by the economics group of this study in which data on processing and processing costs were obtained from a sample group of processors. If the processor keeps adequate records and is willing to participate, this technique will obtain useful costs and returns for the enterprise being studied and differences between similar enterprises can be used as an estimate of relative efficiency. Averaging over all enterprises loses much of the benefit of the individual information.

Monthly interviews of processors were carried out to obtain processing costs incurred on the day of the interview or on the previous day. Daily data on the amounts processed were collected independently. Thus, the monthly interview data could establish costs of processing various amounts of green mussels.

The amount of family and hired labor, and the cost of hired labor were obtained during the monthly interview. Accurate labor inputs were difficult to obtain, particularly where they involved family labor for varying portions of the day and in varying amounts: the total labor force might consist of six people and total labor time on a particular day might total only four hours. Labor needs varied with the quantity of mussels to be processed, the tide cycle, the amount of available sunshine, and other factors. Generally the product landed in the morning would need to be shucked and made ready for drying during the same day.

Supplies used in processing were included in the data recorded during interviews. For butterfly mussels the supplies were limited: the green mussels were shucked with a knife and the meat was spread on racks for drying. When dried the butterfly would be carried to the local buyer in a pan or bucket. Boiling and drying supplies included fuel, salt and sacks for the finished product.

Capital investment was determined elsewhere but changes in capital items were recorded during the monthly interviews and these, whether increases or decreases, would be charged to the fixed cost components for the enterprise.

Estimating Costs and Returns

Cost and returns were computed per household and per kilogram of the processed product (Appendix Table 22). Costs per kilogram do not bear a constant relationship to the cost per household: household cost and returns are averaged over all households while costs and returns per kilogram are averaged over all kilograms processed. Neither figure is especially informative without supporting data on the firm. The daily data on processing indicated that butterfly processors in Samae Khao averaged less than 3 buckets of green mussel a day for processing, while the butterfly processors in Ban Laem were much more commercial and processed a higher number of buckets daily:

the cost of in-shell green mussel as an input per household was 55 per cent higher in Ban Laem even though the cost of the green mussels was lower.

The reported cost per kilogram of green mussels for boiled dry was significantly less than the cost for butterfly dried, indicating that a different size or source of green mussel was used for the two products. However, other research indicated that there was no difference between the final weights of the two products, so it is assumed that the input costs must differ (Chongpeepien et al. 1983). If the green mussels were sorted, and the small size was used for processing into boiled dried, the cost would be reduced, but not to the extent shown by the survey data. Other evidence indicates that processors do not use sorted mussels.

A second method was used to estimate processing costs for Samae Khao processors. The biological research group estimated the monthly weight of in-shell green mussels harvested. The price per bucket was independently determined by both the biological and economic groups. The biological group also determined the dry processed weight for each type of processed product for a measured quantity of green mussel raw material. The product was processed by villagers and weighed at the Brackishwater Fisheries Laboratory.

Processors pay about 18 baht for a bucket containing an average of 17.58/kg giving a cost per kg of 1.03 baht. After processing, the dried form comprised 5.13 per cent of the intial weight at landing and at this yield 1 kg of dried product would require 19.50 kg of raw material costing 19.97 baht for dried butterfly mussels. Processors received an average of 34 baht per kg during the study period. These measurements indicated that butterfly dried earned positive returns for the four-month period of the survey while returns on boiled dried did not cover the cost of the raw material. Since boiled dried processing does occur and relatively large plants are engaged in this, it would appear that some factor is missing from this analysis.

Capital investment is used as a base for the computation of depreciation, interest on capital, and as a factor in the analysis of differences in efficiency. Changes in capital would give the appearance of capital as a variable cost factor since the cost could change for individual firms on a monthly basis. This feature is true of many firms in which accounting is done on a monthly basis and is not unique to mussel processing firms. The changes would indicate whether the firm is replacing capital items or simply continuing to operate with the capital already in place. Many processors of boiled dried green mussels use covered structures made from local materials, others have more complex structures built specifically for the processing operations.

Operating costs are of primary concern to any business. If the firm has operating costs higher than revenue and the situation persists, then the firm cannot remain in business. The table row "Operating Profit" indicates cash returns over cash costs. The operating profit for butterfly was positive from June through September in both locations (Samae Khao and Ban Laem). However, operating profits for boiled mussels were all negative (see Appendix Table 22).

Among the costs recorded, the highest cash cost was for the in-shell green mussels. The use of family labor, a noncash cost, priced at the minimum wage rate, was next in terms of budget cost. The negative returns to capital and management indicate that enterprise revenues were not sufficient to pay the minimum wage for family labor. The family could, of course, choose to accept less than the minimum wage and continue operations. The minimum wage may not be an appropriate scale to use for the family labor engaged in green mussel processing. If elderly and young family members contribute their labor, or alternative employment is not available, then the opportunity cost for labor is essentially zero and any income over cash cost from green mussel processing is acceptable.

Evaluation of the Processing Activities

The processing cost analysis was designed to determine cost differentials for different kinds of processing Monitoring performance over time allowed consideration of factors that influence available supplies of the raw material.

Processing costs are strongly influenced by raw material cost (in-shell green mussels) and labor and fuel costs. Revenue, on the other hand, is determined from conversion ratios in processing, product prices and ouput. Processors can maintain control over labor cost by paying "piece rate", i.e., labor is paid on a unit-of-output basis. Other costs are less controllable.

Processors may incur short-run losses in order to maintain relationships with suppliers and/or buyers. In general processors would not be expected to operate when the majority of the mussels are in the spent stage following spawning.

The condition of the raw material is an important determinant of the costs and returns in processing and processors will respond to these conditions.

In all events the profitability of processing dried green mussels appears to be very low. The processing of butterfly dried is primarily a cottage industry to gain additional household income, but the boiled dried processing is largely a commercial operation.

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Appendix Table 1. Number of boats landing daily with harvested green mussel for duck feed (D) and for market in the morning (M) and evening (E) with total market number (T = M + E) by month at Samae Khao, Chachoengsao Province, June-December 1984.

Day	June				July				August				September			
	D	M	E	T	D	M	E	T	D	M	E	T	D	M	E	T
1	2	6	8	14	2	10	16	26	1	9	14	23	1	4	7	11
2	2	7	8	15	2	8	16	24	1	9	14	23	1	4	7	11
3	2	7	9	16	2	8	16	24	1	9	14	23	1	3	5	8
4	2	8	9	17	2	8	16	24	1	9	14	23	1		5	5
5	2	6	8	14	2	8	16	24	1	9	14	23	1		5	5
6	2	7	9	16	2	8	16	24	1	9	14	23	1		5	5
7	2	7	9	16	2	8	14	22	1	9	14	23	1		5	5
8	2	7	10	17	2	8	14	22	1	9	14	23	1		5	5
9	2	7	10	17	2	8	14	22	1	7	14	21	1		5	5
10	2	5	9	14	2	8	14	22	1	7	14	21	1		3	3
11	2	4	9	13	2	8	14	22	1	7	14	21	1		3	3
12	2	5	9	14	2	0	0	0	1	7	12	19	1		3	3
13	2	5	9	14	2	2	6	8	1	7	12	19	1		3	3
14	2	6	9	15	2	6	8	14	1	7	12	19	1		3	3
15	2	6	10	16	2	10	16	26	1	8	12	20	2		4	4
16	2	6	10	16	2	10	16	26	1	8	12	20	2		4	4
17	2	7	10	17	2	10	16	26	1	8	4	12	2		4	4
18	2	7	10	17	2	10	16	26	1	8	4	12	2		4	4
19	2	7	10	17	2	10	15	25	1	8	4	12	2		5	5
21	2	5	11	16	2	10	15	25	1	8	4	12	2		5	5
21	2	5	12	17	2	10	15	25	1	5	4	9	2		5	5
22	2	3	12	15	2	10	16	26	1	5	4	9	2		5	5
23	2	9	13	22	2	10	16	26	1	5	4	9	2		5	5
24	2	9	12	21	2	10	16	26	1	5	4	9			3	3
25	2	7	13	20	2	10	16	26	1	7	8	15			3	3
26	2	7	13	20	2	11	16	27	1	7	8	15			3	3
27	2	7	13	20	2	11	16	27	1	7	8	15			3	3
28	2	7	16	23	2	11	16	27	1	7	8	15			4	4
29	2	7	16	23	2	11	16	27	1	7	8	15			4	4
30	2	8	16	24	2	11	16	27	1	3	10	13			4	4
31	0	0	0	0	0	11	16	27	1	4	7	11				0
Totals	60	194	322	516	60	274	449	723	31	224	303	527	32	11	129	140

Day	October				November				December			
	D	M	E	T	D	M	E	T	D	M	E	T
1	1		3	3	1		1	1	3	15	5	20
2	1		3	3	1		1	1	3	15	5	20
3	1		3	3	1		1	1	3	14	5	19
4	1		3	3	1		1	1	3	13	5	18
5	1		3	3	1		1	1	4	15	6	21
6	1		2	2	1		1	1	4	15	6	21
7	1		2	2	1		2	2	4	15	6	21
8	1		2	2	1		2	2	4	15	6	21
9	1		2	2	1		2	2	4	15	6	21
10	1		3	3	1		2	2	4	15	6	21
11	1		3	3	2		5	5	4	15	6	21
12	1		3	3	2	11	5	16	4	13	3	16
13	1		3	3	2	12	5	17	4	13	3	16
14	1		2	2	2	16	5	21	4	13	3	16
15	1		2	2	2	16	3	19	3	4	3	7
16	1		2	2	2	16	3	19	3	10	5	15
17	1		2	2	2	16	3	19	3	10	5	15
18	1		2	2	2	14	4	18	3	10	5	15
19	1		1	1	2	16	4	20	3	10	5	15
21	1		1	1	2	12	4	16	3	10	5	15
21	1		1	1	2	12	4	16	3	8	5	13
22	1		1	1	2	17	5	22	3	8	5	13
23	1		1	1	2	17	5	22	3	8	5	13
24	1		2	2	0	16	5	21	3	7	6	13
25	1		2	2	1	16	5	21	3	7	6	13
26	1		2	2	2	15	5	20	3	10	6	16
27	1		2	2	2	15	5	20	3	10	6	16
28	1		2	2	2	15	5	20	3	10	6	16
29	1		2	2	2	15	5	20	3	10	6	16
30	1		2	2	3	15	5	20	5	12	6	18
31	1		1	1	0	0	0	0	5	12	6	18
Totals	31	0	65	65	48	282	104	386	107	357	162	519

Appendix Table 2. Number of boats landing daily with harvested green mussel for duck feed (D) and for market in the morning (M) and evening (E) with total market number (T = M + E) by month at Samae Khao, Chachoengsao Province, January-June 1985.

Day	January				February				March				April				May				June			
	D	M	E	T	D	M	E	T	D	M	E	T	D	M	E	T	D	M	E	T	D	M	E	T
1	5	12	6	18	4	2	10	12		10	2	12	1	9	16	25		10	10	20		9	15	24
2	5	0	6	6	4	2	10	12		10	2	12	1	9	16	25		10	10	20		9	15	24
3	5	0	6	6	4	10	5	15		10	2	12	1	9	16	25		10	10	20		8	15	23
4	5	0	6	6	4	10	5	15		10	2	12	1	9	16	25		10	15	25		8	15	23
5	5	2	10	12	1		7	7		10	4	14	1	9	16	25		10	15	25		8	15	23
6	5	2	10	12	1		7	7		10	4	14	1	9	16	25		10	15	25		10	16	26
7	5	2	10	12	1		7	7		10	4	14	1	9	14	23		10	15	25		10	16	26
8	5	2	10	12	1		7	7		10	4	14	1	9	14	23		10	15	25		8	14	22
9	5	2	10	12	1		7	7		10	4	14	1	7	14	21		10	15	25		9	14	23
10	5	2	8	10	1		7	7		10	4	14	1	7	14	21		10	15	25		9	14	23
11	5	2	8	10	1		7	7		10	4	14	1	7	14	21		10	12	22		9	14	23
12	5	2	10	12	1		7	7		10	4	14	1	7	0	7		8	10	18		12	16	28
13	5	2	10	12	1		7	7		10	4	14	1	7	8	15		8	10	18		10	16	26
14	5	2	10	12	1		7	7		10	4	14	1	7	16	23		8	10	18		10	16	26
15	5	2	10	12	1		6	6		12	5	17	1	8	16	24		8	10	18		10	12	22
16	5	2	10	12			6	6		12	5	17	1	8	16	24		8	10	18		10	12	22
17	5	2	10	12			6	6		12	5	17	1	8	16	24		9	10	19		10	12	22
18	5	2	8	10			8	8		12	5	17	1	8	15	23				0		10	12	22
19	5	2	8	10			8	8		12	5	17	1	8	15	23				0		10	12	22
21	5	0	8	8			8	8		12	5	17	1	8	16	24				0		[illegible]	12	21
21	5	1	10	11			8	8		12	5	17	1	5	16	21				0		9	13	22
22	5	1	10	11			8	8		13	5	18	1	5	16	21				0		10	16	26
23	5	1	8	9			8	8		10	5	15	1	5	16	21				0		10	16	26
24	5	1	8	9			8	8		10	5	15	1	5	16	21				0		10	16	26
25	5	1	8	9		8	2	10		10	5	15	1	7	16	23				0		10	16	26
26	5	1	8	9		10	2	12		10	7	17	1	7	16	23				0		10	16	26
27	5	1	10	11		10	2	12		10	7	17	1	7	16	23				0		10	16	26
28	5	1	10	11		8	2	10		10	10	20	1	7	16	23				0		10	16	26
29	5	1	10	11				0		10	10	20	1	0	16	16				0		10	16	26
30	5	1	10	11				0		10	10	20	0	0	16	16				0		10	14	24
31	5	1	10	11				0		10	8	18	0	0	16	16				0		0	0	0
Totals	155	53	276	329	27	60	182	242	0	327	155	482	29	210	460	670	0	159	207	366	0	287	438	725

Appendix Table 3. Number of boats landing green mussels daily at two landings in Ban Laem, Phetchaburi Province, June-December 1984.

Day	June			July			August			September			October			November			December		
	One	Two	Total	One	Two	Total	One	Two	Total	One	Two	Total	One	Two	Total	One	Two	Total	One	Two	Total
1	12	10	22	6	8	14	9	7	16	9	8	17	8	9	17	11	13	24	5	6	11
2	12	11	23	7	8	15	8	7	15	7	8	15	7	11	18	12	13	25	12	13	25
3	9	9	18	6	8	14	8	6	14	7	7	14	7	10	17	11	13	24	11	10	21
4	9	6	15	7	9	16	7	6	13	9	5	14	9	9	18	12	13	25	8	10	18
5	8	4	12	6	7	13	6	6	12	6	6	12	10	7	17	11	13	24	7	9	16
6	9	5	14	7	7	14	7	6	13	8	7	15	12	11	23	12	13	25	8	11	19
7	10	10	20	8	7	15	6	5	11	9	8	17	13	13	26	11	13	24	7	12	19
8	6	7	13	7	8	15	6	4	10	11	10	21	14	12	26	12	13	25	10	13	23
9	6	8	14	7	8	15	6	6	12	9	8	17	12	13	25	11	12	23	11	14	25
10	4	6	10	6	6	12	6	7	13	12	9	21	11	10	21	10	11	21	12	12	24
11	5	8	13	6	5	11	1	3	4	9	11	20	10	8	18	12	16	28	12	13	25
12	8	7	15	3	4	7	0	0	0	8	11	19	9	7	16	15	16	31	13	10	23
13	5	10	15	4	3	7	0	0	0	7	10	17	7	9	16	16	17	33	13	12	25
14	0	0	0	7	8	15	0	0	0	11	12	23	8	9	17	17	18	35	17	18	35
15	4	5	9	7	8	15	0	0	0	10	9	19	6	10	16	12	13	25	18	17	35
16	4	6	10	6	6	12	7	9	16	8	9	17	5	13	18	13	14	27	16	16	32
17	4	4	8	8	5	13	10	12	22	11	7	18	7	12	19	17	18	35	9	15	24
18	4	7	11	9	3	12	11	10	21	14	6	20	8	14	22	14	15	29	10	10	20
19	6	6	12	9	6	15	11	10	21	14	8	22	12	12	24	14	15	29	8	12	20
20	5	8	13	8	6	14	12	10	22	10	5	15	7	10	17	11	12	23	12	10	22
21	9	7	16	9	6	15	13	11	24	12	12	24	11	11	22	10	11	21	8	9	17
22	5	6	11	7	5	12	11	10	21	9	10	19	10	14	24	10	11	21	6	8	14
23	0	0	0	8	9	17	13	9	22	10	11	21	9	13	22	7	8	15	6	10	16
24	4	8	12	9	10	19	12	12	24	11	10	21	14	12	26	11	12	23	5	11	16
25	6	9	15	9	12	21	10	10	20	12	9	21	13	9	22	11	12	23	8	13	21
26	6	5	11	8	11	19	10	5	15	12	9	21	12	11	23	4	6	10	10	12	22
27	6	5	11	10	9	19	8	10	18	12	8	20	14	8	22	8	10	18	12	10	22
28	6	5	11	9	8	17	10	12	22	0	10	10	11	10	21	7	8	15	15	9	24
29	6	6	12	9	5	14	9	9	18	0	7	7	13	7	20	8	9	17	19	8	27
30	6	6	12	5	9	14	7	8	15	0	7	7	9	8	17	9	10	19	10	11	21
31	0	0	0	9	9	18	9	8	17	0	0	0	0	10	10	0	0	0	19	13	32
Totals	184	194	378	226	223	449	233	218	451*	267	257	524	298	322	620	339	378	717	337	357	694

Appendix Table 4. Number of boats landing green mussels daily at three landings in Ban Laem, Phetchaburi Province, January-June 1985.

Day	January landing				February landing				March landing				April landing				May landing				June landing			
	1	2	3	Total	1	2	3	Total	1	2	3	Total	1	2	3	Total	1	2	3	Total	1	2	3	Total
1	7	7	8	22	5	10	9	24	8	10	8	26	5	6	10	21	12	15	10	37	10	12	8	30
2	8	6	9	23	3	6	10	19	8	9	9	26	7	8	11	26	13	10	9	32	12	12	9	33
3	8	7	8	23	6	12	9	27	5	9	7	21	8	10	9	27	12	9	11	32	13	12	9	34
4	8	6	8	22	5	10	8	23	8	9	7	24	6	7	8	21	15	8	10	33	14	14	10	38
5	9	7	7	23	3	6	9	18	7	8	8	23	5	6	9	20	4	10	8	22	12	10	7	29
6	8	8	8	24	8	8	6	22	7	7	9	23	9	13	10	32	14	12	8	34	13	10	5	28
7	10	9	8	27	6	6	8	20	5	6	7	18	8	9	11	28	21	8	8	37	12	11	6	29
8	8	6	9	23	5	5	6	16	7	7	8	22	7	12	9	28	10	14	9	33	12	9	8	29
9	7	7	9	23	10	10	7	27	7	6	9	22	5	7	8	20	7	8	10	25	12	8	8	28
10	8	9	7	24	8	8	9	25	7	8	9	24	10	11	10	31	9	9	10	28	10	9	8	27
11	8	8	7	23	7	8	8	23	6	8	9	23	7	8	11	26	11	10	12	33	10	9	10	29
12	7	8	7	22	5	6	8	19	6	8	8	22	13	10	8	31	8	9	9	26	11	9	10	30
13	8	9	9	26	11	12	8	31	5	6	7	18	10	9	8	27	3	6	8	17	9	10	8	27
14	8	10	8	26	8	9	6	23	7	9	10	26	8	8	9	25	10	12	9	31	9	10	8	27
15	9	12	9	30	6	7	9	22	8	8	8	24	9	11	7	27	7	8	10	25	12	11	9	32
16	7	6	10	23	5	8	6	19	8	9	7	24	11	13	8	32	5	6	7	18	13	10	8	31
17	9	5	8	22	6	8	5	19	8	7	9	24	10	12	6	28	6	14	8	28	13	8	6	27
18	7	7	8	22	8	8	6	22	10	12	7	29	13	11	10	34	6	7	8	21	12	8	6	26
19	7	8	9	24	6	7	6	19	9	10	6	25	8	10	9	27	7	8	9	24	11	9	6	26
20	8	9	9	26	5	6	5	16	9	10	8	27	12	14	8	34	5	6	8	19	11	8	5	24
21	7	8	7	22	8	11	7	26	8	8	8	24	10	12	8	30	18	15	11	44	11	11	6	28
22	8	9	8	25	8	9	9	26	8	8	6	22	12	13	9	34	15	13	12	40	9	11	7	27
23	10	8	9	27	8	9	8	25	7	8	9	24	13	15	7	35	9	10	10	29	8	10	7	25
24	7	7	7	21	5	8	8	21	8	7	8	23	12	8	7	27	5	8	11	24	9	12	6	27
25	8	6	7	21	8	11	8	27	6	7	7	20	13	9	9	31	7	9	9	25	12	12	6	30
26	6	7	8	21	8	9	7	24	5	7	6	18	10	13	11	34	13	12	8	33	14	12	8	34
27	7	5	7	19	7	8	9	24	6	8	9	23	11	8	10	29	0	0	10	10	14	16	8	38
28	9	9	7	25	5	8	7	20	6	9	6	21	9	8	8	25	0	0	11	11	14	14	7	35
29	8	8	8	24	0	0		0	6	8	7	21	10	9	7	26	0	0	9	9	12	12	7	31
30	6	6	6	18	0	0		0	8	7	7	22	7	7	8	22	0	0	10	10	10	12	7	29
31	9	7	7	23	0	0		0	8	7	9	24	0	0	0	0	0	0	10	10	0	0	0	0
Totals	244	234	246	724	183	233	211	627	221	250	242	713	278	297	263	838	252	256	292	800	344	321	223	888

Appendix Table 5. Statistical measures for the total number of boats harvesting green mussels for market at Samae Khao, Chachoengsao Province, June 1984-June 1985.

	No. boats				Coefficient
	Total	Min.	Max.	Mean	of variation
June	516	13	24	17.20	17.33
July	723	0	27	23.32	24.72
August	527	9	23	17.00	29.77
September	140	3	11	4.66	42.97
October	65	1	3	2.09	32.85
November	386	1	22	12.86	67.08
December	519	7	21	16.74	19.83
January	329	6	18	10.61	21.36
February	242	6	15	8.64	29.37
March	482	12	20	15.54	14.86
April	654	7	25	21.80	17.38
May	366	0	25	11.80	92.76
June	725	21	28	24.16	7.78

Appendix Table 6. Analysis of variance of number of boats harvesting green mussels at two landings at Ban Laem, Phetchaburi Province, June-December 1984.

Source of variation	Sum squared	Degrees of freedom	Mean squared	F
Boats	3,399.17	6	566.53	21.41
Error	5,478.14	207	26.46	
Total	8,877.31	213		

Appendix Table 7. Statistical measures for number of boats landing green mussels, buckets of production, and average buckets per boat at two landings at Ban Laem, Phetchaburi Province, June-December 1984.

	Total	Min.	Max.	Mean	Coefficient of variation
June 1984					
Boats, site 1	184	0	12	6.13	45.28
Buckets	38,613	0	2,149	1,287.10	33.72
Buckets/boat	–	0	366	213.74	40.79
Boats, site 2	194	0	11	6.46	38.86
Buckets	43,383	0	2,934	1,446.13	44.67
Total boats	378	0	23	12.60	38.31
July 1984					
Boats, site 1	226	3	10	7.29	21.81
Buckets	60,000	883	3,198	1,935.48	32.58
Buckets/boat	–	147	394	266.20	23.24
Boats, site 2	223	3	12	7.19	29.41
Buckets	59,280	673	3,522	1,912.26	38.76
Total boats	449	7	21	14.48	21.03
August 1984					
Boats, site 1	233	0	13	7.51	50.67
Buckets	90,655	0	5,655	2,924.35	54.92
Buckets/boat	–	0	542	340.86	43.69
Boats, site 2	218	0	12	7.03	50.62
Buckets	86,169	0	5,821	2,779.66	57.85
Total boats	451	0	24	14.54	49.40
September 1984					
Boats, site 1	267	0	14	8.89	40.02
Buckets	88,481	0	4,662	2,949.36	37.41
Buckets/boat	–	0	518	310.79	42.04
Boats, site 2	257	5	12	8.56	21.87
Buckets	88,367	1,501	4,892	2,945.58	31.84
Total boats	524	7	24	17.46	24.36
October 1984					
Boats, site 1	298	0	14	9.61	31.89
Buckets	90,311	0	4,242	2,913.25	28.77
Buckets/boat	–	0	426	298.51	22.32
Boats, site 2	322	7	14	10.38	19.51
Buckets	99,185	2,107	5,971	3,199.54	24.14
Total boats	620	10	26	20.00	18.49
November 1984					
Boats, site 1	339	4	17	11.30	25.25
Buckets	92,133	1,478	4,522	3,071.10	28.11
Buckets/boat	–	157	521	277.53	24.55
Boats, site 2	378	6	18	12.60	22.31
Buckets	103,097	1,889	4,848	3,436.57	26.22
Total boats	717	10	35	23.90	23.55
December 1984					
Boats, site 1	337	5	19	10.87	35.95
Buckets	80,489	1,002	4,532	2,596.42	32.88
Buckets/boat	–	114	378	247.26	22.01
Boats, site 2	357	6	18	11.51	22.80
Buckets	86,610	1,377	4,559	2,793.87	26.17
Total boats	694	11	35	22.38	25.00

Appendix Table 8. Number of buckets per boat by month at Samae Khao, Chachoengsao Province, and Ban Laem, Phetchaburi Province, June 1984-June 1985.

Month	Samae Khao Buckets/boat	Ban Laem Buckets/boat*	
June	181.60	213.74	(106.87)
July	183.00	266.20	(133.10)
August	140.00	340.86	(170.43)
September	125.00	310.79	(152.39)
October	125.00	298.51	(149.25)
November	140.00	277.53	(138.76)
December	165.00	247.26	(123.13)
January	137.00	122.00	
February	137.00	80.91	
March	125.00	98.28	
April	160.00	54.08	
May	152.00	46.35	
June	180.00	94.28	
Total	150.05	188.52	

*Numbers in parenthesis are theoretical adjustments to 20-liter bucket.

Appendix Table 9. Statistical measures for monthly average buckets at Samae Khao, Chachoengsao Province and Ban Laem, Phetchaburi Province, January-June 1985.

	Min.	Max.	Mean	Coefficient of variation
Samae Khao	125.00	183.00	150.04	13.99
Ban Laem	46.35	340.86	188.52	54.97

Appendix Table 10. Mussel weight components from production and processing at Samae Khao, Chachoengsao Province, Thailand, June 1984-June 1985.

Month	Boat buckets	Average weight (kg)	Sample 1 Weight (kg)	In-shell (kg)	Waste (kg)	Wet meat (kg)	Dry (kg)	In-shell (%)	Meat (%)	Dry (%)
June	181.60	17.58	17.55	14.50	3.05	4.33	0.90	82.62	24.67	5.13
July	183.00	16.71	16.25	11.60	4.65	3.50	0.88	71.38	21.54	5.42
August	140.00	16.95	13.60	9.30	4.30	3.43	0.53	68.38	25.22	3.90
September	125.00	14.22	14.25	9.15	5.10	2.58	0.73	64.21	18.11	5.12
October	125.00	10.90	11.65	9.55	2.10	2.30	0.70	81.97	19.74	6.01
November	140.00	13.02	13.90	11.00	2.90	2.90	0.75	79.14	20.86	5.40
December	165.00	15.08	9.75	7.90	1.85	1.98	0.78	81.03	20.31	8.00
January	137.00	15.51	14.40	9.60	4.80	2.30	0.73	66.67	15.97	5.07
February	137.00	14.91	14.65	8.05	6.60	2.50	0.89	54.95	17.06	6.08
March	125.00	15.50	14.80	10.65	4.15	3.00	0.83	71.96	20.27	5.61
April	160.00	16.55	14.10	10.90	3.20	4.03	1.15	77.30	28.58	8.16
May	152.00	15.78	15.20	11.20	4.00	2.80	0.59	73.68	18.42	3.85
June	180.00	16.90	16.65	13.15	3.50	3.23	0.67	78.98	19.40	4.02
Total	150.05	15.47	14.56	10.66	3.90	3.08	0.82	73.32	21.05	5.63

Appendix Table 11. Mussel weight components from production and processing at Samae Khao, Chachoengsao Province, Thailand, June 1984-June 1985.

Month	Sample 2 Weight (kg)	Meat (kg)	Boiled (kg)	Dry (kg)	Meat (%)	Boiled (%)	Dry (%)
June	26.80	4.90	4.85	2.75	18.28	18.10	10.26
July	28.50	3.90	3.60	2.60	13.68	12.63	9.12
August	35.50	4.25	3.95	2.05	11.97	11.13	5.77
September	25.40	3.60	3.50	1.87	14.17	13.78	7.35
October	27.10	2.90	2.80	1.50	10.70	10.33	5.54
November	24.20	3.80	3.48	1.91	15.70	14.38	7.89
December	30.20	3.15	2.85	1.68	10.43	9.44	5.56
January	23.80	3.10	2.70	1.55	13.03	11.34	6.51
February	30.00	5.45	5.40	3.00	18.17	18.00	10.00
March	29.80	5.40	5.10	2.10	18.12	17.11	7.05
April	26.40	5.60	5.10	3.16	21.21	19.32	11.97
May	23.80	3.50	3.10	1.90	14.71	13.03	7.98
June	29.80	5.80	5.30	2.85	19.46	17.79	9.56

Appendix Table 12. Mussel weight components from production and processing at Ban Laem, Phetchaburi Province, June 1984-June 1985.

Month	Sample (kg)	Large Total (kg)	Large Product (kg)	Large Waste (kg)	Small Total (kg)	Small Product (kg)	Small Waste (kg)	Waste (kg)	Other (kg)	Proportion Large (%)	Proportion Small (%)
June	26.95	10.95	10.40	0.55	10.95	10.50	0.45	4.15	0.90	38.59	38.96
July	26.85	11.50	10.85	0.65	13.25	12.50	0.75	1.25	0.85	40.41	46.55
August	29.20	18.20	16.80	1.40	6.85	6.10	0.75	2.90	1.25	57.53	20.89
September	27.40	9.35	8.70	0.65	14.10	12.55	1.55	3.10	0.85	31.75	45.80
October	30.70	8.95	8.00	0.95	14.20	12.70	1.50	3.70	3.85	26.06	41.37
November	24.95	13.15	11.50	1.65	7.70	6.75	0.95	3.50	0.60	46.09	27.05
December	32.25	14.30	12.35	1.95	14.10	13.50	0.60	2.50	1.35	38.29	41.86
January	28.65	9.70	8.80	0.90	12.80	11.75	1.05	4.50	1.65	30.72	41.01
February	28.85	12.40	11.50	0.90	9.95	9.20	0.75	5.20	1.30	39.86	31.89
March	25.20	14.25	13.20	1.05	7.25	7.10	0.15	2.75	0.95	52.38	28.17
April	27.90	7.25	7.25	0.45	13.10	12.30	0.80	6.70	0.85	25.99	44.09
May	30.75	9.60	9.50	0.10	14.40	14.10	0.30	5.30	1.45	30.89	45.85
June	28.45	12.00	11.45	0.55	12.20	11.60	0.60	2.70	1.55	40.25	40.77
Average	28.12	11.61	10.79	0.85	10.88	10.18	0.71	4.37	1.25	38.65	35.96

Appendix Table 13. Mussel weight components from production and processing at Ban Laem, Phetchaburi Province, June 1984-June 1985.

Month	Sample (kg)	Shucked flesh Large (kg)	Shucked flesh Small (kg)	Cleaned Large (%)	Cleaned Small (%)	Sorted cleaned Large (%)	Sorted cleaned Small (%)	Sorted uncleaned Large (%)	Sorted uncleaned Small (%)	Total (%)	Dry (%)
June	2.00	0.60	0.63	30.00	31.50	28.49	30.21	11.58	12.27	23.85	0.05
July	2.00	0.68	0.68	34.00	34.00	32.08	32.08	13.74	15.83	29.57	0.07
August	2.00	0.58	0.60	29.00	30.00	26.77	26.72	16.68	6.27	22.95	0.04
September	2.00	0.65	0.63	32.50	31.50	30.24	28.04	10.32	14.43	24.75	0.04
October	2.00	0.78	0.78	39.00	39.00	34.86	34.88	10.16	16.13	26.30	0.07
November	2.00	0.68	0.58	34.00	29.00	29.73	25.42	15.67	7.85	23.52	0.04
December	2.00	0.65	0.63	32.50	31.50	28.07	30.16	12.45	13.19	25.63	0.04
January	2.00	0.60	0.55	30.00	27.50	27.22	25.24	9.21	11.28	20.49	0.03
February	2.00	0.55	0.55	27.50	27.50	25.50	25.43	10.96	8.77	19.73	0.03
March	2.00	0.51	0.58	25.50	29.00	23.62	28.40	13.36	8.17	21.53	0.04
April	2.00	0.60	0.63	30.00	31.50	30.00	29.58	7.80	13.89	21.68	0.04
May	2.00	0.68	0.68	34.00	34.00	33.65	33.29	10.50	15.59	26.09	0.06
June	2.00	0.64	0.68	32.00	34.00	30.53	32.33	12.88	13.86	26.74	0.06
Average	2.00	0.61	0.62	30.69	31.03	28.61	29.01	11.75	11.34	23.09	0.04

Appendix Table 14. Mussel weight components from production and processing at Ban Laem, Phetchaburi Province, June 1984-June 1985.

Month	Large Total (kg)	Large Flesh (kg)	Large Dry (kg)	Small Total (kg)	Small Flesh (kg)	Small Dry (kg)	Average Total (kg)	Average Flesh (kg)	Average Dry (kg)	Computed proportions (decimal) Flesh	Dry	Dry to flesh	Moist[1]	30%[2] (kg)	Bfly
June	26.14	6.27	1.08	18.18	4.39	0.74	22.16	5.33	0.91	0.24	0.04	0.17	0.83	1.30	0.06
July	30.03	8.23	1.57	17.69	4.98	0.95	23.86	6.61	1.26	0.28	0.05	0.19	0.81	1.80	0.08
August	36.64	7.95	1.16	20.48	4.06	0.67	28.56	6.01	0.92	0.21	0.03	0.15	0.85	1.31	0.05
September	33.06	8.22	1.35	21.42	5.09	0.83	27.24	6.66	1.09	0.24	0.04	0.16	0.84	1.56	0.06
October	38.24	9.61	2.56	23.51	6.00	1.62	30.88	7.81	2.09	0.25	0.07	0.27	0.73	2.98	0.10
November	39.97	8.72	1.48	30.90	7.33	1.23	35.44	8.03	1.35	0.23	0.04	0.17	0.83	1.93	0.05
December	34.25	5.78	1.18	28.52	4.88	0.94	31.39	5.33	1.06	0.17	0.03	0.20	0.80	1.52	0.05
January	40.62	7.65	1.12	22.60	4.23	0.65	31.61	5.94	0.89	0.19	0.03	0.15	0.85	1.26	0.04
February	30.45	5.30	0.90	21.17	3.63	0.41	25.81	4.47	0.66	0.17	0.03	0.15	0.85	0.94	0.04
March	37.83	8.23	1.14	20.29	5.56	0.66	29.06	6.90	0.90	0.24	0.03	0.13	0.87	1.28	0.04
April	25.01	6.26	1.11	19.70	4.70	0.87	22.36	5.48	0.99	0.25	0.04	0.18	0.82	1.41	0.06
May	24.61	7.94	1.29	16.63	5.13	0.85	20.62	6.54	1.07	0.32	0.05	0.16	0.84	1.53	0.07
June	25.99	6.53	1.33	16.21	4.33	0.86	21.10	5.43	1.09	0.26	0.05	0.20	0.80	1.56	0.07

[1] Moist is the computed percentage of moisture in wet weight.
[2] 30% is the computed weight at 30 per cent moisture.

Appendix Table 15. Number of boats, buckets per boat, weight per bucket, and total weight for green mussel harvested for market at Samae Khao, Chachoengsao Province, Thailand, June 1984-June 1985.

Month	Boats (no.)	Bucket/boat (no.)	Weight/bucket (kg)	Production (kg)
June	516	181.60	17.58	1,647,344
July	723	183.00	16.71	2,174,639
August	527	140.00	16.95	1,250,571
September	140	125.00	14.22	248,850
October	65	125.00	10.90	88,563
November	386	140.00	13.02	703,601
December	519	165.00	15.08	1,291,376
January	329	137.00	15.51	699,082
February	242	137.00	14.91	494,326
March	482	125.00	15.50	933,875
April	670	160.00	16.55	1,774,160
May	366	152.00	15.78	877,873
June	725	180.00	16.90	2,205,450
Average	5,690	150.05	15.47	14,389,710

Appendix Table 16. Number of boats, buckets per boat, weight per bucket, and total harvested weight of green mussel at two landings, June 1984-December 1984 and three landings, January 1985-June 1985, Ban Laem, Phetchaburi Province.

Month	Boats (no.)	Bucket/boat (no.)	Weight/bucket (kg)	Production (kg)
June	378	213.74	12.69	1,040,543
July	449	266.20	13.22	1,576,883
August	451	340.86	14.39	2,544,508
September	524	310.79	13.25	2,343,243
October	620	298.51	14.03	2,658,640
November	717	277.53	13.42	2,619,989
December	694	247.26	15.75	2,631,814
January	724	122.00	13.85	1,223,343
February	627	80.91	14.50	738,719
March	713	98.28	12.71	890,169
April	838	54.08	14.19	643,313
May	800	46.35	15.24	627,113
June	888	94.28	14.75	1,228,029
Total	8,423	188.52	13.93	20,766,306

Appendix Table 17. Total production, percentage large size, quantity of large size, percentage small size, quantity of small size, landed at two landings from June 1984-December 1984 and three landings from January 1985-June 1985, Ban Laem, Phetchaburi Province.

Month	Total production (kg)	Large (%)	Large Quantity (kg)	Small (%)	Small Quantity (kg)
June	1,040,543	39	401,545	39	405,406
July	1,576,883	40	637,213	47	734,117
August	2,544,508	58	1,463,963	21	531,558
September	2,343,243	32	744,022	46	1,073,274
October	2,658,640	26	692,805	41	1,099,828
November	2,619,989	46	1,207,610	27	708,815
December	2,631,814	38	1,007,842	42	1,101,689
January	1,223,343	31	375,756	41	501,720
February	738,719	40	294,463	32	235,571
March	890,169	52	466,279	28	250,801
April	643,313	26	167,169	44	283,611
May	627,113	31	193,742	46	287,554
June	1,228,029	40	494,233	41	500,708
Total	20,766,306	39	8,146,645	36	7,714,653

Appendix Table 18. Price received by processors of green mussel products at Samae Khao, Chachoengsao Province, Thailand, June 1984-June 1985.

Month	Fresh in-shell B/bck	Duck feed B/bck	Fresh shucked B/kg	Butterfly Boiled B/kg	Butterfly Dried B/kg	Boiled dried B/kg
June	18.00	10.00	12.00	20.00	40.00	20.00
July	23.00	10.00	12.00	18.00	38.00	21.00
August	18.00	10.00	13.00	15.00	38.00	22.00
September	20.00	10.00	13.00	18.00	38.50	20.00
October	20.00	10.00	13.00	20.00	39.50	20.00
November	20.00	10.00	12.00	18.00	33.00	20.00
December	18.00	10.00	13.00	25.00	30.00	20.00
January	18.00	10.00	12.00	18.00	30.00	20.00
February	20.00	10.00	12.00	14.00	35.00	20.00
March	20.00	10.00	12.00	14.00	35.00	25.00
April	20.00	10.00	10.00	15.00	35.00	20.00
May	20.00	10.00	10.00	15.00	32.00	20.00
June	18.00	10.00	12.00	15.00	30.00	20.00
Average	19.68	10.00	12.00	17.50	35.29	21.29

Appendix Table 19. Weight and price received by producers and processors at Ban Laem, Phetchaburi Province, June 1984-June 1985.

Month	Price bucket B/bck	Weight bucket kg	In-shell B/kg	Large B/kg	Small B/kg	Butterfly B/kg	Boiled dried B/kg
June	20	12.69	1.58	6.00	3.00	38.00	18.00
July	20	13.22	1.51	4.50	3.00	35.00	18.00
August	16	14.39	1.11	4.00	2.50	31.00	17.00
September	14	13.25	1.06	4.00	2.50	30.00	
October	15	14.03	1.07	4.00	2.50	28.00	
November	16	13.42	1.19	4 00	3.00	30.00	
December	20	15.75	1.27	4.00	2.50	30.00	
January	20	13.85	1.44	4.00	3.00	38.00	
February	30	14.50	2.07	3.00	2.00	38.00	
March	30	12.71	2.36	4.00	2.00	38.00	
April	26	14.19	1.83	4.00	2.00	36.00	
May	22	15.24	1.44	4.00	2.50	34.00	22.00
June	22	14.75	1.49	3.50	2.50	30.00	22.00
Average	22.56	13.93	1.63			33.54	19.40

Appendix Table 20. Price received by producers per bucket and processors per kilogram of small green mussel at Ban Laem, Phetchaburi Province, June 1984-June 1985.

Month	Price bucket B/bck	Small B/kg
June	20	3.00
July	20	3.00
August	16	2.50
September	14	2.50
October	15	2.50
November	16	3.00
December	20	2.50
January	20	3.00
February	30	2.00
March	30	2.00
April	26	2.00
May	22	2.50
June	22	2.50

Appendix Table 21. Processing at Ban Laem, Phetchaburi Province, June 1984.

Day	M 3 BD Sample buckets	M 3 BD No	M 6 BD Sample buckets	M 6 BD No	M 7 BD Sample buckets	M 7 BD No	M 6 DB Sample buckets	M 3 Process buckets	M 6 BD Process buckets	M 7 Process buckets	M 6 DB Process buckets	Total butterfly buckets	Total boiled buckets
1	73	10	121	10	49	10		365.00	399	176	0.00	1,011.85	0.00
2	76	10	121	10	49	10		380.00	399	176	0.00	1,027.98	0.00
3	78	10	121	10	51	10	130	390.00	399	183	390.00	1,046.48	780.00
4	78	10	121	10	55	10	185	390.00	399	198	555.00	1,061.97	1,110.00
5	73	10	121	10	48	10	230	365.00	399	172	690.00	1,007.97	1,380.00
6	0	0	45	4	0	0		0.00	148	0	0.00	159.73	0.00
7	81	10	121	10	53	10	55	405.00	399	190	165.00	1,070.36	330.00
8	84	10	121	10	53	10	350	420.00	399	190	1,050.00	1,086.49	2,100.00
9	81	10	121	10	50	10	205	405.00	399	180	615.00	1,058.74	1,230.00
10	80	10	121	10	52	10	228	400.00	399	187	684.00	1,061.11	1,368.00
11	82	10	121	10	59	10	550	410.00	399	212	1,650.00	1,098.97	3,300.00
12	87	10	121	10	62	10	175	435.00	399	223	525.00	1,137.48	1,050.00
13	89	10	45	4	0	0		445.00	148	0	0.00	638.39	0.00
14	82	10	121	10	54	10		410.00	399	194	0.00	1,079.61	0.00
15	89	10	121	10	71	10	125	445.00	399	255	375.00	1,183.09	750.00
16	0	0	121	10	69	10		0.00	399	248	0.00	696.69	0.00
17	91	9	121	10	66	10	130	455.00	399	237	390.00	1,174.48	780.00
18	90	10	121	10	60	10	240	450.00	399	216	720.00	1,145.87	1,440.00
19	86	10	121	10	55	10		430.00	399	198	0.00	1,104.99	0.00
20	81	10	121	10	55	10		405.00	399	198	0.00	1,078.10	0.00
21	5	1	45	4	0	0		25.00	148	0	0.00	186.62	0.00
22	70	10	121	10	65	10	100	350.00	399	234	300.00	1,057.67	600.00
23	75	10	121	10	54	10	110	375.00	399	194	330.00	1,041.96	660.00
24	68	10	121	10	52	10		340.00	399	187	0.00	996.57	0.00
25	54	8	123	10	25	5	85	270.00	405	90	255.00	823.83	510.00
26	55	8	130	10	46	10	230	275.00	429	165	690.00	935.37	1,380.00
27	32	5	40	4	0	0	135	160.00	132	0	405.00	314.08	810.00
28	75	10	122	10	61	10	110	375.00	402	219	330.00	1,072.62	660.00
29	53	7	124	10	72	10	110	265.00	409	259	330.00	1,003.99	660.00
30	43	5	118	10	76	10	100	215.00	389	273	300.00	944.40	600.00
Total	2,102		3,454		1,528		3,713	10,510.00	11,398	5,500	11,139.00	29,481.95	22,278.00

Day	In-shell Total fresh kg	In-shell Value fresh Baht	Processed Butterfly kg	Processed Boiled kg	Value Butterfly Baht	Value Boiled Baht	Net over in-shell Butterfly Baht	Net over in-shell Boiled Baht	Net Total Baht
1	12,840	20,236	584	0.00	22,208.10	0.00	9,367.78	0.00	9,367.78
2	13,045	20,559	593	0.00	22,562.22	0.00	9,517.15	0.00	9,517.15
3	23,178	36,529	604	450.51	22,968.28	8,109.25	9,688.44	−1,788.95	7,899.49
4	27,562	43,439	613	641.12	23,308.23	11,540.09	9,831.84	−2,545.81	7,286.02
5	30,303	47,759	582	797.06	22,123.11	14,347.13	9,331.93	−3,165.07	6,166.86
6	2,026	3,194	92	0.00	3,505.80	0.00	1,478.81	0.00	1,478.81
7	17,770	28,007	618	190.60	23,492.37	3,430.84	9,909.51	−756.86	9,152.65
8	40,436	63,729	627	1,212.92	23,846.50	21,832.60	10,058.89	−4,816.40	5,242.48
9	29,044	45,774	611	710.43	23,237.41	12,787.60	9,801.96	−2,821.04	6,980.92
10	30,825	48,582	612	790.13	23,289.35	14,222.38	9,823.87	−3,137.54	6,686.33
11	55,822	87,979	634	1,906.02	24,120.35	34,308.37	10,174.40	−7,568.63	2,605.77
12	27,759	43,749	656	606.46	24,965.52	10,916.30	10,530.91	−2,408.20	8,122.71
13	8,101	12,767	368	0.00	14,011.38	0.00	5,910.25	0.00	5,910.25
14	13,700	21,592	623	0.00	23,695.40	0.00	9,995.15	0.00	9,995.15
15	24,530	38,661	683	433.19	25,966.50	7,797.36	10,953.14	−1,720.14	9,233.00
16	8,840	13,933	402	0.00	15,290.94	0.00	6,449.99	0.00	6,449.99
17	24,802	39,089	678	450.51	25,777.63	8,109.25	10,873.47	−1,788.95	9,084.52
18	32,814	51,717	661	831.72	25,149.66	14,970.92	10,608.58	−3,302.68	7,305.91
19	14,022	22,099	638	0.00	24,252.55	0.00	10,230.17	0.00	10,230.17
20	13,681	21,562	622	0.00	23,662.35	0.00	9,981.21	0.00	9,981.21
21	2,368	3,732	107	0.00	4,096.00	0.00	1,727.77	0.00	1,727.77
22	21,035	33,153	610	346.55	23,213.80	6,237.88	9,792.00	−1,376.12	8,415.89
23	21,597	34,039	601	381.20	22,869.12	6,861.67	9,646.61	−1,513.73	8,132.88
24	12,646	19,931	575	0.00	21,872.86	0.00	9,226.37	0.00	9,226.37
25	19,926	26,676	475	294.57	18,081.41	5,302.20	7,627.07	−1,169.70	6,457.37
26	29,382	46,307	540	797.06	20,529.56	14,347.13	8,659.74	−3,165.07	5,494.68
27	14,264	22,481	181	467.84	6,893.55	8,421.14	2,907.83	−1,857.76	1,050.07
28	21,986	34,652	619	381.20	23,541.95	6,861.67	9,930.42	−1,513.73	8,416.70
29	21,116	33,279	579	381.20	22,035.76	6,861.67	9,295.08	−1,513.73	7,781.36
30	19,598	30,888	645	346.55	20,727.87	6,237.88	8,743.39	−1,376.12	7,367.28
Total	656,833	1,035,198	17,028	12,867.37	647,073.15	231,612.66	272,947.22	−51,095.16	221,852.06

Appendix Table 22. Cost and returns from processing dried green mussels at Samae Khao, Chachoengsao Province and Ban Laem, Phetchaburi Province, by dried form and month June-September 1984.

	Samae Khao June Dried Bfly kg	Samae Khao June Dried Boil kg	Ban Laem June Dried Bfly kg	Ban Laem June Dried Boil kg	Samae Khao July Dried Bfly kg	Samae Khao July Dried Boil kg	Ban Laem July Dried Bfly kg	Ban Laem July Dried Boil kg	Samae Khao August Dried Bfly kg	Samae Khao August Dried Boil kg	Ban Laem August Dried Bfly kg	Ban Laem August Dried Boil kg	Samae Khao September Dried Bfly kg	Samae Khao September Dried Boil kg	Ban Laem September Dried Bfly kg
ITEM															
Variable cost:															
In-shell mussel	19.97	19.97	26.85	26.85	25.42	25.42	20.09	20.09	27.25	27.25	24.25	24.25	27.46	27.46	18.45
Supplies	1.99	1.62	2.02	1.73	1.80	1.60	1.94	1.49	1.73	1.30	1.56	2.00	1.47	2.50	0.76
Hired labor	0.00	1.28	0.61	3.67	0.00	1.15	0.58	3.67	0.00	1.08	0.77	3.67	0.00	2.78	1.56
Subtotal	21.96	22.87	29.48	32.25	27.22	28.17	22.61	25.25	28.98	29.63	26.58	29.92	28.93	32.74	20.77
Fixed cost:															
Depreciation	0.38	0.13	0.40	0.05	0.42	0.20	0.25	0.05	0.52	0.23	0.25	0.12	0.41	0.87	0.52
Subtotal	0.38	0.13	0.40	0.05	0.42	0.20	0.25	0.05	0.52	0.23	0.25	0.12	0.41	0.87	0.52
Owned inputs:															
Family labor	25.23	0.71	32.81	1.57	21.26	0.56	26.23	1.58	22.39	0.75	25.07	1.04	22.75	1.47	41.31
Interest on operating capital	3.44	1.70	3.11	1.65	2.94	1.49	1.93	1.62	3.02	1.27	2.45	1.68	2.94	1.97	3.21
Interest on fixed capital	0.05	0.02	0.05	0.01	0.44	0.02	0.03	0.01	0.06	0.03	0.03	0.01	0.45	0.10	0.06
Subtotal	28.72	2.43	35.97	3.23	24.64	2.07	28.19	3.21	25.47	2.05	27.55	2.73	26.14	3.54	44.58
Total cost	51.06	25.43	65.85	35.53	52.28	30.44	51.05	28.51	54.97	31.91	54.38	32.77	55.48	37.15	65.87
Gross revenue	38.56	20.00	35.37	18.00	37.84	21.00	33.02	17.00	38.00	22.00	29.64	17.00	38.50	20.00	28.87
Return:															
Operating profit	16.60	−2.87	5.89	−14.25	10.62	−7.17	10.41	−8.25	9.02	−7.63	3.06	−12.92	9.57	−12.74	8.10
Net income	16.22	−3.00	5.49	−14.30	10.20	−7.37	10.16	−8.30	8.50	−7.86	2.81	−13.04	9.16	−13.61	7.58
Return to capital and management	−9.01	−3.71	−27.32	−15.87	−11.06	−7.93	−16.07	−9.88	−13.89	−8.61	−22.26	−14.08	−13.59	−15.08	−33.73
Net profit	−12.50	−5.43	−30.48	−17.53	−14.44	−9.44	−18.03	−11.51	−16.97	−9.91	−24.74	−15.77	−16.98	−17.15	−37.00

Procedures for Standardizing Bioeconomic Data on the Various Products from Green Mussels in Thailand*

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Abstract

The paper describes a procedure for converting the various prices of different green mussel (*Perna viridis*, L.) product forms into a uniform "price per unit of weight" to enable direct comparison of product profitability. The procedure is illustrated using the examples of three product forms: fresh in-shell, dried butterfly and boiled.

Introduction

In terms of quantity, the green mussel (*Perna viridis*, L.) is the major shellfish species cultured in Thailand. It reaches the market in a number of product forms of which the most common are fresh in-shell, fresh shucked, boiled, dried butterfly and brined.

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Prices vary considerably between the various product forms. For example, in 1984-1985 the retail price of fresh in-shell green mussel was around 8 to 10 Baht/kg, while the dried butterfly form could cost as much as 60 Baht/kg.

The raw product is purchased from producers by volume (by the bucketful) but thereafter all transactions are by weight. Processing (sorting, cleaning, shucking, drying/boiling) reduces the volume and weight substantially but not uniformly between the various product forms. For example, in preparing fresh in-shell mussels for sale about 17% of the harvest weight is lost when trash and encrustations are removed; the dried butterfly form is only about 6% of the raw product weight. These two examples make apparent the difficulties faced in comparing the product types and in determining the income they might generate.

The Concept of a "Unit Price"

Fisheries statisticians often have to deal with similar kinds of problems, when for instance summarizing the catch and effort data of a fishery that comprises various fishing gears that cannot be compared directly. That led to the introduction of a standard unit by which all contributing catches are expressed, the "catch per unit of effort". In this paper a method is developed to convert the prices obtained for the various green mussel products into a standardized unit, called here "price per unit of weight."

Standardization

The unit of weight selected for this study is one kilogram of green mussel fresh in-shell as it comes off the farmer's boat. This unit is considered the most suitable as it will allow, at a later stage, a straightforward assessment of the economic value of a given quantity of green mussel harvested.

In the next step the changes in weight of defined samples are monitored through all the stages of cleaning, sorting, and processing that are usually applied by local collectors. The weight of the final or end product is used to calculate an average "conversion factor" that represents the amount of final product that is obtained from the "unit" product.

For each product form under investigation two prices were obtained by interviewing local collectors:

1. Purchase price: the price paid to the green mussel farmer for one "bucket" of green mussel;
2. Selling price: the price expected for one kilogram of the final product when sold on the market.

Green mussel farmers sell their product by the "bucket". On land the mussels are usually transported in "baskets". Depending on the size of the bucket two to four are needed to fill one basket. In order to convert purchase prices from Baht per bucket to Baht per kilogram the average weight of ten baskets and the number of buckets needed to fill one basket were recorded during each survey. The price in Baht per kilogram is defined as "COST per unit of weight", which represents the gross income of the mussel farmer.

The selling price of each processed product as quoted by the collector, multiplied by its respective conversion factor, gives a measure of "REVENUE per unit of weight".

The final step is to calculate the gross market margin (GMM) for each product form, where GMM = REVENUE - COST.

The standardization procedure is illustrated below for three product forms:

Product	Sampling location
• Fresh in-shell, large and small sizes	Ban Laem, Petchaburi Province
• Dried butterfly	Samae Khao, Chachoengsao Province
• Boiled	Samae Khao, Chachoengsao Province

Fresh In-Shell, Large and Small Sizes

Processing to the fresh in-shell form involves sorting and cleaning. Survey data based on samples of ten baskets of green mussels were obtained on one day each month for 15 months (April 1984 to June 1985). The data are summarized in Tables 1 and 2.

Table 1. Weight losses in processing to fresh in-shell green mussel.

Month 1984-1985	Sample weight* (kg)	Weight losses due to: Sorting Trash (kg)	Other (kg)	Large Cleaning Encrust. (kg)	Large Shucking Water (kg)	Large Shucking Shell (kg)	Small Cleaning Encrust. (kg)	Small Shucking Water (kg)	Small Shucking Shell (kg)	Flesh weight Large (kg)	Flesh weight Small (kg)
4	28.10	8.60	0.90	0.70	0.85	0.70	0.50	0.67	0.78	0.45	0.55
5	27.25	7.35	0.70	0.25	0.65	0.80	0.45	0.59	0.79	0.57	0.62
6	26.95	4.15	0.90	0.55	0.65	0.80	0.45	0.59	0.78	0.60	0.63
7	26.85	1.25	0.85	0.65	0.52	0.80	0.75	0.54	0.78	0.68	0.68
8	29.20	2.90	1.25	1.40	0.64	0.80	0.75	0.60	0.80	0.58	0.60
9	27.40	3.10	0.85	0.65	0.60	0.80	1.55	0.67	0.80	0.65	0.63
10	30.70	3.70	3.85	0.95	0.39	0.80	1.50	0.34	0.88	0.78	0.78
11	24.95	3.50	0.60	1.65	0.49	0.80	0.95	0.57	0.85	0.68	0.58
12	32.25	2.50	1.35	1.95	0.55	0.80	0.60	0.54	0.83	0.65	0.63
1	28.65	4.50	1.65	0.90	0.50	0.90	1.05	0.55	0.90	0.60	0.55
2	28.85	5.20	1.30	0.90	0.75	0.70	0.75	0.67	0.78	0.55	0.55
3	25.20	2.75	0.90	1.05	0.71	0.80	0.15	0.61	0.81	0.51	0.58
4	27.90	6.70	0.85	0.45	0.62	0.80	0.80	0.58	0.79	0.60	0.63
5	30.75	5.30	1.45	0.10	0.58	0.80	0.30	0.48	0.85	0.68	0.68
6	28.45	2.70	1.55	0.55	0.58	0.80	0.60	0.46	0.86	0.64	0.68
Mean	28.23	4.28	1.26	0.85	0.61	0.79	0.74	0.56	0.82	0.61	0.62
% sample weight		15	4	3	2	3	3	2	3	2	2

*Average weight of ten sample baskets.

Table 2. Calculation of gross margin (in Baht) for fresh in-shell mussels.

Month 1984-1985	Waste (kg)	Sorting Large (kg)	Sorting Small (kg)	Revenue Conversion factor Large	Revenue Conversion factor Small	Selling price per kg Large	Selling price per kg Small	Revenue per kg purchased Large	Revenue per kg purchased Small	Cost price per bucket	No. buckets per basket	Sample weight* (kg)	Percentage mussel suitable for sale (per kg purchased) Large	Percentage mussel suitable for sale (per kg purchased) Small	Average cost (per kg purchased) Total	Average cost (per kg purchased) Large	Average cost (per kg purchased) Small	Gross market margin Total	Gross market margin Large	Gross market margin Small
4	8.60	11.20	7.40	10.37	6.85	6.50	3.00	67.41	20.56	32.00	2.00	28.10	60.22	39.78	2.28	1.37	0.91	85.69	66.04	19.65
5	7.35	7.15	12.05	6.62	11.16	5.00	3.00	33.10	33.47	24.00	2.00	27.25	37.24	62.76	1.76	0.66	1.11	64.81	32.45	32.37
6	4.15	10.95	10.95	10.14	10.14	6.00	3.00	60.83	30.42	20.00	2.00	26.95	50.00	50.00	1.48	0.74	0.74	89.77	60.09	29.67
7	1.25	11.50	13.25	10.65	12.27	4.50	3.00	47.92	36.81	10.00	4.00	26.85	46.46	53.54	1.49	0.69	0.80	83.23	47.22	36.01
8	2.90	18.20	6.85	16.85	6.34	4.00	2.50	67.41	15.86	8.00	4.00	29.20	72.65	27.35	1.10	0.80	0.30	82.17	66.61	15.56
9	3.10	9.35	14.00	8.66	12.95	4.00	2.50	34.63	32.41	14.00	2.00	27.40	40.04	59.96	1.02	0.41	0.61	66.02	34.22	31.79
10	3.70	8.95	14.20	8.29	13.15	4.00	2.50	33.15	32.87	15.00	2.00	30.70	38.66	61.34	0.98	0.38	0.60	65.04	32.77	32.27
11	3.50	13.15	7.70	12.18	7.13	4.00	3.00	48.70	21.39	16.00	2.00	24.95	63.07	36.93	1.28	0.81	0.47	68.81	47.89	20.92
12	2.50	14.30	14.10	13.24	13.06	4.00	2.50	52.96	32.64	20.00	2.00	32.25	50.35	49.65	1.24	0.62	0.62	84.36	52.34	32.02
1	4.50	9.70	12.80	8.98	11.85	4.00	3.00	35.93	35.56	20.00	2.00	28.65	43.11	56.89	1.40	0.60	0.79	70.09	35.32	34.76
2	5.20	12.40	9.95	11.48	9.21	3.00	2.00	34.44	18.43	30.00	2.00	28.85	55.48	44.52	2.08	1.15	0.93	50.79	33.29	17.50
3	2.75	14.25	7.25	13.19	6.71	4.00	2.00	52.78	13.43	30.00	2.00	25.20	66.23	33.72	2.38	1.58	0.80	63.82	51.20	12.62
4	6.70	7.25	13.10	6.71	12.13	4.00	2.00	26.85	24.26	13.00	4.00	27.90	35.63	64.37	1.86	0.66	1.20	49.25	26.19	23.06
5	5.30	9.60	14.40	8.89	13.33	4.00	2.50	35.56	33.33	11.00	4.00	30.75	40.00	60.00	1.43	0.57	0.86	67.46	34.98	32.47
6	2.70	12.00	12.20	11.11	11.30	3.50	2.00	38.89	22.59	12.00	2.00	28.45	45.59	50.41	0.84	0.42	0.43	60.64	38.47	22.17
Mean	4.28	11.33	11.35	10.49	10.51	4.30	2.57	44.70	26.93	18.33	2.53	28.23	49.92	50.08	1.51	0.76	0.74	70.13	43.94	26.19

*Average weight of 10 sample baskets.

Sorting

Two baskets of mussels from the sample were given to local labor for sorting. The weight of the components, "large", "small" and "trash" were recorded. To account for weight losses in the sample that could not be recorded directly (such as water and small trash) the differences between the weight of the sample and the combined weights of the three sorted components were recorded as "other losses".

Sorting is the only processing activity involved before the product is packed in 50 kg sacks and transported to the wholesale market.

Cleaning and shucking

At a later stage retailers usually remove encrustations from the shells if the mussels are to be sold fresh in-shell, or remove the flesh from the shell if it is to be sold as shucked mussel. To estimate changes in weight due to these additional processing activities local labor was asked to clean and shuck samples of sorted mussels. The components "large" and "small" were cleaned and reweighed and the difference in weight was defined as "encrustation". Subsamples of two kilograms each were also shucked and the weights of "flesh" and "shell" were recorded. "Water" is the calculated difference between the combined weight of the two components and the original 2-kg sample.

Gross market margin

The procedure used to calculate the gross market margin for fresh in-shell green mussel is as follows.

Table headings			Computation procedure
1.	SAMPLING DATE		
2.	SORTING		
2.1	Components per kg purchased:		
2.1.1	Large	(kg)	Large/sample weight
2.1.2	Small	(kg)	Small/sample weight
2.1.3	Waste	(kg)	(Trash + other losses)/(sample weight)
3.	REVENUE		
3.1	Adjustment factor*		50 kg/54 kg
3.2	Adjustment conversion factor IS/T:		
3.2.1	Large		(3.1) * (2.1.1)
3.2.2	Small		(3.1) * (2.1.2)
3.3	Price/kg (selling):		
3.3.1	Large	(Baht)	(survey data)
3.3.2	Small	(Baht)	(survey data)
3.4	Revenue per kg purchased:		
3.4.1	Large	(Baht)	(3.3.1) * (3.2.1)
3.4.2	Small	(Baht)	(3.3.2) * (3.2.2)

continued

Gross market margin (continued)

4.	COST		
4.1	Price per bucket	(Baht)	(survey data)
4.2	No. of buckets per basket		(survey data)
4.3	Av. weight per basket		Basket weight, average
4.4	Share of mussel suitable for sale (per kg purchased):**		
4.4.1	Large	(%)	100/(large + small)*large
4.4.2	Small	(%)	100/(large + small)*small
4.5	Av. cost per kg purchased:		
4.5.1	Total	(Baht)	(4.1)*(4.2)/(4.3)
4.5.2	Large	(Baht)	(4.5.1)/100*(4.4.1)
4.5.3	Small	(Baht)	(4.5.1)/100*(4.4.2)
5.	GROSS MARGIN		
5.1	Large	(Baht)	(3.4.1)–(4.5.2)
5.2	Small	(Baht)	(3.4.2)–(4.5.3)
5.3	Total	(Baht)	(5.1)+(5.2)

*An adjustment factor was introduced because collectors actually fill their sacks with 54 kg of green mussel to compensate for loss of water during transportation. At the wholesale market the sacks weigh close to 50 kg.

**When calculating the cost of green mussel on a "per kg" base, account must be taken of the trash, undersized mussels, etc., included in each bucket purchased. The cost of this should be allocated proportionally to the cost of "large" and "small" green mussels in the bucket.

Results

The results obtained from this procedure indicate that fresh in-shell green mussel is not a profitable product form, particularly for the "small" category for which the costs included in the computations of gross income are barely covered. Other costs (for which data were not obtained), such as for labor and transportation, could result in a net income that is close to zero.

Attempts to relate variations in the purchase price per bucket with known biological parameters were not fruitful and it was concluded that market factors played the leading role.

Dried Butterfly

In this product form the mussel meat is spread in a "butterfly" shape on nets and exposed to the sun for about two days. Survey data based on samples of ten baskets were obtained on one day each month for 14 months (May 1984 to June 1985) at a landing stage in Samae Khao. The data are summarized in Tables 3 and 4.

Sorting and shucking

From each sample of ten baskets one was divided into two subsamples and given to local labor for processing. The subsamples were first sorted into the components "in-shell" and "trash" (with "other losses" computed as for fresh in-shell). The "in-shell" component was then shucked and the weight of both components was recorded. The difference in weight between the combined components "flesh" and "shell" and the "in-shell" sample was recorded as "water".

Table 3. Weight losses in processing to dried butterfly form of green mussels.

Month 1984-1985	Sample weight* (kg)	Weight losses due to:			Dried flesh		Percentage weight losses due to:					
		Sorting (kg)	Shucking (kg)	Drying (kg)	Weight (kg)	% sample weight (kg)	Sorting: Trash	Sorting: Other	Shucking: Water	Shucking: Shell	Drying	Conversion factor
5	17.10	4.40	8.50	2.85	1.35	8	25	1	23	27	17	0.08
6	17.55	3.05	10.17	3.43	0.90	5	12	6	26	32	20	0.05
7	16:25	4.65	8.10	2.62	0.88	5	27	2	24	26	16	0.05
8	13.60	4.30	5.88	2.89	0.53	4	31	1	16	27	21	0.04
9	14.25	5.10	6.58	1.84	0.73	5	34	2	19	27	13	0.05
10	11.65	2.10	7.25	1.60	0.70	6	16	2	30	32	14	0.06
11	13.90	2.90	8.10	2.15	0.75	5	19	1	27	31	15	0.05
12	9.75	1.85	5.92	1.20	0.78	8	19	0	21	40	12	0.08
1	14.40	4.80	7.30	1.57	0.73	5	33	1	24	27	11	0.05
2	14.65	6.60	5.55	1.61	0.89	6	44	1	17	21	11	0.06
3	14.80	4.15	7.65	2.17	0.83	6	27	1	22	30	15	0.06
4	14.10	3.20	6.88	2.87	1.15	8	18	4	20	28	20	0.08
5	15.20	4.00	8.40	2.21	0.59	4	26	0	24	31	15	0.04
6	16.65	3.50	9.93	2.55	0.67	4	21	0	23	37	15	0.04
Mean	14.56	3.90	7.59	2.26	0.82	6	25	2	23	29	16	0.06

*Average weight of ten sample baskets.

Table 4. Calculation of gross margin (Baht/kg) for dried butterfly form of green mussels.

Month 1984-1985	Purchase cost	Selling price	Conversion factor (Table 3)	Revenue generated	Gross market margin
5	1.33	40	0.08	3.16	1.83
6	1.02	40	0.05	2.04	1.02
7	1.38	38	0.05	2.05	0.67
8	1.06	38	0.04	1.47	0.41
9	1.41	40	0.05	2.04	0.63
10	1.83	40	0.06	2.4	0.57
11	1.54	30	0.05	1.62	0.08
12	1.19	30	0.08	2.38	1.19
1	1.16	30	0.05	1.51	0.35
2	1.34	35	0.06	2.11	0.77
3	1.29	35	0.06	1.95	0.66
4	1.21	32	0.08	2.61	1.4
5	1.27	30	0.04	1.15	−0.11
6	1.06	30	0.04	1.21	0.14
Mean	1.29	34.86	0.06	1.98	0.69

Drying

The weight of the dried butterfly product was recorded before it was sent to market. Information on selling prices was obtained from the collector.

Gross market margin

(i) Conversion factor (DB/T): DB/T = weight flesh dried/weight total

(ii) Cost (per kilogram purchased): Cost = (No. buckets per basket)*(price per bucket)/(average weight per basket)

(iii) Revenue (per kilogram purchased): Revenue = (selling price per kilogram dried butterfly)*(DB/T)

(iv) Gross market margin (per kilogram purchased): GMM = revenue - cost

Results

An attempt to correlate the variables "cost", "revenue" and "conversion factor", respectively, with data on the condition of green mussel from the same culture area did not produce any significant relationships. It was expected that the conversion factor would reflect, to a certain extent, the condition of the mussels (the condition of the gonads) but as the data did not support this, it can be assumed that other factors such as the total number of hours of exposure to the sun and the humidity are stronger influence on the final weight of the product than its biological condition.

Boiled Green Mussel

In this product form the "flesh, wet" is boiled for about ten minutes and then spread over small-meshed nets to allow the water to drip off. The final weight was recorded as "flesh, boiled". The survey data based on samples of ten baskets were obtained on one day each month for 15 months (April 1984 to June 1985) at Samae Khao. The data are summarized in Tables 5 and 6.

Gross market margin

(i) Conversion factor (B/T): B/T = weight flesh boiled/weight total

(ii) Cost (per kilogram purchased): Cost = (No. buckets per basket)*(price per bucket)/(average weight per basket)

(iii) Revenue (per kilogram purchased): Revenue = (selling price per 1 kg boiled mussel)*(B/T)

(iv) Gross market margin (per kilogram purchased): GMM = revenue - cost

Table 5. Weight losses in processing to boiled green mussels.

Month 1984-1985	Sample weight* (kg)	Losses due to: Shucking (kg)	Losses due to: Boiling (kg)	Boiled flesh Weight (kg)	Boiled flesh % sample weight	Percentage weight losses due to: Shucking Water (kg)	Percentage weight losses due to: Shell + trash (kg)	Percentage weight losses due to: Boiling (kg)	Conversion factor
4	68.30	58.00	0.80	9.50	14	60	25	1	0.14
5	29.60	24.10	0.50	5.00	17	46	36	2	0.17
6	26.80	21.90	0.50	4.85	18	45	36	2	0.18
7	28.50	24.60	0.30	3.60	13	58	29	1	0.13
8	35.50	31.25	0.30	3.95	11	53	36	1	0.11
9	25.40	21.80	0.10	3.50	14	50	35	3	0.14
10	27.10	24.20	0.10	2.80	10	54	36	1	0.10
11	24.20	20.40	0.32	3.48	14	46	38	1	0.14
12	30.20	27.05	0.30	2.85	9	35	54	1	0.09
1	23.80	20.70	0.40	2.70	11	48	39	2	0.11
2	30.00	2[illegible].55	0.05	5.40	18	44	38	2	0.18
3	29.80	24.40	0.30	5.10	17	40	42	1	0.17
4	26.40	20.80	0.50	5.10	19	43	36	2	0.19
5	23.80	20.30	0.40	3.10	13	41	45	2	0.13
6	29.80	24.00	0.50	5.30	18	46	35	2	0.18
Mean	30 61	25.87	0.36	4.42	14.40	47.27	37.33	1.60	0.14

*Average weight of ten sample baskets.

Table 6. Calculation of gross margin (Baht/kg) for boiled green mussels.

Month 1984-1985	Purchase cost	Selling price	Conversion factor (Table 5)	Revenue generated	Gross market margin
4	1.25	20	0.14	2.78	1.53
5	1.33	20	0.17	3.38	2.05
6	1.49	2[illegible]	0.18	3.62	2.13
7	1.08	18	0.13	2.27	1.20
8	1.19	15	0.11	1.67	0.48
9	1.41	18	0.14	2.48	1.07
10	1.58	20	0.10	2.07	0.49
11	1.54	18	0.14	2.59	1.05
12	1.26	25	0.09	2.36	1.10
1	1.16	18	0.11	2.04	0.88
2	1.34	14	0.18	2.52	1.18
3	1.15	14	0.17	2.40	1.25
4	1.21	15	0.19	2.90	1.69
5	1.27	15	0.13	1.95	0.69
6	1.13	15	0.18	2.67	1.53
Mean	1.29	17.67	0.14	2.51	1.22

Results

The atte[illegible]t to relate the economic findings to the biological parameter "condition" revealed, as in the case of dried butterfly, that costs were independent of the actual condition of the green mussel. However, for boiled mussel there was significant correlation (1% level) between a condition index (Vakily and Tuaycharoen 1985) and the conversion factor ($r^2 = 0.550$).

Revenue per unit of weight was also significantly correlated with the condition of the mussels. However, this is a result of the procedure by which the variable is computed with the help of the conversion factor rather than the operation of market forces. As in the case of dried butterfly, it is assumed that market forces play the major role in price determination for boiled green mussel, but for the boiled product the condition of the green mussel did influence the weight of the final product.

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Transplantation of Green Mussels in Thailand, 1979-1981*

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Abstract

A pilot project on transplantation of green mussels (*Perna viridis* Linnaeus) was conducted from February 1979 to January 1981. The 3-month old mussels with an average size of 3.8 cm were collected from Sawi Bay, Ban Tung Ka, Chumphon Province, and transported to Ban Bor Keng, Songkhla Province, by truck. Average mortality rates during transport was 5.75%.

The mussels were reared in net baskets hung in the lake for 7 months until reaching maturity. The mussels were then transported to Pattani Bay in September 1979. Three months later, mussel spat were found attached to fixed wooden poles in the area. The spat were 2-3 weeks old with a length of 0.5-0.8 cm. Density of spat was 1.3-51.2 spat/1,000 cm^2. Spat were found year-round. The highest density was found from June to August. The second peak of density was from November to December. Water quality parameters from October 1979 to January 1981 are described.

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*Translated from Thai into English by Kosol Mutarasint.

Introduction

Green mussels are distributed in brackishwater zones including estuaries, rivers and canals, bays and also shallow water areas of the inner part of the Gulf of Thailand, including the east and west coasts of the Gulf. They are abundant in Chachoengsao, Chon Buri and Chumphon Provinces.

Transplantation of green mussels to zone which does not contain this shellfish was not recorded prior to this study. The transplantation to Pattani Bay was the first recorded trial with expressed purpose of study. The primary experiment was designed to be a pilot project for this type of activity.

The objectives of the experiment were: (1) to test the transplantation of green mussel by transportation tank; (2) to define the spatfall season, distribution and abundance in the new area; (3) to determine the growth rate of mussels spawned in Pattani Bay; and (4) to obtain water quality data from the study site.

On site investigation indicated that there were no green mussels in Pattani Bay. However, environmental conditions in the Bay seemed to be suitable for green mussel culture. Mussels were transported from Ban Tung Ka, Sawi Bay, Chumphon Province, for the experimental transplantation. The duration of study was from 21 February 1979 to 15 January 1981.

Materials and Methods

Cylindrical fiberglass transportation tanks of 1.5 m^3 with a covered opening on top were equipped with six small battery-operated aerators. One set of 1/4-hp engine aerators was used as spares. Twenty rectangular net baskets (35 cm x 70 cm x 15 cm in height) with stretched mesh size of 2 cm of polyethylene (number 370/15) were used for containers. Iron rods of 4 mm were applied as reinforcement to form the shape of the basket. Circular net baskets, with a diameter of 40 cm, made of the same material were also used. The equipment and materials were all on a 3.5-tonne truck under a canvas roof.

About 500-600 small green mussels were put in these baskets and hung under water from wooden supports at Ban Bor Keng near the mouth of Songkhla Lake. The mussels were raised to maturation at this location from February to August 1979. The mussels were then transported by boat to Pattani Bay for transportation. The net baskets filled with mussel were hung from a strong rack constructed of palm wood on 2 September 1979.

Approximately 100,000 mussels were also collected from Sawi Bay, Chumphon Province. They were about three months old, 2.90-4.80 cm long (average length 3.7 cm), on palm wood *(Phoenix peludosa)* poles, 5-6 m long and 3-5 cm in diameter, which were used for spat collection.

Transportation of mussel seed

Fifty wooden poles densely set with small mussels in Sawi Bay were brought ashore, rinsed with pumped seawater in order to remove dirt, fouling and other marine animals which might cause spoilage during transportation. The poles were cut down to lengths of approximately 0.6 m and placed in the transportation tank lying on top of each other. Mussels which came loose from the poles were put in net baskets at 4,000-5,000 per basket. Clean seawater was pumped into the tank to cover all the mussels. The battery-powered air pumps were operated through air stones.

To prevent an increase in water temperature in the transportation tank, chilling was applied by using ice blocks in plastic bags. The opening of the tank was covered. Temperature during transportation ranged from 24 to 26°C, with time in transport of about 11-12 hours.

After arrival at Songkhla Fisheries Station, four baskets of mussels were sampled for mortality. The mussels were kept in the net cage temporarily for further maneuvering.

Growout of mussels

The mussels were taken from the poles by cutting the byssus. Subsequently, all other undesired objects were removed. The mussels were cleaned and put in the round net baskets at a density of about 500 pieces/basket. Two hundred baskets totalling 100,000 mussels were used. The baskets were hung from the wooden supports for growth to adults.

During culture, weekly cleaning and defouling of the net baskets by brushing and shaking the baskets were necessary. After reaching maturation which took about 5-6 months, the adult mussels were transported to Pattani Province for transplantation.

Transportation of mussels for transplantation

The adult mussels were transported by boat from Songkhla to the study site. The trip took about 7-8 hours. The mussels were hung from an open wooden platform, 1-1.5 m below the low water level. The transfer was between 2 and 3 September 1979.

Spatfall season, abundance and distribution of mussel

Twenty stations were designated within the Bay (Fig. 1). Two mangrove poles were driven into the sea bottom at each station. The poles were checked for spatfall between the 15th and 18th of every month and were replaced instantly for further checking. To study abundance, the number of spat were counted monthly and the surface area of the pole from the first animal attached to the most upper part of the pole to the lowest one was calculated. There onward, number of spat would be calculated to a standard area of 1,000 cm^2.

Surface seawater temperature, turbidity, pH, salinity, dissolved oxygen and hardness were measured during spatfall monitoring.

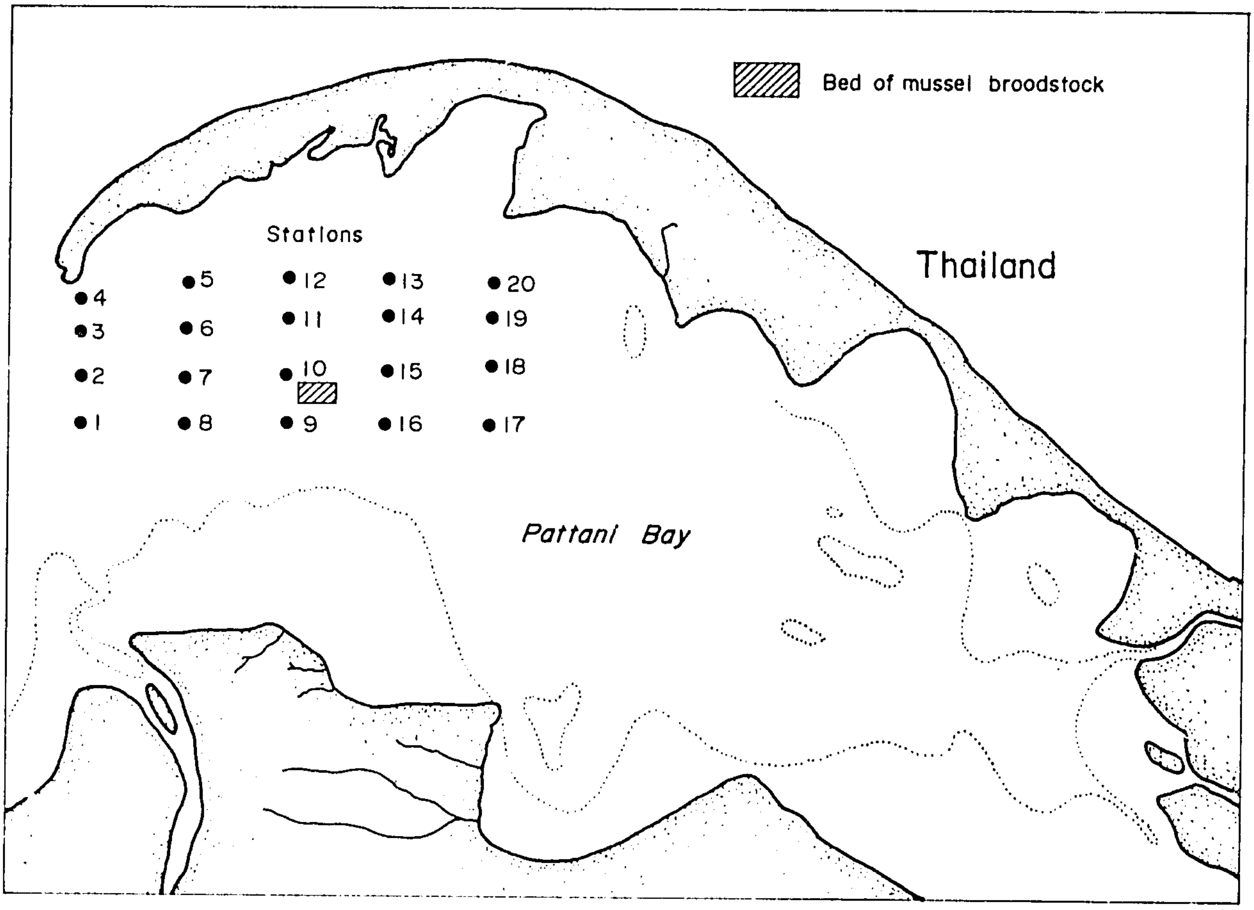

Fig. 1. Map showing positions of stations designed for checking green mussel spatfall and the broodstock beds in Pattani Bay, 1979-1981.

Growth of the transplanted mussels

An additional 30 poles were used for this study and were placed near the tip of Laem Ta Chi inside the Bay, 1-2 November 1979 for the first batch and during 1-2 June 1980 for the second batch. After finding the spat attached to the pole, monthly random samples of 30 mussels were taken for total length measurement of the shell until the age of the new generation reached 8-11 months.

Results and Discussion

The transportation of small mussels, length 2-3 cm, age 2-3 months, by using aerated water with temperature control between 24 and 26°C under shade resulted in a mortality of 5.6% after 12 hours (Table 1).

Transportation of mussels to Pattani in September 1979 was successful, and the mussels spawned in October. Spat were found in November of the same year. Spawning of green mussels in Pattani Bay occurred throughout the year during the study period. Plentiful supplies of spat were found during May-August 1980 with another lesser peak in November-December 1980 (see Table 2 and Fig. 2).

Table 1. Mortality rate of green mussels *(Perna viridis)* during a 12-hour transport period from Chumphon Province to Songkhla Province using a truck-mounted seawater tank.

Mussel	Basket No. 1	Basket No. 2	Basket No. 3	Basket No. 4	Total
Alive	4,303	4,462	4,816	5,215	18,796
Dead	201	371	218	287	1,077
Total	4,504	4.833	5,034	5,502	19,873
% Mortality	4.5	7.7	4.3	5.2	5.4

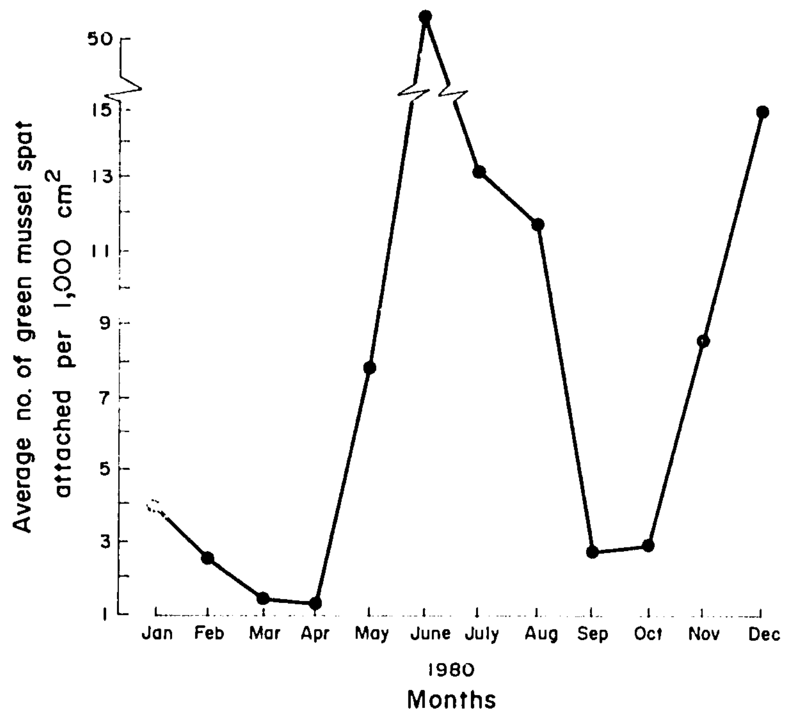

Fig. 2. Number of green mussel spat attached per 1,000 cm^2 by month,1980.

Young mussels were found attached at all 20 stations except the first where none were found throughout the year. This might be because the station was located in rather deeper water where strong current prevailed together with very dense fouling (Table 2).

At the beginning, spat were generally low in density, 12-15 pieces/1,000 cm^2 at stations 4, 9 and 16. The number increased in the following year after these young mussels spawned in 1980. The pattern should repeat every year and increase the population of mussels. There would then be sufficient broodstock left after being exploited by small fishermen. However, more broodstock are needed. They should be set on long-lasting wood and the area be treated as a sanctuary.

The study revealed that the new generation spawned by the transplanted mussels at Pattani grew as well as in other places in Thailand, reaching market size at 6-7 months of age (Tables 3 and 4).

Some physical and chemical conditions of seawater at the study site, i.e., water temperature, salinity, pH, DO, turbidity and water hardness, were generally considered very suitable for survival, growth and reproduction of green mussels (Table 5).

Table 2. Number of green mussel *(Perna viridis)* spat found at each sampling location in Pattani Bay by location and month, 1980.

Station	Number of spat per 1,000 cm^2 of pole surface													
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Average
1														
2												15.92	15.92	1.33
3					6.40	31.82		6.62				11.94	56.86	4.74
4						125.00	27.04	7.24			15.90		175.18	14.60
5	2.66			1.59	5.30	16.66	9.54				15.90	11.94	63.59	5.30
6						15.90		3.18			7.64	7.94	34.66	2.89
7		2.53				11.72	2.02	6.62				7.28	30.22	2.52
8						11.88	22.72	14.14	2.60		5.10	9.20	65.64	5.47
9	5.30				10.62	97.54	21.22	9.10			5.24	25.46	174.48	14.54
10	7.94		1.16	1.01	7.94	38.86	12.24	8.90			9.10	29.70	116.85	9.74
11	2.66				14.70							11.94	29.30	2.44
12					7.92								7.92	0.66
13												31.82	31.82	2.65
14			1.76			54.96	7.96			2.65			67.33	5.61
15						5.16	8.48	14.14			3.64		31.42	2.62
16						166.06	8.48	11.94			2.32	12.76	152.16	12.68
17						63.64		28.92					92.56	7.71
18								25.46				3.54	29.00	2.42
19	5.33				2.64	78.90	13.40	6.96			9.54	15.92	132.69	11.06
20						48.20							48.20	4.02
Total	23.89	2.58	2.92	2.60	55.60	716.90	133.10	43.22	2.60	2.65	74.38	195.36	1,355.80	
months	5	1.	2	2	7	14	10	12	1	1	9	13	19	
average	4.78	2.58	1.46	1.30	7.34	51.21	13.31	11.94	2.60	2.65	8.26	15.03		

Table 3. Growth rate of green mussels (*Perna viridis*) spawned in Pattani Bay, Batch 1.

Month 1979-1980	Length (cm) Mean	Range	Growth rate (%)
November	1.54	0.6- 1.8	
December	2.31	1.5- 3.2	50.00
January	3.17	1.8- 4.7	37.23
February	4.37	2.9- 5.7	37.85
March	4.38	4.2- 5.6	11 67
April	6.61	4.2- 7.9	35.45
May	7.15	6.2- 9.0	8.17
June	7.91	6.5- 9.0	10.63
July	8.64	6.8-10.0	9.23
August	9.31	8.4-10.0	7.75
Septemoer	9.49	8.4-10.5	1.93

Note: Mussels were 1-1/2 months old at the beginning (November). Mussels spawned during September-October 1979.

Table 4. Growth rate of green mussels (*Perna viridis*) spawned in Pattani Bay, Batch 2.

Month 1979-1980	Length (cm) Mean	Range	Growth rate (%)
June	0.57	0.3-1.0	
July	1.90	1.3-2.6	233.33
August	3.10	2.0-3.9	63.16
September	4.39	2.0-5.3	41.61
October	5.43	4.5-6.6	23.69
November	5.77	4.6-6.8	6.26
December	6.24	5.1-7.2	8.15
January	6.96	5.4-8.9	11.54

Note: Age from 1-8 months. Mussels spawned approximately at the beginning of May

Table 5. Water quality parameters at the study site in Pattani Bay by month.

Month		Water Temperature (°C)	Salinity (ppt)	Turbidity (cm)	pH	CO_2 mg2/1t	O_2 mg2/1t	$CaCO_3$ mg/13
October	79	28.10	23.25	64	7.45	2.43	7.55	114.63
November	79	27.90	25.00	67	7.35	1.02	6.72	85.85
December	79	26.73	30.41	38	7.62	1.40	5.06	103.35
January	80	27.05	31.69	39	7.87	0.54	7.96	106.45
February	80	28.88	32.38	97	8.05	0.83	7.20	109.22
March	80	29.54	33.63	68	8.63	0.79	5.91	124.09
April	80	29.31	32.28	80	8.48	1.36	5.20	120.77
May	80	29.82	31.00	98	7.35	0.81	6.28	135.97
June	80	29.83	33.50	31	8.51	1.10	6.43	110.97
July	80	28.40	30.68	40	8.47	1.77	7.11	136.35
August	80	30.00	31.53	52	8.16	1.09	6.36	122.32
September	80	31.85	31.95	61	7.69	2.17	6.41	140.17
October	80	29.23	30.10	27	7.83	2.52	7.27	138.25
November	80	31.30	27.26	65	6.98	1.60	6.66	131.02
December	80	26.53	29.46	67	7.41	1.36	4.95	108.14
January	81	28.84	30.16	92	7.30	2.19	7.46	151.87

Note: Checked monthly at every station. Average of all stations are shown.

The study indicated that distribution of young mussels was mainly dependent on the current pattern. Mussel spat were found not only in the Bay but also outside the Bay in the adjacent waters.

Acknowledgements

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Growth and Maturation of the Green Mussel (*Perna viridis*) in Thailand*

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Abstract

Monthly random samples of green mussels (*Perna viridis*) from Ban Laem, Petchaburi Province, and Samae Khao, Chachoengsao Province, from March 1984 through June 1985, indicated that gametogenesis occurred in mussels from a minimum of 21.3 mm in length. Six stages of gonad development were classified. Gonad development was similar for both locations. Two spawning periods were identified, the first from May through August and the second from November through February. Spat settlement occurs 17-21 days following spawning.

Length-frequency data obtained from green mussel populations at these sites were used to construct growth curves. Condition index as well as other biological information was incorporated into the model to demonstrate the validity of the growth curves obtained. The length-at-age data read off from the growth curve were used to compute the parameters of the von Bertalanffy Growth Formula. Values of asymptotic length computed for both areas were 107 mm and 112 mm, respectively. This result suggested no significant difference in growth performance between the two culture sites.

Length-at-age data then were compared with published data sets from surveys of green mussel rope culture conducted in waters off Chachoengsao Province and Singapore. It was demonstrated that all populations showed quite a similar growth pattern during the first three months. However, using nursery ropes as spat collectors and the thinning out of the young green mussel to production ropes - a technique applied in Singapore - leads to a drastic increase in length growth.

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Introduction

Perna viridis (Linnaeus) is the major single species used in shellfish culture in Thai waters (earlier reports on this species also use the synonyms *Mytilus viridis* and *Mytilus smaragdinus*).

Historically the major mussel production areas in Thailand have been along the east and west coast of the inner Gulf of Thailand near outlets of the major rivers. Industrialization and other competing uses of the upper Gulf has reduced the area suitable for green mussel production. Production through transplantation has been initiated in the south of Thailand and on the Andaman Sea coast. Some locations, notably Sawi Bay in Chumphon Province, have substantial natural reproduction sufficient for commercial operations. Other similar locations have very limited reproduction. The quantity of spat in an area may be related to the period of reproduction and the biological and oceanographic conditions that prevail at the time of spawning and spat set.

The farming method employed in Thailand consists of planting bamboo stakes in areas where natural spatfall is expected. The green mussels are harvested after a growing period of six to seven months, when they have attained an average size of 5-6 cm.

Green mussels are modestly priced compared to other shellfish species sold for human consumption. This makes the green mussel an inexpensive source of animal protein. On the other hand, the low income generated by green mussel farming does not encourage the introduction of innovative culture methods.

To introduce any kind of general management for green mussel culture, fisheries scientists need data that enable them to decide which culture method or which farming area yields best growth performance. This paper presents an approach on how to obtain such growth parameters for green mussel.

Materials and Methods

Growth studies

The study of growth parameters of the green mussel was part of a research project on bioeconomic aspects of green mussel farming in the northern Gulf of Thailand.

Data were collected at two major green mussel production areas, Ban Laem, Phetchaburi Province and Samae Khao, Chaçhoengsao Province. From March 1984 to June 1985 these sites were visited every month, keeping the time intervals as equidistant as possible. The samples were taken at landing areas after the green mussels were unloaded from the farmers' boats.

Growth performance was to be determined through analysis of length frequencies. Length in the context of this study is defined as the distance in mm from the umbo to the posterior tip of the shell. Shell length was measured to the nearest mm using an L-shaped measurement board with an additional "fixing block" that slid along the length scale and allowed parallax-free reading of the length.

In Ban Laem samples were from baskets that contained green mussels previously sorted by local labor. Trash and "undersized" green mussels were first removed and the remaining mussels sorted into "small" and "large".

The reason for the sorting is differences in prices and/or differences in further processing. The classification is purely economically defined and varies from month to month. However, within a sample, the sorting was found to be fairly consistent.

Length frequencies were taken from both "large" and "small", each sample comprising 200-300 animals. For the purpose of this study, the frequencies then were recombined and regrouped in 3-mm classes. The adjustment of the data by using the sample size as a weighting factor was found to have no effect on the position of "peaks" and was therefore omitted. The elimination of small green mussels before sampling introduced a bias. This limited to some extent the possibility of tracing secondary growth curves. This disadvantage was considered less important as the secondary growth curves did not play any role in computing growth parameters.

In Samae Khao, length frequencies were taken from unsorted samples and re-arranged in 3-mm classes for further analysis.

Parameter estimation

Growth in shellfish is often described in the form of growth rates over time using the mean length or weight of two consecutive samples. The method implies that the recorded means are representative of the general growth of the population. This assumption is most probably met whenever the measured properties have a normal distribution. However, in cases where the variable is distributed with more than one modal class, the arithmetic mean of the sample becomes increasingly unsuitable for use in growth analysis.

Length frequencies that are taken from natural green mussel populations, especially from those in tropical waters, usually extend over a wide length range with various "peaks". The data obtained during this survey were no exception. Reasons for the sample variance are to be found both in the biology of the green mussel and the culture method since:

- Green mussels have two spawning seasons per year. This introduces a second, sometimes clearly defined modal class into most of the samples.
- Spawning usually occurs over an extended period of time which makes peaks less distinguishable.
- The stakes on which the green mussel spat settle become "overcrowded" after several months, resulting in a decrease of the growth rate of those green mussels located in an unfavorable position.

As a consequence of the above, the use of the parameters of the von Bertalanffy Growth Formula (VBGF) to describe the growth performance of a given green mussel population has been suggested. The equation as it is used here has the form

$$L_t = L_\infty (1 - e [-K(t-t_0)]) \quad \text{... 1)}$$

where

L_t is the recorded length at age t;

t is the age of the green mussel at the time the length is measured;

L_∞ is the asymptotic length, that is the mean length the green mussels of a given population would reach if they were to grow indefinitely;

K is a growth constant with dimension $time^{-1}$;

t_0 is the age of the animal at "zero length" if it had always grown in the manner described by the equation and its value is assumed further below to be sufficiently close to zero for this parameter to be neglected.

As outlined in Pauly (1984), a simple re-arranging of Equation (1) can help find an L that creates a growth curve which fits bests the given data set with the correlation coefficient r being the test orientation. When re-arranged, the VBGF becomes

$$-1n\,[1 - (L_t/L_\infty)] = -Kt_0 + Kt \qquad \text{... 2)}$$

which has the form of a linear regression, y = a + bx

Where $y = -1n\,[1 - (L_t/L_\infty)]$

and x + t

which, given a set of length-at-age data and an estimate of L_∞, provides values of intercept (a) and slope (b). The latter is used to obtain K through

$$K = -b \qquad \text{... 3)}$$

When using the same data set but different values of L_∞, various values of r are obtained. As the correlation coefficient is an indicator of the linearity of the regression, the L_∞ producing the maximum r is selected as the final value for the asymptotic length and the parameter K is according to Equation (3).

Maturation

Random samples of green mussels were collected from the landing at Samae Khao, Chachoengsao Province, on the east coast of the inner Gulf and from one landing at Ban Laem, Phetchaburi Province on the west coast of the inner Gulf. Sampling was conducted once per month from March 1984 through June 1985, a period of 16 months. Approximately 50 individual shellfish were collected monthly at each location. The sample collection area was the same as that used for condition index measures (Vakily et al., this report) and for bioeconomic analysis. Shellfish at the landings were harvested for market, thus harvesting did not begin until the minimum market size was attained. The sampled population would have more size uniformity than would be expected in nature.

The samples were preserved in 10% formalin and transported to the Brackishwater Fisheries Division Histology Laboratory at Bangkhen, Bangkok, Thailand. The gonads were removed from the individual shellfish and sectioned at 5 µm. The gonad sections were stained with Haematoxylin and Eosin. Identification of the stage of gonad development was by high microscope method (Dredge 1981).

The green mussel samples used to determine gonad condition were over 20 mm in length. The gonad occupies two areas in green mussels. The first extends over the mantle and encloses the digestive tract. The second, ventral portion is connected to the foot under the digestive tract. The gonad has only one lobe which is in the mantle cavity.

Color of the mantle and the gonad can be used to estimate stage of mature development. The color differs by sex of the green mussel. The mussel is mature when the gonad is creamy white for male, and reddish or orange for female. After spawning or prior to maturity the gonad is indeterminant in color. Also when the gonad is intermediate between pale orange and creamy white the mussel may be a mature hermaphrodite. Color thus can be used to subdivide mussels into three sex groups, male (creamy white), female (red) and indeterminant. Two development groups can be established from the sex groups, mature (males and females) and not mature (indeterminant). The proportion in each group will allow a rough estimation of the stage of gonad development. The market participants commonly use this method to indicate the degree of 'fat' in the green mussel.

Microtechnique methods were used for examination of the histology of 1,600 gonad samples. Gametogenesis was determined to begin in gonads of green mussels over 21.3 mm in length. At this length for green mussel the gonad is moderately developed with enormous development of connective tissue. The connective tissue retains the Haematoxylin stain. Small dots are spread over the connective tissue. The male mussels have spermatozoa. The females have oogenesis from oogonia and young oocytes developing into mature oocytes. Sex of the green mussel can be determined in this stage by microtechniques.

Histological examination was used to divide the gonad condition into six main stages of development: prefollicular development stage, initial development stage, developing stage, mature stage, partially spawned stage and spent stage.

1. Prefolicular development stage. The mussel has shrunken gonad with much connective tissue between the small follicles. Sometimes spermatogonia and oogonia are in close contact with the connective tissue.

2. Initial development stage. Gametogenesis begins and the follicles increase in size.

3. Developing stage. Additional increase in follicle size. Males have spermatogonia in follicle walls; many spermatocycytes, spermatids, free spermatozoa sometimes present in follicle lumen. Females have oogenesis, many young oocytes attached by stalks to the follicle wall. Sometimes a few free oocytes in lumen.

4. Mature stage. Gonad is fully distended. Oocytes are mature in females and attached to the follicle wall by a narrow stalk or free in the lumen. Males have follicles filled with spermatozoa or sperm.

5. Partially spawned stage. Some oocytes and sperm have been released. Dissimilar to developing stage in that oocytes and sperm present are mature.

6. Spent stage. Oocytes and sperm have been released. Gonad is shrunken. Majority of follicles are empty. A few residual gametes may be present. Similar to stage 1.

The developing stage (3) had some follicles with gametes in initial development (2) and some in mature stage (4) but the majority of follicles were in the developing stage. In the mature stage (4) some follicles were in the developing stage (3) but most were in the mature stage. The partially spawned stage included follicles in the mature stage. The six stages represent a continuum, not a series of abrupt transitions. No hermaphrodite stage was observed in the study.

The period of release of gonad products is important for culture purposes. Knowledge of the time of spawning is equally important for market purposes. The green mussel has low value for consumption after spawning. The time period for regeneration of gonads is both biologically and economically important: biologically in determining the sequence of spawning; economically in determining the length of period when product value is reduced.

Results and Discussion

Length frequencies were sequentially re-arranged with the sampling months becoming the time axis, as shown in Tables 1 and 2. In the next step all "peaks" were graphically marked. A peak was defined as all those length classes which contained a frequency higher than those in both the preceding and following length class.

A growth curve was drawn directly upon the length-frequency sample such that the majority of the peaks are on or close to the line. This method, commonly called "Integrated Modal Class Progression Analysis" (Pauly 1980), is based on the assumption that a single, smooth growth curve represents best the average growth of the organism (here green mussel) under investigation (Table 3).

Instead of using calculated arithmetic means the average length of the green mussel was read directly from the growth curve for every sampling month. The corresponding age was established by defining the origin of the growth curve as the "birth-month". The length-at-age data pairs obtained for both culture sites are listed in Table 3.

The growth parameters of the VBGF were computed on a Hewlett Packard HP-41 C programmable calculator using a program described in Vakily and Pauly (1986). Using the length-at-age data set from Table 3, the program searches automatically for the value of L_∞ that produces the highest correlation coefficient. The results obtained from the two locations are listed in Table 4.

The "Integrated Modal Class Progression Analysis" is an attempt to produce growth data that allow direct comparison of two populations. The method is partially based on a subjective (but not necessarily erroneous) fitting of a growth curve into a given data set. To assess the validity of the estimated parameters, additional biological information should be considered that either could support or refute the findings of this method.

Growth performance over time is described by the growth curve. Growth is a largely biologically determined factor. As a consequence, growth curves drawn for successive generations of a population should remain constant in shape and only vary in respect to their origin.

The point at which the growth curve cuts the x-axis determines the "birth month" and, hence, the age assigned to the successive samples. In Ban Laem the main growth curve starts in August 1983, the other two in December/January and June. To consider these months as dates of birth of the respective green mussel populations becomes a reasonable assumption when comparing them with gonad development at the sampling sites (Table 5). The occurrences of partially spent and spent gonads were maximum in July and August, respectively. The pattern of gonad maturation in Samae Khao (Table 5) seems to support the information given by other authors (Chongpeepien 1982) that spawning occurs in that area throughout the year, generally without a clear peak

Table 1. *Perna viridis* length frequencies (regrouped); March 1984-June 1985.

Sampling Area: Ban Laem
Sampling Size: Small + Large (combined)

Month:	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
N:	405	495	658	494	454	555	533	515	523	575	676	550	783	587	789	462
Mean:	55.3	62.6	63.3	68.1	69.4	74.1	75.7	77.8	79.4	76.7	73.0	68.7	74.6	69.0	65.0	70.0
Length (mm)																
21.5																
24.5	1															
27.5	4															
30.5	11	3														
33.5	12															
36.5	19	3	4													
39.5	8	4	1													
42.5	17	1	9		1											
45.5	22	15	10		1							2			5	1
48.5	48	27	20		3				2			4			18	1
51.5	43	43	45	1	8	3		1		1	9	10	4	2	27	4
54.5	53	52	53	9	11	4	3	3	6	4	9	22	11	1	47	18
57.5	23	38	68	31	13	9	1	5	7	5	21	32	20	13	74	13
60.5	19	50	85	61	28	25	12	11	7	11	31	47	30	30	85	33
63.5	14	37	88	52	49	45	31	12	14	31	47	59	61	72	98	33
66.5	12	47	79	82	61	61	34	19	23	38	71	66	78	123	122	67
69.5	17	40	50	95	81	69	63	44	23	46	69	70	68	131	113	73
72.5	24	47	47	56	54	55	60	48	29	63	91	71	73	93	93	58
75.5	26	38	32	52	67	59	78	76	57	69	87	71	100	66	60	60
78.5	16	28	21	27	31	56	89	62	75	69	72	37	84	38	25	39
81.5	9	13	17	10	30	63	61	87	84	90	65	27	96	14	15	39
84.5	5	5	7	9	8	50	47	56	70	66	53	20	69		4	11
87.5		4	8	7	4	26	20	54	54	41	23	8	35	4	3	9
90.5	1		7	2	4	14	21	20	36	17	17	2	25			3
93.5			5			3	5	9	16	16	7	1	16			
96.5			2			6	5	3	12	6	4	1	6			
99.5						4	3	3	5	2			2			
102.5					2							3				
105.5					1		2	3				2				
108.5																

Table 2. *Perna viridis* length frequencies (regrouped); March 1984-June 1985.

Sampling Area: Samae Khao
Sampling Size: Unsorted

Month:	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
N:	322	364	560	325	304	371	412	416	332	592	497	649	702	416	307	419
Mean:	38.6	46.4	55.5	56.0	60.5	52.2	58.7	71.3	67.8	65.4	71.2	54.7	56.5	60.3	64.8	59.2
Length (mm)																
21.5	17									2						
24.5	16	4								5	1	3	2			
27.5	27					2				22	3	3	3			
30.5	21	13	2			5				27	9	3	3			
33.5	25	12	1			4	2			20	8	5	10			
36.5	33	35	2			4	1			7	2	7	7	2		1
39.5	38	39	11		1	21	4			9		27	7	1		3
42.5	39	39	20	1		27	17			4		26	20	3	1	8
45.5	32	43	43	5	1	41	27	1		1		49	33	12	4	10
48.5	34	39	61	34	3	41	32	5		2		47	69	35	3	29
51.5	23	42	76	44	32	50	33	8	1	7	1	68	79	23	6	37
54.5	11	38	68	75	42	48	51	11	3	7	6	75	71	47	23	63
57.5	2	24	68	64	48	41	43	14	9	16	8	106	102	44	21	59
60.5	3	20	83	52	52	32	37	27	30	33	22	81	86	57	44	59
63.5	1	12	54	31	48	18	51	45	52	43	34	65	80	51	34	33
66.5		4	31	15	35	13	42	43	75	49	64	45	53	58	61	49
69.5			13	2	19	12	23	47	62	57	76	28	35	36	39	28
72.5			12	2	8	6	15	50	50	60	47	6	16	22	32	14
75.5			12		8	4	11	40	23	56	61	3	11	14	23	11
78.5			2		2	1	7	34	15	52	37	1	8	7	10	8
81.5			1		1	1	12	34	5	43	42		5	2	5	5
84.5					2		4	15	6	40	28	1	2	1		
87.5								21		12	19			1		1
90.5					2			11		11	20					1
93.5								4		6	7					
96.5								4								
99.5								2		1						
102.5											1					
105.5											1					
108.5																

Table 3. Length-at-age data for Ban Laem and Samae Khao.

Age (months)	Ban Laem length (mm)	Samae Khao length (mm)
5		44.5
6	-	49.5
7	57.0	54.5
8	61.0	59.0
9	65.0	63.5
10	69.0	67.0
11	72.5	70.0
12	75.5	73.0
13	78.5	76.0
14	81.0	79.0
15	83.5	81.5
16	86.0	84.0
17	88.0	86.0
18	90.0	87.5
19	91.5	89.0
20	-	90.5

Table 4. Summary of growth parameters of green mussels for Ban Laem and Samae Khao.

Paramêter	Ban Laem	Samae Khao
L_∞ (mm)	111.9	107.2
K (per year)	1.000	1.071
Corr. Coeff. (r)	1.000	0.999

season. This would explain the relatively large number of growth curves that could be drawn through the samples.

The computed asymptotic length for the green mussel from Ban Laem was 112 mm and 107 mm for Samae Khao. Over the whole period of data collection no green mussel was recorded exceeding 112 mm.

Parameter interpretation

The growth parameters derived for the two green mussel culture areas of Ban Laem and Samae Khao (Table 4) lead to the conclusion that there is little difference in growth performance between the two sites.

The slightly higher value K in Samae Khao suggests that the average increase in length per month slows down faster in comparison with the culture site in Ban Laem. This is also reflected by the lower asymptotic length of green mussels in Samae Khao.

From the length-at-age data summarized in Table 3, the conclusion can be drawn that the growth rate of younger green mussels is slightly better in Ban Laem as they have reached an average length of 57 mm after seven months compared to 54.5 mm for Samae Khao.

Table 5. Stages of gonad development as percentages of total mussel samples at Ban Laem, Petchaburi Province, and Samae Khao, Chachoengsao Province by Month, March 1984-June 1985.

Month	Phetchaburi Province								Chachoengsao Province							
	X	P	I	D	M	PSP	SPT	No.	X	P	I	D	M	PSP	SPT	No.
March	62.9		2.0	82.0	14.0	2.0		50	44.0			18	66	16		50
April	63.9	4.0	2.0	56.0	30.0	6.0	2.0	50	51.0	2	18	68	12			50
May	67.0			18.0	70.0	8.0	4.0	50	61.0			4	28	66	2	50
June	70.6				60.0	30.0	10.0	50	58.9			10	18	70	2	50
July	72.0			4.0	10.0	80.0	6.0	50	62.0	2			4	46	48	50
August	76.0	2.0	4.0	4.0	2.0	18.0	70.0	50	54.6	30	14	24	6	2	24	50
September	79.3	6.0	16.0	60.0	16.0		2.0	50	66.0		6	44	42	8		50
October	80.0	4.0	16.0	48.0	24.0		8.0	50	80.6	2	6	32	42	8	10	50
November	81.7	4.0	2.0	34.0	20.0	28.0	12.0	50	71.9				22	62	16	50
December	78.0	10.9	2.2	4.3	2.2	30.4	50.0	46	76.4	6	4	4	16	18	52	50
January	75.0	22.0	20.0	14.0	14.0	24.0	6.0	50	76.1	8			22	12	58	50
February	71.3	22.9	50.0	22.9	2.1		2.1	48	61.0				44	54	2	50
March	76.0	20.4	53.1	20.4			6.1	49	63.0	4	2	72	6	10	6	50
April	68.9		6.0	90.0	4.0			50	59.9	6	6	22	20	30	16	50
May	70.5	2.0		20.0	50.0	16.0	12.0	50	68.9	2		8	40	22	28	50
June	70.8				62.0	32.0	6.0	50	69.4			4	72	24		50

X Average Shell Length (mm)
P Prefollicular developments
I Initial development
D Developing
M Mature
PSP Partially spawned
SPT Spent
No. Total number of mussels

After having established a set of reasonable growth data, a comparison of the growth rates achieved with other culture techniques might help to assess the general status of green mussel culture as it is carried out in the two areas under investigation.

For this purpose, the length-at-age data of the first eight months from Samae Khao (as listed in Table 2) were compared with the respective data from:

1) a rope culture experiment carried out in the same area by Chonchuenchob et al. (1980)

2) an investigation of raft-based rope culture in Singapore (Cheong and Chen 1980).

When comparing the growth performance of green mussels in the rope experiment with the one described by the data in Table 3, there is obviously no significant difference between the two culture techniques in the same area (Table 6).

Table 6. *Perna viridis* length-at-age data: comparison of different culture methods.

Culture method	Stakes		Hanging ropes			
Location	Chachoengsao Province		Chachoengsao Province[1]		Singapore[2]	
"Thinning Out"	no		no		yes	
Age (months)	Length (mm)	Increment (mm)	Length (mm)	Increment (mm)	Length (mm)	Increment (mm)
2	23.0	-	21.4	-	21.8	-
3	30.0	7.0	29.4	8.0	30.8	9.0
4	37.5	7.5	37.8	8.4	47.0	16.2
5	44.5	7.0	43.4	5.6	61.3	14.3
6	49.5	5.0	48.4	5.0	66.3	5.0
7	54.5	5.0	54.1	5.7	72.0	5 7
8	59.0	4.5	57.0	2.9	-	-

[1]From Chonchuenchob et al. (1980).
[2]From Cheong and Chen (1980).

The length-at-age data of the green mussel cultured in Singapore display a growth pattern similar to the Thai green mussel during the first three months. Subsequently the growth rate in Singapore doubles that in Thailand. The reason is probably the fact that in Singapore the green mussel spat are collected with nursery ropes which are thinned out to production ropes after the mussels have attained an age of three months (2 months after spat settlement).

The similarity in growth of green mussel during the first three months at Thai and Singapore culture sites suggests that the marine environment both at Ban Laem and Samae Khao is not the primary growth limiting factor and that it could support a much higher production if culture techniques were improved. The crucial part of such an improvement would be transplantation of young green mussels from spat collectors to growout devices.

Maturity cycles

This study of gonad development indicated the presence of active gametes (developing, mature or partially spawned) in green mussels throughout the year. Gametogenesis occupied two periods from the prefollicular to spent stage. The first period occurred from April to August and the second from September to January. The first period required about 6 months (Table 5). In April, gonads were in disynchronization. The period from prefollicular to mature stage was about 2-3 months. The period from prefollicular to mature stage condition was from May to August. In September gametogenesis began, with spawning from November to January. From February the gonads were in the spent stage for 3-4 months.

All stages of gonad development were found every month although the majority were normally in one stage (Table 5). A previous study on gonad condition at Samae Khao (Chongpeepien 1982) did not indicate the same degree of variation. The spawning season was reported to occur in two periods, July to September and October to March. The sample was collected from a staked area and the age of the sample was known.

The sample of this study was collected from the landing and the age of the mussels may have varied since length of the mussels sampled declined in January and again in April in Samae Khao. In Ban Laem the average length of sample declined in November and again in February. The staking period for green mussels at Samae Khao extends over several months. The Ban Laem green mussels were harvested from fish traps and could have settled over a variable time period. The study indicated that some spawning occurs every month in the areas sampled.

Two periods of maturation were identified for each of the sample areas. In Ban Laem, Phetchaburi Province, the first period was April-July and the second in September-November. Mature mussels comprised 70% of the sample in May and 60% in June 1984, and in 1985, 50% in May and 62% in June. The cycle was repeated during the survey. The second period was much lower with 24% in October.

In Samae Khao, the first period was in March 1984 with 66% of the sample mature. However, the March sample was collected from harvest in Samut Prakan. The peak period for Samae Khao mussels was in September-October 1984 then May-June 1985. Mature gonads were found in every month from the Samae Khao sample with the lowest period in July-August 1984 and March 1985. The cycle did not repeat at Samae Khao. In 1984 the May sample had 4% in developing, 28% in mature and 66% in partial spawning. In 1985, the May sample had 8% in developing, 40% in mature and 22% in partial spawning. The 1985 sample appeared to be one stage behind the 1984 sample (Table 5).

Mature gonads were found in female green mussels 21.3 mm in length and in male green mussel of 23.0 mm in length (Table 5). Sexual maturity corresponds with an age of 2 months as determined by growth rate (Table 3). A study by Narasimham (1980) reported mature gonads in this species above 28 mm in length and an age of 2 months.

Spawning seasons

The major spawning in Ban Laem was June-August 1984 and November 1984-January 1985. The second period included a lower percentage of the population spawning. At Samae Khao, the spawning period was May-July 1984 with a second season, from November 1984-February 1985. A third period occurred in April-May 1985. The spawning period at Samae Khao was prolonged for a six-month period.

Narasimham (1980) reported that the green mussel spawning season was prolonged, extending from December to July with peak activity January to May. Nagabhushanan and Mane (1975) reported two spawning periods for *Perna viridis* at Ratnagiri, India: one from February to March and the other in June-September. Yap et al. (1977) reported the season in Iloilo, Philippines, as April-May and November-December. The spawning season at Saipan Bay, Philippines, has two periods. The highest spawning in February to March and the second, smaller one in September (Young and Serna 1982).

The spawning seasons as identified in this study have the same characteristics as indicated from other studies: multiple spawning and seasonal peaks which vary by location and by conditions and location.

Spatfall

The hatchery study on induced breeding of green mussels during the Project (see Sahavatcharint et al., this report) indicated that spat settlement occurred 17-21 days after spawning under laboratory conditions.

Based on these results, spatfall in Ban Laem would occur from July to September and again from December to February. In Samae Khao, spatfall would occur from June to August and again from December to March.

Spat Collection

Producers in Samae Khao place bamboo stakes in the soft muddy bottom as substrate for collection of spat. In Ban Laem, bamboo stakes are also used but the stakes form the extended wing of a fish trap. Short (3-m) bamboo stakes are used for the nearshore area. About 2 m are available for spat attachment. Longer, 13-m, stakes are used in deeper water. However, less than 10 m are available for spat attachment. A study during the present Project of labor use in green mussel production from fish traps, including Ban Laem sites, indicated concentration of stake placement from May through August. January through March was the lowest period. The gonad study indicates flow spat available at Ban Laem during February and March which tends to confirm the latter data.

Spatfall at Kakinada, India, occurs from October to December (Silas et al. 1982). At Selat Tebran Yohore, Malaysia, the spatfall occurs in two periods, the first in November-February and the second May-June (Ng et al. 1982). Spatfall at Saipan Bay, Philippines, is from March-May and August-November (Young and Serna 1982). Spatfall in Singapore has two different sets of periods. On the east of the island, spatfall is February-May and October-November. On the west, June-August and November-December (Cheong 1982). Singapore thus represents a combination of the situations in all areas of green mussel populations.

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Growth, Mortality and Transportation Studies on Transplanted Cockles (Fam. Arcidae) in Nakhon Bay, Thailand

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HANSOPA, Y., K. THANORMKIAT, S. LIMSAKUL, Y. CHAROENVITTAYAKUL, T. CHONGPEEPIEN, C. MONGKOLMANN and S. TUAYCHAROEN. 1988. Growth mortality and transportation studies on transplanted cockles (Fam. Arcidae) in Nakhon Bay, Thailand, p. 102-108. *In* E.W. McCoy and T. Chongpeepien (eds.) Bivalve mollusc culture research in Thailand. ICLARM Technical Reports 19, 170 p. Department of Fisheries, Bangkok, Thailand; International Center for Living Aquatic Resources Management, Manila, Philippines; and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn, Federal Republic of Germany.

Abstract

The effects of transplanting young cockles *(Anadara granosa* and *A. nodifera)* to Nakhon Bay, Thailand, were investigated. During the first month *A. nodifera* underwent 20-85% mortality at different sampling sites. Best growth was of *A. granosa* stocked at 300/m^2 which grew from 3.0 to 12.8 g in 13 months. Predation by drilling snails affected cockles smaller than 20 mm in length. Transportation of *A. nodifera* in sacks allowed high survival for up to 72 hours but nearly complete mortality by 96 hours. Data on the food organisms of *A. granosa* from two other sites are included.

Introduction

Cockles (*Anadara* spp.) are amongst the most important seafoods produced in Thailand. Domestic production is insufficient to supply domestic demand. Thailand imports a significant amount of cockles from Malaysia resulting in substantial loss in foreign exchange. Domestic production has encountered many problems in expansion including: 1) lack of sufficient domestic seed supplies resulting in the necessity to import seed from Malaysia and 2) lack of knowledge regarding suitable areas for production.

Culture of cockle in the southern provinces of Thailand requires purchase and transport of seed from Malaysia. Transport time is more than 12 hours. The time and stocking in a different environment causes stress on the cockle. Stress can cause mortality. Even the surviving cockles will undergo a period of reduced growth rate.

Limited research specific to these problems has been conducted. Biological parameters for shellfish growth differ between different areas, yet biological feasibility of culture must be established prior to promotion of culture activities in an area. A study in Nakhon Bay was carried out during the Project to determine the biological feasibility of expansion of culture activities in the Bay. The study examined the performance of two cockle species, *Anadara granosa* and *A. nodifera*. The study was conducted from December 1983 through June 1985.

Methods and Materials

The experimental site selected for environmental and biological studies was a privately operated cockle farm located in Nakhon Bay. The farm had been in operation since 1979. An experimental plot was also established near the farm.

Five stations were established within the farm. Data were collected monthly at each station for the measurement of biological and environmental parameters.

Fifteen rai (one rai = 1,600 m^2) were selected near the cockle farm for the experimental culture site. Three tonnes of cockle seed *(Anadara granosa)* were provided by the Malaysian government and were stocked in the experimental plot at a stocking rate of 300 seed/m^2. The growth rates of cockle in the farm and the culture site were compared. Growth rates of two sources of cockle seed were also compared in the experimental plots. Samples were collected monthly for determination of growth, survival and gonad condition.

Bottom-dwelling slow moving predators were sampled by use of an Ekman grab. A 2.5-cm mesh drift net, 1 m in depth and 20 m in length was used to collect faster moving predators in the water column. The net was allowed to remain in the water 50 minutes.

Samples were collected from each station and the experimental plot. Length and total weight of 120 individual shells were recorded each sampling period.

Plankton abundance and species composition were determined by standard methods. Samples of phytoplankton were collected from the surface and bottom layers of the water column. Zooplankton samples were collected throughout the water column. A plankton net was drawn for a linear distance of 50 mm against the current. The sample was collected at the tide change when tidal influence was minimized.

Cockle seeds obtained from Phetchaburi Province *(Anadara nodifera)* were also stocked in Nakhon Bay. Growth and survival rates were compared to the Malaysian supply.

After the harvest the Phetchaburi cockles were used for a market transport experiment from Nakhon to Bangkok. The cockles were transported in a covered truck. Two types of sacks were used in transport, closed weave and open weave plastic. Survival rate and weight loss during and following transport were determined.

Analysis of stomach contents of *A. granosa* was carried out over 12 months in two other sites in a separate study. The data are included in this report. Identification of the (planktonic) food organisms was done as in Dakin and Colefax (1940), Cupp (1943), Davis (1955), Shirota (1966) and Boonyapivat (1978). Twenty cockles per month were examined. Cockles chosen were all longer than 1.5 cm.

Results and Discussion

Results from the private farm indicated mortality of *A. nodifera* during the first month following stocking from 20 to 85.5% depending on stocking density. Lower mortality was associated with lower stocking density.

The predator study results did not enable the researchers to establish a relationship between number of predators and production decrease. Few predators were found. The average number of empty cockle shells found with evidence of drilling snail was 3.1% of total cockles stocked over all months and all stations sampled.

Predators found by grab technique included two drilling snails and a crab. Only catfish, as a possible predator, was found by the drift-net technique. All cockles lost to predators were small, 5-12 mm. No cockles larger than 20 mm were found with evidence of drilling snail.

In the initial period after stocking, histological examination of the gonads revealed abnormal cells and a breakdown of the gametes. One month after stocking, new gonad cells developed normally.

Mortality rate during the first period was related to distribution and density of stocked seed. The producer desired a relatively uniform dense distribution in the early period with restocking of the seed after a period of growth. The sampling indicated that density was not uniform but clumped. Density was very high in the clumps.

The system preferred by producers was not biologically ideal. The seed cockle had a high mortality rate in the clumps.

The producer did not know the density of stocking. Sampling indicated a density range from 200 to 1,200/m^2 at different locations in the farm.

Growth

Cockle growth rate of *A. nodifera* was studied in the farm for 18 months: November 1983-April 1985, and in the experimental plot for 14 months: March 1984-April 1985. Growth rates differed between locations on the farm. At stations 1, 2, 3 cockles grew from 256, 325, 501 individuals/kg to 106, 125, 128 individuals/kg, respectively in 18 months. The cockle did not reach market size during the sample period. At stations 4 and 5 cockles grew from 146 and 241 individuals/kg to 68 and 71 individuals/kg, respectively during the sample period. These cockles did attain market size.

In the experimental plot *A. granosa* grew from 328 individuals/kg (3.0 g each) to 78 individuals/kg (12.8 g each) in 13 months. Stocking density of the plot was 300/m^2. Harvesting density was 210/m^2.

Sex ratio and gonad development

Sex ratio and gonad development of *A. nodifera* were determined utilizing 50 samples collected each month. The study did not find any evidence of the hermaphrodite condition. (This condition was very common in cockles examined at Phetchaburi.) Sex ratio did not differ from 1:1. After spawning the sex cannot be determined until a new cycle of gametogenesis is instituted within the gonad. The spawning period was July-October with a peak in September. After spawning the gonads remained in the undifferentiated stage for 4 months, November-March. April was the beginning of the new cycle of development. The development period required 4-5 months. One cycle of gonad development, considering the overall stock, requires one year.

Seed of *A. granosa* from Malaysia, stocked in the experimental plot, were initially stressed and gonad development was delayed. After the gonads recovered, development was the same as in *A. nodifera*. Spawning was at the same time as that of the cockles in the farm.

Soil quality

The soil was found to be alkaline with a pH of 7.85 to 8.68, similar to that in a cockle seed bed from Batu Maung, Malaysia, a very important cockle seed collection area.

Organic matter was in the range of 1.64 to 2.14%. Soil texture was silty clay with soil particles less than 2 mm composed of clay 41-52%, silt 40-46%, and sand 3-14%. When compared to soil texture of Batu Maung, organic matter in Nakhon Bay was significantly lower (organic matter at Batu Maung was 2.87-3.24%). The quantity of silt and sand was also lower than at Batu Maung.

Plankton

Data analysis from a 12-month plankton study indicated that April had the highest quantity of phytoplankton, surface 48.3 million and bottom 98.3 million cells/m^3. February and September had the lowest quantity. Water level was lowest in April and the maximum penetration of sunlight through the water column occurred during this month.

Dominant species of phytoplankton found during the study were: *Coscinodiscus* sp., *Rhizosolenia* sp. and *Chaetoceros* sp., the same species as reported for the cockle beds at Samut Songkhram and Phetchaburi Provinces. Larger quantities of each species were recorded in Nakhon Bay.

Phytoplankton was more abundant than in the traditional cockle culture areas of Thailand, Samut Songkhram and Phetchaburi. From a standpoint of food supply, Nakhon Bay is thus very suitable for cockle culture based on food availability.

Zooplankton abundance was highest in January, March and June in 1985, and was relatively low from July to December. Dominant groups were copepods, mysids, decapod larvae, gastropods, chaetognaths and palaemonid shrimps. Bivalve larvae were present in limited numbers, perhaps because the preservation method was not designed for bivalve larvae. Species identification was not made.

Food organisms

The 12-month study of food organisms of *A. granosa* was made using cockles from two stations in the western coast of the Gulf of Thailand, near Klongklone, Samut Songkhram Province, and near Bangkunsai, Phetchaburi Province, respectively.

The most abundant item was detritus. All cockles had ingested detritus in their stomachs. Of recognizable planktonic organisms, the most abundant were algae and diatoms, *Chlorella* sp., *Coscinodiscus* spp., *Rhizosolenia* spp. and *Nitzschia* spp. The proportions of the various organisms varied between sites and by month as shown in Table 1, and summary data are shown in Table 2.

Table 1. Percentages of organisms by genera in stomachs of cockles, February 1981-January 1982. Note: all stomachs contained detritus also.

Genera	Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Jan	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Diatom																								
Coscinodiscus	85 10	41 70	85 30	80 30	15 20	47 90	9 20	7 10	5 00	3 60	25 00	46 50	5 30	14 30	8 20	17 90	35 20	25 80	19 40		1 50	1 20		3 40
Rhizosolenia	13 90	2 40	10 20	8 30	32 80	29 70	7 00	7 50	0 80		7 80	2.30	3 90	4 80	4 10		18 40	30 30	29 00	35 80	46 40	37 50	35 50	5 10
Nitzschia	0 20	14 70	3 90	5 00	5 20	8 60			5 80	5 60	4.70	1 20	10 50	7 90	12 30	9 00	11 80	6 70	10 30	4 50	13 20	0 60	6 40	
Synedra		0 03	0 30	1 20		0 40					3.10	1 20	9 20	3 20	4.10	7 70		3 40	6 50	11 90	3 97			0 02
Diatoma						1 10			2 70	0 30	4.70	5 80	2 30	1 60	5 50	5.10	1 30			4 50				
Gyrosigma		0 01			6 00	5 70					1 60	4 70			1 40						0 99			
Pleurosigma			0 20	0 60		1 60	0 20											2 30			7 70	0 60		
Thalassiothrix	0 10					1 40						2.30									0 30	2 60		
Chaetoceros							0 30											2 30						
Biddulphia																		1 10						
Surirella									0.30													5 70		
Grammatophora																						0 60		
Licmophora								0 20	2.40															
Ditylum						0.70															0 70			
Fragilaria	0 10																					2.60		
Planktoniella																								2.50
Thalassiosira																						0 60		
Algae																								
Chlorella							83.20	85.00	85.20	89.50	51.60	84.90	67.70	58.30	60.30	55.10	30.30	28.10	33.90	35.00	12.70	49.70	58.10	
Micrasterias	0 60					0.70			0.30	0.40														88 20
Staurastrum		41 70		4.40	40.00																			
Trichodesmium	0 02																				8.40	1.90		0 60
Unknown filamentous algae												1.20			4.10	3.90				7.60	0 30			
Others																								
Phacus							0.20																	
Tintinnopsis				0.20				1.20																
Rhabdonella						0.70																		
Pyrocystis						0.90																		
Ceratium					0 40						1.60				0.90									
Leucosolenia					0 40																			0.24
Codonellopsis																						0.60		

Station 1 Klongklone, Samut Songkhram Province
Station 2 Bangkunsai Phetchaburi Province

The two dominant diatom genera are the same as those dominating the plankton in Nakhon Bay.

Chlorella were not observed in the latter, although they may not have been recognizable after preservation of plankton samples.

Transportation of mature cockles to market

The experimental plots were harvested 18 months following stocking. The harvested cockles *(A. nodifera)* were transported to Bangkok. Cockles attained a size of 70 individuals/kg. Survival rate and weight loss during transportation, survival after transportation and type of container were studied. Two types of container were tested, fertilizer sacks (closed mesh) and onion sacks (open mesh). A covered truck was used for transport. Phetchaburi cockles seeded in Nakhon were transported in the same truck to compare survival rate between the two types of cockle. The Phetchaburi cockles were stocked at 210 individuals/kg. The culture period was 11 months and harvest size was 102 individuals/kg.

Survival rate was determined at 24, 48, 72 and 96 hours following harvest (removal from the water). The Malaysian samples were divided into two groups: 1) removed from sack and 2) kept in the sack. The Phetchaburi samples were all removed from the sacks following transport. Transportation time from Nakhon to Bangkok was 19 hours after leaving the landing.

Table 2. Percentages of organisms in cockle stomachs by station and month, February 1981-January 1982. Note: all stomachs contained detritus also.

Month	Station	Diatoms	Algae	Others
February	1	99.4	0.6	
	2	58.3	41.7	
March	1	100.0		
	2	65.4	4.5	0.2
April	1	59.3	40.0	0.8
	2	97.7	0.7	1.6
May	1	16.6	63.2	0.2
	2	14.8	85.0	0.2
June	1	17.0	65.4	
	2	10.2	89.9	
July	1	46.9	51.6	1.6
	2	64.0	36.0	
August	1	30.3	69.7	
	2	31.8	68.3	
September	1	35.6	64.4	
	2	39.7	59.0	
October	1	67.7	30.3	
	2	71.9	28.1	
November	1	66.1	33.7	
	2	56.7	43.3	
December	1	78.7	21.1	
	2	47.8	51.6	0.6
January	1	41.9	58.1	
	2	11.0	88.8	0.2

Station 1: Klongklone, Samut Songkhram Province
Station 2: Bangkunsai, Phetchaburi Province

Study results indicated that survival rate was high with an average of 2% mortality at 24 hours. Cockles removed from the sack had a high mortality after 72 hours, averaging 21.5%, and near total mortality occurred by 96 hours. The cockles left in the sack had high survival at 72 hours but 99% were dead after 96 hours. Allowing cockles to remain in the sack until sale prolonged survival. The packed condition may allow the cockle to retain moisture. Cockle sales must occur before 96 hours following harvest. Survival rate did not differ between the two types of cockle. The cockles packed in fertilizer sacks had a slightly higher survival rate than those packed in onion sacks. No mortality occurred among cockles packed in fertilizer sacks during the first 24-hour period. Although 2-3% mortality occurred in the onion sacks during the same period, the difference was not significant. Weight loss during transport differed by type of sack, but again the variation was small and not significant.

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Transplantation of Cockles (Fam. Arcidae) into Sawi Bay, Thailand*

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Abstract

Mature cockles *(Anadara granosa)*, stocked in early 1984 in Sawi Bay, Thailand, where natural stocks had virtually disappeared, had 49% survival after 2 years. Most mortality occurred in the first month. Spawning peaks were in June-July 1984 and May-June 1985. Settlement occurred but there was over 90% mortality of cockles 2-10 mm long. *A. nodifera*, stocked as seed grew well in the Bay but suffered mortality from predators and competitors, as well as losses from tidal movement and poaching.

Introduction

The Department of Fisheries was concerned about the situation with regard to cockle culture. The lack of natural seed supply within Thailand was a constraint to expansion of culture activities.

It was decided to attempt to establish a natural population of cockles in an area. The natural population would serve as broodstock for seed supply for other areas. The area near the mouth of the Mae Klong River, offshore from Samut Songkhram and Phetchaburi Provinces, currently has the only natural seed supply sufficient for culture purposes in Thailand.

Sawi Bay was chosen as the site for a pilot test of the concept. The study was initiated in 1984 during Phase II of the DOF/ICLARM/GTZ Project and continued into Phase III. Biological parameters were monitored in the Bay and cockle were

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transplanted into an area to serve as parent stock in an attempt to re-establishing a natural breeding population.

Sawi Bay is located in Chumphon Province. The Bay is enclosed with a narrow opening to the Gulf of Thailand. The coastline of the interior of the Bay is about 20 km in length. The bottom of the Bay is muddy. Organic matter particles are carried into the Bay by many canals such as Klong Ilat, Klong Chumphon and Klong Wisai. Many species of brackishwater fauna, including cockles were formerly abundant in the Bay. Overfishing and possibly changes in environmental factors led to a decline in natural populations. Cockles, for example, were reduced to near extinction in the Bay.

The area was the site of a previous Department of Fisheries effort to establish green mussel *(Perna viridis)* culture. The transplantation was successful and a substantial quantity of green mussels is now produced in the Bay. The previous effort aided in gaining assistance from local fishing families in the cockle research.

Methods and Materials

During 1984, 15.43 tonnes of mature cockles *(Anadara granosa)* from Malaysia, 25-35 mm in length averaging 86.5/kg were imported from Malaysia and stocked in a 5-rai experimental area (1 rai = 1,600 m^2). Baseline biological parameters of the stocked population were established. After stocking, growth, survival and gonad development rate were checked monthly. Samples of 100 cockles were collected monthly for growth rate measurement. Some 200-300 individuals were collected to determine survival rate. Thirty individuals were collected to determine stage of gonad development. Environmental factors, i.e., salinity, transparency, current, chlorophyll *a*, pH, O_2 and bottom condition, were monitored monthly.

During 1985, 5 t of seed cockle *(Anadara nodifera)* from Phetchaburi Province were stocked in a 6-rai experimental area in the Bay. At delivery, the supply was checked for size distribution, trash and proportion of live seed. After stocking, survival and growth rate were monitored monthly. Some environmental factors were checked monthly.

Samples were transported to Prachuap Khiri Khan Brackishwater Fisheries Station for biological and chemical analysis. Analysis was directed to determining the feasibility of establishing a seed supply in the Bay.

Results

The mature *A. granosa* from Malaysia were transported in January 1984. Transport time was for 42 hours and the cockles were in weak condition at stocking. After 1 month, mortality was 70%. Mortality was at a very low level after the first month.

The cockles had a growth rate of 1 mm in length per month over a 7-month period. Cockles grew from an average length of 30.3 mm and 10 g in weight to 35.6 mm in length and 16.4 g. Pattern of growth was a normal sigmoid curve.

Ripe gametes were present in the gonads during every month, indicating that the cockles could spawn every month. The spawning peak occurred during July and August. In a sample of 210 individuals, there were 90 males, 119 females and one hermaphrodite. Ratio of male to female was 1:1.32.

Data collection for the study was interrupted in August 1984 for a four-month period and reinstituted for January to November 1985.

Mortality of the *A. granosa* increased slightly in 1985. In January 1985 the percentage of empty shells was 43.6. The average percentage of empty shells for January-November 1985 was 49.13.

The growth rate during 1985 was 0.39 mm/month. The spawning season was June-July. Highest condition index was 263.39 in May and decreased rapidly to 11.72 in the next month when spawning occurred. The lowest value was in September, 9.17. The stage of gonad development and the condition index can be related. Induced spawning experiments at Prachuap Khiri Khan Brackishwater Fisheries Station indicated that cockles from Sawi Bay could be spawned in June and July. The number spawning averaged 3.33% from each induced spawning sample of 200 individuals.

A natural seed settlement was found nearshore. The seed area was located by determining the prevailing current patterns during the spawning season by use of floating balls. Balls were released every 30 minutes during the period of high tide and during the period of low tide. Six balls were released during each period.

Very high mortality occurred in the seed bed, 17.5-60 empty shells, 2-10 mm in length, and only 0.05-1 viable seed per m^2 were found. The seed bed was located 1.5 km northwest of the pilot project area. The bed was 500-700 m from the shore and extended 1 km along the shoreline. Cause of mortality was not determined but the use of trawl nets and/or the presence of a freshwater inlet in the area may have been contributing factors.

Wind and current were major determinants of the settlement area for seed cockle. During the spawning season the area was under the influence of the southwest monsoon. Current direction was from offshore to inshore on an oblique angle to the right at high tide. The direction was offshore at an oblique angle to the left at low tide.

In July 1985, cockle seed were transported from Phetchaburi Province and stocked in Sawi Bay. The cockle seed had an average length of 20.3 mm, average weight of 2.8 g. Transport time was 21 hours from collection to stocking. Mortality before stocking was 4%. Stocking density was 169.7/m^2.

The cockles acclimated well. Growth rate was 1.55 mm per month. Cockles grew to an average length of 26.5 mm and average weight of 5.7 g by November. Stock density after 4 months was 65.1/m^2, a survival rate of 35.2% after 4 months. However, survival rate was estimated at 80% during the first 4 months of the growing period based on the empty shells found in the culture area. The cockles were being moved away from the shore due to tidal factors. Thus, stock decrease was due both to mortality and movement of the cockles.

Mortality in the experiments was due to three factors in addition to acclimation: 1) time, and possibly method, of transportation; 2) natural predators and parasites in the culture area, including starfish and other marine organisms that feed on shellfish, and barnacles or other external parasites that restrict growth of the cockle; 3) human predation in the culture area. The third factor was a major source of loss. The experimental culture area was 180 km from the station, 1 hour by boat from the village and relatively isolated in the Bay.

Water quality and other biological factors were monitored in the culture area. Salinity averaged 26.4 ppt, transparency was 111.8 cm on average. Oxygen averaged 6.83 ppm at the surface and 6.69 ppm at the bottom, well distributed throughout the water column. Water surface pH was 8.04. Water temperature at the bottom was 28°C. Nitrite and nitrate averaged 0.1719 and 0.6864 µg per liter, respectively. Average chlorophyll *a* from March to September 1984 was 1.25 mg/m³. Peak was in March 1984, 2.99 mg/m³. The lowest amount was in May, 0.16 mg/m³.

Bottom soil texture was silty loam. Soil composition was 49% silt, sediment moisture was 54.1%, organic matter was 2%. The amount of organic matter was lower than organic matter in sampled cockle beds in Malaysia (Broom 1985) and Nakhon Bay. Slope of the area was 1/466. The muddy bottom was 30 cm in depth. Water was of high quality with a high level of natural nutrients. The combination of environmental factors indicates that the area was very suitable for cockle culture. The biological factors were less certain. The cockles spawned and settlement occurred but a seed bed was not established in the initial location. Settlement density was low and very high mortality occurred.

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Annex 1

Unpublished Reports and Theses Produced during the Project

1. *Unpublished Reports* - copies can be obtained or request from ICLARM, subject to the approval of authors and payment of copying and mailing costs

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Annex 3

Research Projects on Molluscs Conducted by Personnel of the Brackishwater Fisheries Division (BWFD), Thailand Department of Fisheries, from 1976 to 1985

A) OYSTERS

NO.	TITLE	UNIT	YEAR
1.	Research in spawning and growth oyster	Phuket	1976
2.	Research on culture and spawning of oyster	Chanthaburi	1976
3.	Study on abundance and growth of large oyster at Prachuap Khiri Khan	Prachuap Khiri Khan	1976
4.	Experiment on culture of small oyster	Songkhla	1976
5.	Study of conditions influencing seasonal rate of growth of small oyster and green mussel from culture and natural grounds on the Eastern Coast of the Gulf of Thailand	BWFD	77-80
6.	Study of effect of water pollution on small oyster and green mussel in Chonburi	BWFD	1977
7.	Research on spawning large oyster	Phuket	1977
8.	Experiment on culturing small oysters in wooden trays	Songkhla	1977
9.	Survey of spawning season of small oyster in Songkhla lake outlet and Khlong Takbai in Narathiwat Province	Songkhla	1977
10.	Study of biological aspects and experiments on culture of small oyster	Surat Thani	1977
11.	Study of growth of small oyster	Surat Thani	1977
12.	Study of rate of growth, survival and dispersion of seed of small and large oyster in Phetchaburi	BWFD	1978

13.	Survey of movement of origin of green mussel, small oyster and large oyster	BWFD	1978
14.	Continuation of No. 5 above	BWFD	1979
15.	Experiment in culture of small oyster in baskets	Songkhla	1978
16.	Study of the abundance and distribution of oyster spat in Khlong Suakyom, Thephaa District, Songkhla Province	Songkhla	1978
17.	Experiment on culture of small oyster in Khlong Waan	Prachuap Khiri Khan	1978
18.	Experiment on breeding to increase seed of large oyster	Phuket	1978
19.	Study of the abundance and distribution of large oyster	Phuket	1978
20.	Study of biology and some requirements of small oyster at Bang Proong Bay, Saensuk Subdistrict, Muang District, Chonburi Province	BWFD	1979
21.	Study of the abundance and distribution of oyster spat in Khlong ThePhaa, ThePhaa District, Songkhla Province	Songkhla	1979
22.	Experiment on culture of small oyster at Khlong Waan	Prachuap Khiri Khan	1979
23.	Study of growth and well being of large oyster	Surat Thani	1979
24.	Study of spawning season of large oyster	Surat Thani	1979
25.	Study of abundance and distribution of large oyster	Phuket	1979
26.	Experiment on culture of small oyster	Satun	1980
27.	Study of the abundance and distribution of oyster spat in Khlong Paanaare, Pattani Province	Songkhla	1980
28.	Experiment in culture of oyster in baskets	Chanthaburi	1980
29.	Study of survival of oyster at different levels of salinity	Chanthaburi	1980
30.	Study of hatchery culture of seed oyster	Surat Thani	1980
31.	Study of the advantages of various materials for spat collection of large oyster	Satun	1980
32.	Experiment on culturing large oyster in various materials	Satun	1980
33.	Seasonal attachment to	Satun	1980

34.	Experiment and demonstration of various types of oyster culture	BWFD	1980
35.	Experiment on spawning of oyster in shrimp ponds	Songkhla	1980
36.	Demonstration of culture of oyster in Khlong Tan Yong Paw, Pattani Province	Songkhla	1980
37.	Experiment on spawning of oyster	Surat Thani	1981
38.	Study of abundance and distribution of oyster	Phuket	1981
39.	Study of spawning season, location of spawning beds, distribution and abundance of large oyster seed in the coastal area of Phangnga Bay	Phuket	1981
40.	Study of the type of collector and season of attachment of oyster spat in Satun and Trang Provinces	Satun	1981
41.	Experiment on culture of large oyster in trays and raft	Phuket	1981
42.	Experiment on spawning large oyster	Satun	1981
43.	Culture of oyster in shrimp ponds	Satun	1981
44.	Investigation of oyster spawning and care of larval stages	Satun	1982
45.	Experiment on breeding and larval rearing of large oyster	BWFD	1982
46.	Survey of the abundance and distribution of oyster in Phangnga Bay	Phuket	1982
47.	Demonstration of culture of oyster in Khung Kra Baen Bay, Chanthaburi Province	BWFD	1982
48.	Experiment in culture of oyster in sea bass pond	Prachuap	1982
49.	Investigation on spawning oyster	Surat Thani	1983
50.	Experiment on spawning oyster by changing temperature	Surat Thani	1983
51.	Experiment on spawning and raising large oyster	Surat Thani	1983
52.	Study on spawning season and abundance of seed oyster in Khung Kra Baen Bay	BWFD	1983
53.	Experiments on water from Khung Kra Baen Bay, Chanthaburi used for raising oyster	BWFD	1983
54.	Study of the biological history and conditions influencing small and large	BWFD	1983

	oysters in the vicinity of the Welu river, Kawsaming District, Trat Province		
55.	Experiments on water from Khung Kra Baen Bay, Chanthaburi Province used for growing oyster	BWFD	1984
56.	Experiment to spawn oyster in Khung Kra Baen Bay	BWFD	1984
57.	Survey of season of spawning of oyster in the region of Aang Jaang Grapahng, Trat Province	Chanthaburi	1984
58.	Study of seasonal settlement of oyster Spat	Surat. Thani	1984
59.	Hatchery study of oyster	Prachuap Khiri Khan	1985

B) COCKLES

1.	Study of the population of cockle in the region of Phangnga and Krabi Provinces	Phuket	1978
2.	Survey of the cockle are in Bang Tabun, Phetchaburi	BWFD	1979
3.	Study of culture method and rate of growth of cockle	Satun	1979
4.	Biological factors for cockle in the region of Trang, Krabi and Satun Provinces	Satun	1980
5.	Study of development and age at spawning in cockle at Phetchaburi Province	BWFD	1981
6.	Study of development of gonad products and spat of cockle at Phetchaburi Province	BWFD	1981
7.	Study of food organisms constituting the stomach contents of cockle	BWFD	1981
8.	Survey of cockle production area in the bay of Nakhon Si Thammarat Province	Songkhla	1981
9.	Study of growth and development of cockle from nature and experimental plots	Satun	1981
10.	Study of the chemical, physical and biological conditions in the cockle culture area in Satun Province	Satun	1981
11.	Study on the biology of cockle	Satun	1981

12.	Survey of the abundance and distributional spread of seed cockle in Phangnga Bay	Phuket	1982
13.	Rate of growth and development of cockle in Samut Songkhram Province	BWFD	1982
14.	Study of gonad development and seed of cockle from Samut Songkhram and Phetchaburi Province	BWFD	1982
15.	Study of components of cockle in Phetchaburi and Samut Songkhram	BWFD	1982
16.	Study of the conditions in cockle culture areas in Samut Songkhram Phetchaburi, Surat Thani, Ranong, and Nakhon Si Thammarat Provinces	BWFD	1982
17.	As in 16 above	BWFD	1983
18.	Season of spawning and distribution of see cockle in the coastal region of of Bangkok and Samut Songkhram Province	BWFD	1984
19.	Experimental culture of cockle by transferring brood stock from other areas to Chanthaburi Province	BWFD	1984
20.	Production of cockle from developed culture area	Satun	1984
21.	Cockle seed survey in Surat Thani	Surat Thani	1985
22.	Hatchery study on cockle	Prachuap Khri Khan	1985
23.	Season of spat fall and distribution of cockles in the coastal region of Phetchaburi Province	BWFD	1985
24.	Cockle seed survey in Phangnga Bay	Phuket	1985
25.	Survey and culture of cockle for increase in reproduction, Welu River	Chanthaburi	1985

C) GREEN MUSSELS

1.	Study on some poduction and biological aspects of green mussel in Chonburi, Samut Songkhram and Samut Sakhon Provinces	BWFD	1976
2.	Diseases in green mussel in the Gulf of Thailand	BWFD	1977
3.	Hanging culture of green mussel mussel	BWFD	77-81

4.	Study on some production and biological aspects of green mussel culture in Samut Songkhram, Chonburi and Samut Sakhon Provinces	BWFD	1976
5.	Disease in green mussel in the Gulf of Thailand	BWFD	1978
6.	Study on some production and biological aspects of green mussel in Samut Prakan and Samut Sakhon Provinces	BWFD	1978
7.	Hanging culture of green mussel	BWFD	1978
8.	Experimental culture of green mussel in baskets	BWFD	1978
9.	Culture of green mussel	Chanthaburi	1978
10.	Experimental culture of green mussel mussel	Rayong	1978
11.	Study on the conditions affecting growth rate of green mussel from natural farm culture in Samae Khao Bay, Bang Pakong District, Chachoengsao Province	BWFD	1979
12.	Hanging culture of green mussel	BWFD	1979
13.	Experimental culture of green mussel in baskets	Songkhla	1979
14.	Experiment to increase breeding of shellfish	Songkhla	1979
15.	Study on production of green mussel at Pak Nam Chumphon	Prachuap	1979
16.	Hanging culture of green mussel	BWFD	1980
17.	Experiment to increase breeding of green mussel in Pattani Bay	BWFD	1980
18.	Experiment and demonstration of green mussel production near shore in Pattani Province	Songkhla	1980
19.	Experiment to increase production of seed of green mussel in the Gulf of Pattani Province	Songkhla	1981
20.	Experiment of spawning green mussel	BWFD	1982
21.	Increase production of seed of green mussel from the bay at Nakhon Si Thammarat Province	Songkhla	1982
22.	Hanging culture of green mussel	BWFD	1982
23.	Experimental culture of green mussel near Chaang Island, Laem Ngahp District	BWFD	1982
24.	Raft hanging culture of green mussel	Prachuap Khiri Khan	1983

25.	Assessment of green mussel culture in Chumphon in the year 1983	Prachuap Khiri Khan	1983
26.	Increase in seed supply of green mussel in the Bay at Nakhon Si Thammarat Province for 1982-83	BWFD	1983
27.	Experiment on breeding and rearing green mussel	BWFD	1983
28.	Experimental culture of green mussel in Khung Kra Baen Bay	BWFD	1983
29.	Comparative study of culture of green mussel from rope and bamboo in Samae Khao Bay, Bang Pakong	BWFD	1983
30.	Experiment on culture of green mussel and large oyster near Samet Island	Rayong	1984
31.	Survey of spawning season of green mussel	Satun	1984
32.	Green mussel culture in the Bay, Prachuap Khiri Khan Province	Prachuap	1985

D) SHORT NECKED CLAMS

1.	Study of the early history of short necked clam in Khlong Daan Sub-district, Bang Bah District, Samut Prakan Province	BWFD	1978
2.	Study of the history of short necked clam	Prachuap	1980
3.	Study of some biological aspects of short necked clam in Ao Chah Subdistrict, Trat Province	BWFD	1982
4.	Study of some biological aspects of short necked clam in Ao Chah Subdistrict, Trat Province	BWFD	1983
5.	Study of production, growth, develop-ment and sex ratio of short necked clam	BWFD	1983
6.	Study of alternation of sex organs in short necked clam	BWFD	1983
7.	Study of alternation of sex organs in short necked clam with growth to maturity and some other biological aspects at the mouth of the Thaa Jiin River, Samut Songkhram Province	BWFD	1983

8. Study of the habitat and some biological aspects of short necked clam near Bang Tabun Bay, Phetchaburi Province	BWFD	1984
9. Experimental culture of short necked clam in Khung Kra Baen Bay, Chanthaburi District or Samut Songkhram Province	BWFD	1985
10. Spawning season of short necked clam at Satun Province	Satun	1985
11. Short necked clam project in Surat Thani Province	Surat Thani	1985

E) OTHER MOLLUSCS

1. Characteristics of the eggs and young of Pelecypod	BWFD	1981
2. Characteristics of the eggs and young of some kinds of Shellfish	BWFD	1982
3. Study of some biological aspects of the habitat for Hoy Pim (continued)	Samut Songkhram	1982
4. Experiments on breeding bivalve shellfish of economic importance to Thailand	Prachuap Khiri Khan	1983
5. Study of some biological aspects of sex organs alternation in horse mussel in the coastal area near the mouth of Bang Pakong River, Chachoengsao Province	BWFD	1984
6. Biological investigation of breeding of Hoy Talap in Laem Gliit Sub-district, Muang District, Trat Province	BWFD	1984
7. Beginning experiments regarding production of bivalve shellfish seed	Prachuap Khiri Khan	1984
8. Reproductive physiology of Hoy Talap at Ao Manao, Khlong Waan Subdistrict, Prachuap Khiri Khan	BWFD	1985
9. Biological study of Hoy Talap	Prachuap Khiri Khan	1985
10. Taxonomic identification of coastal shellfish of Thailand	BWFD	1985

Annex 4

Trace Metals in Bivalve Molluscs from Thailand*

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1985. Mar. Environ. Res. 15: 215-234.

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ABSTRACT

Capture fisheries and aquaculture provide a large quantity of bivalve molluscs for human consumption in Thailand each year. The existing information on trace elements in these bivalves is fragmentary and contradictory. This paper reports data for eight metals (cadmium, chromium, copper, iron, lead, nickel, mercury and zinc) in the four major species marketed. These are the clam Paphia undulata, *the cockle* Anadara granosa, *the green mussel* Perna viridis *and the rock oyster* Crassostrea commercialis. *The bivalves analysed were taken at markets or in the field to cover as many of the major sources as possible. The results indicate no major threat to public health from trace elements in these species from Thailand and lend confidence to the expansion of aquaculture operations. In particular, the levels of lead found in the samples analysed are considerably lower than those previously reported by other authors.*

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INTRODUCTION

About 300 000 tonnes of bivalve molluscs are harvested and marketed annually in Thailand. The species of main importance are the clam, *Paphia undulata*, the cockle, *Anadara granosa*, the green mussel, *Perna viridis*, and the oysters, *Crassostrea commercialis* and *C. lugubris*. The clam industry involves capture fisheries only. The other four species are all cultured within Thailand, although capture fisheries also exist in some cases. *A. granosa* is the only species commonly imported into Thailand, mainly from beds in Malaysia.

Paphia undulata is the subject of a considerable capture fishery in Thailand, mainly off the Chao Phraya Estuary, near Samut Prakarn, and near Trat (Fig. 1). About half the clam tonnage landed is sold live; the rest is boiled and canned for marketing locally and overseas. Because the fishery is extensive, limited surveys will not necessarily cover all clam sources, although this is more likely if several markets are sampled.

Anadara granosa makes up about one-third of the total bivalve tonnage marketed in Thailand. About 80% of the cockles marketed in Thailand are imported from Malaysia. These imports are sold at several Gulf markets, but most are routed through Samut Prakarn market near Bangkok. The local cockle culture (sometimes using seed from Malaysia) is scattered through several sites around the Gulf coast (Petchaburi and Surat Thani being the main ones; see Fig. 1), with some culture also at Phang Nga on the Andaman Sea coast.

Perna viridis is the subject of very large-scale culture at Cholburi, to the west and south of the Bang Pakong Estuary (Fig. 1). These beds involve natural spatfall onto stakes (usually bamboo) placed in the bottom mud. The mussels grow rapidly even without thinning and are sold at 6–12 months old at about 6 cm shell length, providing 60% of the Thai mussel crop. The remaining 40% of the mussel tonnage marketed is derived from fish traps along the Petchaburi coast, again over an extensive area. The mussels settle on the fish trap stakes and are marketed at about the same age as those from Cholburi.

Crassostrea commercialis is cultured at Ang Sila and Bang Prong Bays, to the south-east of Bangkok near Cholburi. Spatfall occurs onto concrete trestles in the intertidal zone. Marketing of oysters occurs when the individuals are small, averaging about 2 to 3 g wet flesh weight.

Although a certain amount of information exists for trace elements in

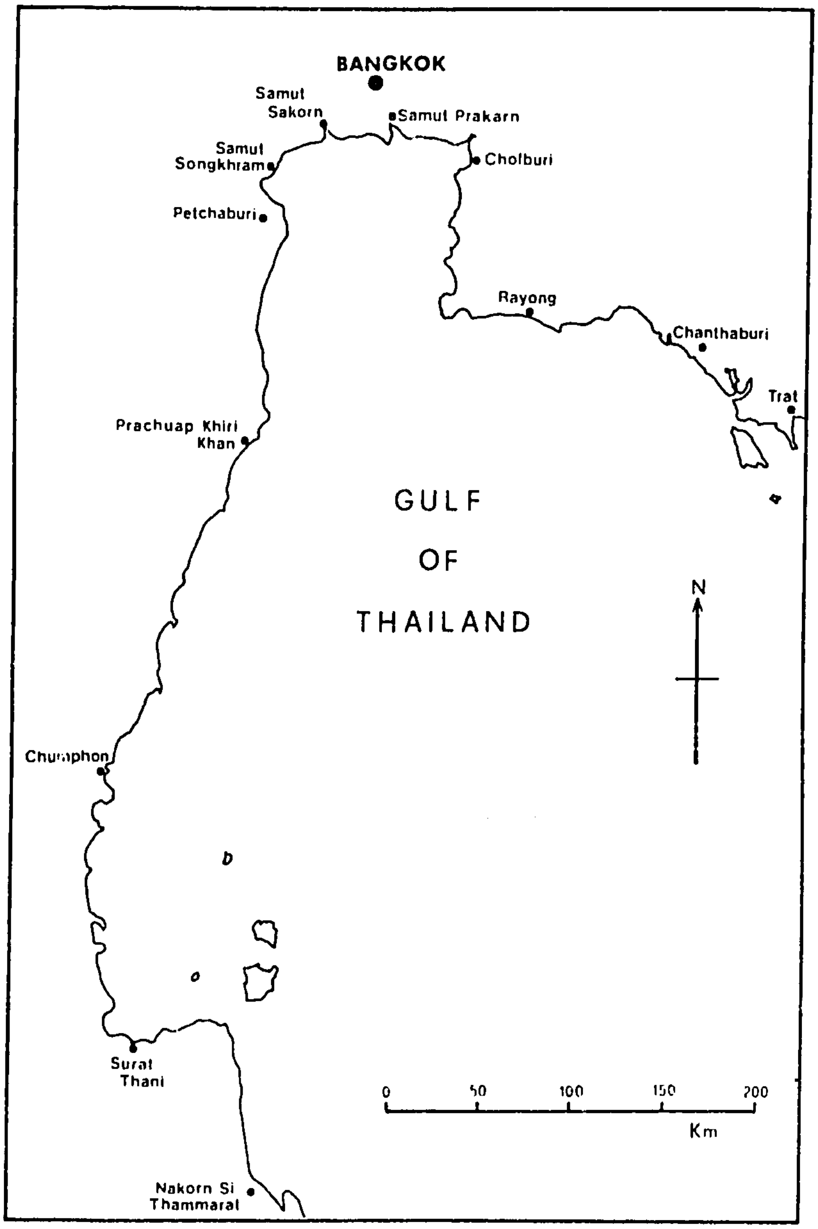

Fig. 1. Map of the Gulf of Thailand, showing the various locations from which samples were derived.

TABLE 1

Sample Codes, Collection Locations and Areas of Origin for Clams, Cockles, Mussels and Oysters Sampled in December, 1982 and January, 1983 in the Gulf of Thailand. See Fig. 1 for Locations and Areas Quoted

Sample code	*Collection location (market/landing/stall)*	*Area of origin (culture/harvest)*	*Sample code*	*Collection location (market/landing/stall)*	*Area of origin (culture/harvest)*
	(a) Clams, *Paphia undulata*			(b) Cockles, *Anadara granosa*	
PSSN	Samut Sakorn	Samut Sakorn	CST-1	Tachang, Surat Thani	Tachang, Surat Thani
PSS-1	Samut Sakorn	Samut Songkhram	CST-2	Tachang, Surat Thani	Tachang, Surat Thani
PSS-2	Samut Sakorn	Samut Songkhram	CST-3	Tachang, Surat Thani	Tachang, Surat Thani
PSS-3	Samut Prakarn	Samut Songkhram	CNS	Nakorn Si Thammarat	Nakorn Bay
PSS-4	Samut Sakorn	Samut Songkhram	CP	Petchaburi	Bang Taboon, Petchaburi
PSP-1	Samut Prakarn	Klong Dan[a]	CSS	Samut Songkhram	Klong Kone[b]
PSP-2	Samut Prakarn	Klong Dan[a]	CM-1	Samut Prakarn	Malaysia
PP	Petchaburi	Petchaburi	CM-2	Samut Prakarn	Malaysia
PS	Samut Sakorn	Surat Thani	CM-3	Samut Prakarn	Malaysia
PC	Samut Prakarn	Cholburi	CM	Samut Prakarn	Malaysia
			CSSN	Samut Sakorn	Samut Sakorn
	(c) Mussels, *Perna viridis*				
MP-1	Ban Laem, Petchaburi	Petchaburi		(d) Oysters, *Crassostrea commercialis*	
MP-2	Ban Laem, Petchaburi	Petchaburi	OASA	Field sample	Ang Sila Bay, Cholburi
MP-3	Ban Laem, Petchaburi	Petchaburi	OASB	Field sample	Ang Sila Bay, Cholburi
MP-4	Ban Laem, Petchaburi	Petchaburi	OASC	Field sample	Ang Sila Bay, Cholburi
MP-5	Ban Laem, Petchaburi	Petchaburi	OBPD	Field sample	Bang Prong Bay, Cholburi
MSS-1	Samut Songkhram	Samut Songkhram	OBPE	Field sample	Bang Prong Bay, Cholburi
MSS-2	Ban Laem, Petchaburi	Samut Songkhram	OBPF	Field sample	Bang Prong Bay, Cholburi
MSS-3	Ban Laem, Petchaburi	Samut Songkhram			
MSS-4	Ban Laem, Petchaburi	Samut Songkhram			
MSS-5	Ban Laem, Petchaburi	Samut Songkhram			
MBP-1	Field sample	Bang Pakong, Cholburi			
MBP-2	Field sample	Bang Pakong, Cholburi			
MBP-3	Field sample	Bang Pakong, Cholburi			
MBP-4	Field sample	Bang Pakong, Cholburi			
MBP-5	Field sample	Bang Pakong, Cholburi			

[a] A district of Samut Prakarn province. [b] A district of Samut Sakorn province.

sediments from the Gulf of Thailand (e.g. Menasveta & Cheevaparanapiwat, 1981; Hungspreugs & Yuanthong, 1983), the data concerning metals in Thai bivalves are sparse, and those studies which have been published on bivalves are often contradictory. This paper presents results concerning trace metal levels in *Paphia undulata*, *A. granosa*, *Perna viridis* and *C. commercialis*, taken from the field or from markets in Thailand. The sampling strategy was designed to cover, as far as possible, all major sources of these species. The data reported are considered valuable in terms of their implications for both water quality and public health in Thailand, particularly where large-scale culture of these species exists or is contemplated.

MATERIALS AND METHODS

Sampling

All samples were collected between 15 December, 1982 and 12 January, 1983. Table 1 lists the collection locations and areas of origin of the samples. In the case of market samples, data on the areas of origin were obtained from retailers and fishermen. For *Paphia undulata*, ten samples were taken from three markets. For *Anadara granosa*, eleven samples were purchased in six different markets to cover most of the possible areas of origin. The *Perna viridis* beds at Cholburi were sampled in the field at five locations. These were spaced at intervals to attempt to characterise trace element levels in each portion of the total area of the beds. A total of ten additional *P. viridis* samples was taken from Petchaburi and Samut Songkhram markets. The *Crassostrea commercialis* beds at Ang Sila Bay were sampled at three sites, as were the beds at Bang Prong Bay; in each case, samples were taken on transects away from the shore. The culture areas for *C. commercialis* further east, near Chanthaburi and Trat, were not sampled. The *C. lugubris* beds in the south of the Gulf of Thailand (near Surat Thani) were also omitted from the present study.

Analysis

Samples were frozen after collection and air-freighted to Hong Kong in February, 1983, packed on dry ice in styrofoam containers. They were stored frozen at $-20\,°C$ until required for analysis. Samples were then thawed and twenty-five individuals were randomly selected from each sample and combined for analysis. Shell lengths (longest dimension) were recorded with calipers and the bivalves were shucked with stainless steel instruments. The shells of all species, and the byssus of *Perna viridis*, were discarded. The soft parts of all species were then bagged for analysis after determination of wet weights.

Subsequent to this preparative phase, each sample was homogenised thoroughly using a non-contaminating commercial blender. Aliquots of each homogenate were taken for determination of wet weight/dry weight ratios, which involved drying to constant weight at 105 °C. Separate aliquots were taken for metal analysis and were subjected to digestion using a 10:1 v:v mixture of nitric and sulphuric acids. Suitably diluted final digests were analysed by atomic absorption spectrophotometry (all elements except mercury), using the flame technique or the graphite furnace, depending on the levels encountered. Mercury was analysed by the vapour generation technique, on a Perkin-Elmer 50A mercury analyser.

Quality control of all analyses was ensured by the concurrent study of various reference materials and intercomparison materials. The tuna fish and oyster standards (National Bureau of Standards, Washington, USA) and intercomparison materials from several sources (International Laboratory of Marine Radioactivity, Monaco; International Council for the Exploration of the Sea) are those in most frequent use. The same methods have been in use for some time in this laboratory, which performs well in intercomparison exercises (Phillips *et al.*, 1982*a*, *b*).

RESULTS

The concentrations of the eight trace elements studied are shown in Tables 2 to 5. Data for shell lengths, mean wet weights and mean dry weights are also included. Intrasample and intersample variability in shell lengths and tissue weights was minor in the clams, cockles and oysters studied. However, the mussel samples varied over a rather greater range. Size is known to be significant in determining element concentrations in some bivalves (e.g. see Boyden, 1974, 1977; Phillips, 1980). However, *Perna viridis* from Hong Kong waters exhibits no significant changes in element concentrations with size (D. J. H. Phillips, in preparation) and

TABLE 2

Shell Lengths, Mean Wet and Dry Weights of Whole Soft Parts, and Concentrations (Means, μg/g Dry Weight) of Eight Trace Elements in Clams, *Paphia undulata*, from Thailand

Sample code	*Shell length (mm) mean ± SD*	*Mean wet weight (g)*	*Mean dry weight (g)*	*Concentrations (μg/g dry weight)*							
				Cd	*Cr*	*Cu*	*Fe*	*Pb*	*Ni*	*Hg*	*Zn*
PSSN	46·2 ± 2·42	2·61	0·52	0·80	1·00	5·50	900·0	1·25	1·75	<0·10	47·5
PSS-1	44·6 ± 5·12	2·98	0·60	0·65	0·35	4·55	550·0	0·80	1·35	<0·10	42·0
PSS-2	47·8 ± 2·65	3·81	0·72	0·74	0·32	5·05	442·1	0·89	1·74	<0·10	46·3
PSS-3	45·9 ± 2·21	2·84	0·57	0·45	0·55	5·00	650·0	0·65	1·30	<0·10	49·5
PSS-4	42·1 ± 7·04	2·78	0·56	0·50	0·60	4·70	750·0	1·05	1·60	<0·10	44·0
PSP-1	44·9 ± 1·58	2·51	0·48	0·47	0·74	5·26	947·4	0·84	2·00	<0·10	52·6
PSP-2	44·8 ± 2·42	2·70	0·54	0·40	0·40	4·60	600·0	0·55	1·60	<0·10	46·0
PP	42·3 ± 3·15	2·34	0·47	0·25	0·75	6·50	750·0	0·75	1·40	<0·10	50·0
PS	45·1 ± 3·09	2·63	0·47	0·67	1·50	4·61	1 055·6	1·39	1·78	<0·10	49·4
PC	46·6 ± 2·28	2·96	0·56	0·37	0·89	7·37	894·7	0·84	1·84	<0·10	57·9

TABLE 3

Shell Lengths, Mean Wet and Dry Weights of Whole Soft Parts, and Concentrations (Means, μg/g Dry Weight) of Eight Trace Elements in Cockles, *Anadara granosa*, from Thailand

Sample code	*Shell length (mm) mean ± SD*	*Mean wet weight (g)*	*Mean dry weight (g)*	*Concentrations (μg/g dry weight)*							
				Cd	*Cr*	*Cu*	*Fe*	*Pb*	*Ni*	*Hg*	*Zn*
CST-1	29·2 ± 1·90	1·82	0·35	3·32	0·26	4·89	394·7	0·63	0·68	<0·10	68·4
CST-2	30·6 ± 1·75	2·02	0·40	2·30	0·30	4·90	385·0	0·50	0·65	<0·10	65·0
CST-3	30·1 ± 2·54	1·88	0·36	2·60	0·26	5·79	415·8	0·37	1·00	<0·10	73·7
CNS	31·3 ± 1·54	1·59	0·27	6·47	0·41	7·65	941·2	0·76	2·24	<0·10	117·6
CP	30·3 ± 2·53	1·92	0·33	2·18	0·24	6·48	535·3	1·41	1·24	<0·10	94·1
CSS	28·8 ± 2·00	1·39	0·24	2·35	0·18	5·35	511·8	1·12	1·29	<0·10	100·0
CM-1	32·1 ± 2·34	2·75	0·52	2·05	0·32	6·32	578·9	0·95	1·11	<0·10	105·3
CM-2	27·2 ± 1·91	1·59	0·29	1·72	0·39	6·67	438·9	0·61	1·56	<0·10	94·4
CM-3	27·8 ± 2·39	1·23	0·20	2·56	0·56	8·75	1 000·0	0·88	2·31	<0·10	125·0
CM	31·8 ± 2·02	2·20	0·42	2·63	0·32	7·37	631·6	0·47	1·58	<0·10	105·3
CSSN	28·4 ± 1·53	1·23	0·22	1·33	0·22	8·33	611·1	1·33	1·33	<0·10	105·6

TABLE 4

Shell Lengths, Mean Wet and Dry Weights of Whole Soft Parts Minus Byssus, and Concentrations (Means, μg/g Dry Weight) of Eight Trace Elements in Mussels, *Perna viridis*, from Thailand

Sample code	*Shell length (mm) mean ± SD*	*Mean wet weight (g)*	*Mean dry weight (g)*	*Concentrations (μg/g dry weight)* Cd	Cr	Cu	Fe	Pb	Ni	Hg	Zn
MP-1	62·6 ± 5·32	5·56	1·06	4·21	0·16	10·00	178·9	0·63	0·26	<0·12	63·15
MP-2	48·5 ± 3·57	2·46	0·37	1·13	0·67	13·33	626·7	0·93	1·60	<0·12	64·00
MP-3	49·2 ± 3·44	2·31	0·37	1·31	0·75	15·63	687·5	1·13	1·69	<0·12	68·75
MP-4	61·4 ± 4·36	4·87	0·88	4·11	0·28	12·22	216·7	0·61	3·06	<0·12	66·67
MP-5	47·1 ± 3·86	2·21	0·40	3·33	0·39	10·00	316·7	1·11	2·06	<0·12	72·22
MSS-1	66·8 ± 4·44	4·99	0·95	6·84	0·74	11·05	378·9	1·53	4·74	<0·12	73·68
MSS-2	57·1 ± 5·45	3·65	0·66	5·33	0·44	12·77	350·0	1·28	3·17	<0·12	72·22
MSS-3	60·0 ± 7·10	4·86	0·87	5·00	0·33	10·56	238·9	0·61	3·67	0·12	66·67
MSS-4	62·3 ± 4·93	4·71	0·80	5·88	0·29	11·18	352·9	1·24	3·88	0·12	76·47
MSS-5	62·2 ± 7·09	4·62	0·83	4·94	0·50	10·56	200·0	1·22	2·61	<0·12	66·67
MBP-1	76·6 ± 6·93	7·88	1·42	1·00	0·78	11·11	666·7	0·50	2·72	<0·12	61·11
MBP-2	73·4 ± 5·90	6·25	1·00	1·00	0·75	13·13	625·0	0·31	3·00	<0·12	75·00
MBP-3	75·5 ± 6·99	6·35	1·08	0·88	0·76	9·41	764·7	0·47	3·06	<0·12	64·71
MBP-4	73·2 ± 7·78	6·01	0·96	1·31	0·88	9·38	687·5	1·06	3·06	<0·12	75·00
MBP-5	76·5 ± 7·39	6·86	1·17	1·18	1·12	9·41	1 000·0	0·71	3·41	<0·12	64·71

TABLE 5

Shell Lengths, Mean Wet and Dry Weights of Whole Soft Parts, and Concentrations (Means, μg/g Dry Weight) of Eight Trace Elements in Rock Oysters, *Crassostrea commercialis*, from Thailand

Sample code	*Shell length (mm) mean ± SD*	*Mean wet weight (g)*	*Mean dry weight (g)*	*Concentrations (μg/g dry weight)*							
				Cd	*Cr*	*Cu*	*Fe*	*Pb*	*Ni*	*Hg*	*Zn*
OASA	40·0 ± 4·46	2·08	0·35	2·35	0·59	170·6	111·8	0·53	1·82	<0·10	823·5
OASB	47·3 ± 4·48	2·73	0·55	2·05	0·35	165·0	105·0	0·20	0·60	<0·10	750·0
OASC	51·3 ± 5·86	2·58	0·54	2·38	0·24	180·9	123·8	0·24	2·52	<0·10	1 047·6
OBPD	43·5 ± 6·44	2·44	0·46	2·84	0·37	136·8	147·4	0·21	0·84	<0·10	684·2
OBPE	44·2 ± 5·70	2·09	0·46	3·82	0·27	113·6	131·8	0·50	0·68	<0·10	681·8
OBPF	40·2 ± 6·19	2·42	0·51	3·24	0·48	100·0	123·8	0·52	0·76	<0·10	571·4

no trend can be discerned from the data in Table 4, tending to confirm this observation.

Data for element concentrations in Tables 2 to 5 are shown based on dry tissue weights in all cases. The equivalent data based on wet weights may be computed using the wet weight/dry weight ratios. Data based on wet weights are useful mainly in comparing the observed element levels with public health standards, most of which are based on wet tissue weights.

DISCUSSION

Data for trace metals in bivalves in the present study are based upon the analysis of twenty-five individuals in each sample, and these were not subjected to depuration prior to their analysis. The available literature on trace element variability within bivalve populations (Gordon *et al.*, 1980; Boyden & Phillips, 1981) suggests that a sample of twenty-five individuals is sufficient to characterise accurately the element concentrations present in a population. The samples were not subjected to depuration because the major thrust of the studies was to define possible toxicological threats to public health. As a result, the concentrations of some metals reported here are higher than would be found in depurated samples. This is particularly the case with iron, which may be expected to be found at high levels in sediment particles remaining in the intestines of the bivalves analysed. Other elements are much less affected (Ouellette, 1978; NAS, 1980; Latouche & Mix, 1982), and the difference between depurated and non-depurated samples for metals other than iron may be expected to be less than 10% of the values quoted.

Analytical results from the present study are discussed individually for each species. In all cases, the variation between samples is discussed first; the data are then compared with other published information on the same, or related, species. The implications of the results for public health are discussed separately.

The clam *Paphia undulata*

Intersample variability in the concentrations of elements determined in clams was negligible for copper, iron, lead, nickel, mercury and zinc (Table 2). Variability of cadmium and chromium concentrations between samples was minor, but consistent, on both weight bases, suggesting relatively small variations in the abundance of these elements in different areas. It is possible that bulking of samples for analysis masked a consistent variability based on location, particularly if samples are composites of catches from multiple locations. Whether this is actually the case depends on the degree of sorting of clams between harvest and retail. On balance it appears unlikely that major variations between individuals exist, at least for the samples analysed in this survey. As the clam fishery in Thailand operates some distance offshore in the northern Gulf region, it is probable that water quality in the area is relatively homogeneous.

The data available from other studies on trace elements in clams of the genus *Paphia* are sparse, and no previous analyses of *Paphia undulata* from Thailand or elsewhere are known to the authors. However, Phillips *et al.* (1982*b*) reported concentrations similar to those found here for *Paphia japonica* taken from a retail market in Hong Kong. Data for various species of *Tapes* from the Mediterranean, Hawaii and Korea also show similarities to the metal levels reported here (Fukai & Broquet, 1965; Establier, 1972, 1975; Won, 1973; Klemmer *et al.*, 1976). By contrast, Geldiay & Uysal (1975) reported much higher concentrations of lead and mercury than those found here, for *Tapes decussatus* from Turkish waters, although levels of copper, iron and zinc were similar to those reported in the present study.

The cockle *Anadara granosa*

Intersample variability in element concentrations found in cockles in the present study was not great (Table 3). No one sample exhibited particularly high levels of more than one metal and it appears that the areas of derivation of these samples are generally similar in terms of metallic contamination. This holds true both for samples derived from Thai waters and those imported from Malaysia; whilst there is a trend towards higher chromium levels in the Malaysian samples, additional analyses would be required to confirm this difference. It therefore appears from this survey (as noted above also for *Paphia undulata*) that element concentrations vary little in marketed samples of *A. granosa* in Thailand.

Data from other authors on trace metals in species of the genus *Anadara* are shown in Table 6, all levels quoted being based on wet tissue weights. Results from the present study agree well with those quoted by

TABLE 6

Reported Concentrations (μg/g Wet Weights, Means) of Trace Elements in Cockles of the Genus *Anadara*. Where More than one Sample was Studied, Results Quoted are Means of all Samples and Locations. All Data Refer to Whole Soft Parts

Species	*Location*	*n*	*Cd*	*Cu*	*Hg*	*Pb*	*Zn*	*Author(s)*
A. granosa	Thailand	11	0·48	1·20	<0·02	0·15	17·2	Present study
A. granosa	Thailand	1	0·28	5·60	0·01	0·18	16·2	Huschenbeth & Harms (1975)
A. granosa	Malaysia	6	1·91	0·51	0·02	0·46	19·2	Jothy *et al.* (1983)
A. granosa bisenensis	Korea	1	0·41	0·75	0·02	1·18	—	Won (1973)
A. broughtonii	Korea	3	0·48	1·13	0·19	0·97	—	Won (1973)
A. inflata	Japan	1	—	—	1·76	—	—	Kitamura (1968)
A. subcrenata	Hong Kong	1	0·80	3·20	0·10	0·90	33·3	Phillips *et al.* (1982*b*)
A. trapezia	Australia	4	0·19	0·19	—	0·06	3·7	Fabris *et al.* (1976)
A. tuberculosa	Mexico	14	—	—	0·05	—	—	Reimer & Reimer (1975)
Anadara sp.	Japan	1	—	—	0·10	—	—	Kondo (1974)
Anadara sp.	Hong Kong	1	0·70	—	0·10	0·40	—	Phillips *et al.* (1982*b*)

Huschenbeth & Harms (1975) for *A. granosa* from Phuket (on the Andaman Sea coast of Thailand), with the exception of the higher copper values quoted in the earlier report. Close agreement also exists with the more recent data of Jothy *et al.* (1983) on metals in *A. granosa* from the Penang and Perak coastal areas in Malaysia. Similar element levels were also reported by Won (1973) for *A. granosa bisenensis* from Gwangyang Bay in Korea. Other species within the genus may vary in their ability to accumulate metals, however, and these data are therefore less useful as a basis for comparison with the present study. There is, in any event, no evidence to show that elements are particularly enriched in the samples of *A. granosa* analysed in this study.

The green mussel *Perna viridis*

There is some evidence of moderate intersample variability in the analytical results for *Perna viridis* in the present study, at least for cadmium, chromium, iron and, to some extent, nickel (Table 4). The

TABLE 7

Reported Concentrations of Trace Elements in Green Mussels, *Perna viridis* and *Perna canaliculus*, from Various Locations

Species	*Location*	*Units*	*Cadmium*	*Copper*	*Lead*	*Mercury*	*Zinc*	*Authors*
P. viridis	Rayong, Thailand	μg/g wet weight	0·38	7·3	0·11	0·02	14·2	Huschenbeth & Harms (1975)
P. viridis	Bang Pakong Est., Thailand	μg/g dry weight	3·5	8·7	241	0·09	66	Menasveta & Cheevaparanapiwat (1981)
P. viridis	Chao Phraya Est., Thailand	μg/g dry weight	3·4	8·7	259	0·21	54	Menasveta & Cheevaparanapiwat (1981)
P. viridis	Ta Chin Est., Thailand	μg/g dry weight	5·0	9·0	256	0·09	72	Menasveta & Cheevaparanapiwat (1981)
P. viridis	Mae Klong Est., Thailand	μg/g dry weight	5·2	6·2	103	0·07	72	Menasveta & Cheevaparanapiwat (1981)
P. viridis	Hua Hin, Thailand	μg/g dry weight	2·7	7·2	13·0	0·04	48	Menasveta & Cheevaparanapiwat (1981)
P. viridis	Market sample, Hong Kong	μg/g wet weight	0·1	2·6	0·70	0·02	11·9	Phillips *et al.* (1982*b*)
P. viridis	Tolo Channel, Hong Kong	μg/g wet weight	0·3	2·4	0·29	0·01	13·6	D. J. H. Phillips (unpublished)
P. canaliculus	New Zealand	μg/g dry weight	0·6	—	0·5	—	9	Nielsen (1974)[a]
P. canaliculus	New Zealand	μg/g wet weight	0·3	1·8	1·8	0·09	21	Nielsen & Nathan (1975)[a]

[a] These data quoted as means only, graphically interpolated in the case of Nielsen (1974).

mussels from Ban Laem, Petchaburi (coded MP-1 to MP-5) appear to be heterogeneous and may be suspected to be derived from several sources, judging from their variable levels of cadmium and nickel. By contrast, samples MSS-1 to MSS-5, derived from Samut Songkhram but purchased either there or at Ben Laem, all exhibited similar metal levels consistent with a single source. Data for the mussels collected from the field in the Bang Pakong Estuary reveal that this area has different metal contamination characteristics from the others studied. In particular, cadmium concentrations are lower—and iron levels are somewhat higher—in the Bang Pakong samples than in the other mussels analysed. The iron levels are mainly a function of inorganic particulates in the gut; this is consistent with the highly turbid waters found in the Bang Pakong Estuary. The lower cadmium levels are interesting and suggest that cadmium contamination is greater to the south-west of Bangkok than to the east of the city. The differences are unlikely to be caused by the unusually large size of the mussels in the field-derived samples compared with the other mussels studied, as Phillips (in preparation) has found no variation of cadmium concentrations with size in *Perna viridis*.

Data concerning trace metals in *Perna viridis* (synonymous with *Mytilus smaragdinus* and various other combinations of nomenclature; see Sidall, 1980) have been reported by several other authors. These data are shown in Table 7, and some results are also included for the related *Perna canaliculus*, which is cultured in New Zealand. Species differences in the accumulation of metals by *P. viridis* and *P. canaliculus* appear to be minor. Data from the present study agree substantially with those of all authors other than Menasveta & Cheevaparanapiwat (1981), although it is notable again here that the copper data of Huschenbeth & Harms (1975) are somewhat higher than other values cited for this element. However, gross anomalies exist between the data reported in the present study and those of Menasveta & Cheevaparanapiwat (1981). The latter authors cite results for metals in *Perna viridis* taken from similar areas to those sampled in the present study. Whilst results for the concentrations of cadmium, copper, mercury and zinc are in reasonable agreement when compared on an equivalent dry weight basis, the levels of lead reported by Menasveta & Cheevaparanapiwat (1981) are at least two orders of magnitude greater than those found in the present study. It is notable here that Hungspreugs & Siriruttanachai (1981) remarked briefly on this disagreement, and claimed levels of 12–13 μg/g dry weight for lead in *P. viridis* from similar locations. The present paper reports results almost an order of magnitude below even these figures.

These differences between the reported data for lead in mussels cannot be reconciled on the basis of minor differences in sampling area, season, size of bivalves or other known parameters. The weight of evidence supports the lower figures and it is notable that the analysis of marine organisms for lead has been fraught with difficulties throughout the last decade at least. The problems of sample contamination in particular are extreme, and matrix problems and/or interferences at the analysis step may also occur (Patterson & Settle, 1976).

The oyster *Crassostrea commercialis*

Analytical results for oysters in the present study reveal only minor intersample variation, suggesting that no major sources of metallic contaminants exist in the two Bays sampled (Table 5). There is a tendency for chromium concentrations in Ang Sila Bay oysters and copper levels in Bang Prong Bay samples to diminish with distance offshore, but further sampling would be required to confirm this, and the gradients are, in any event, not marked.

Comparison of these results with data from other authors is hampered by the taxonomic uncertainties surrounding rock oysters at present. However, it may be noted that the data reported in this study compare favourably with those from other reports on the so-called Sydney rock oyster (*Crassostrea commercialis/Saccostrea cucullata*) from Australian waters (Hussain & Bleiler, 1973; Mackay *et al.*, 1975). Direct comparison of the results from the present survey is possible with data from Siriruttanachai (1980) and from Hungspreugs & Siriruttanachai (1981). Results from these authors are shown in Table 8. It is evident that reasonable agreement exists between the present results and those cited in Table 8 for cadmium, copper and zinc. However, concentrations of lead are again considerably higher in the Thai studies, the difference being greater than an order of magnitude. The comments above relating to Thai data on lead in mussels are again applicable.

Implications for human health

The data reported here, whilst preliminary in that relatively few samples have been analysed, lend considerable confidence to any venture promoting bivalve culture within Thailand. None of the samples analysed

TABLE 8
Reported Concentrations of Cadmium, Copper, Lead and Zinc in Oysters (*Crassostrea commercialis*) from Thailand

Location	*Metal concentrations (μg/g dry weights)* Cadmium	Copper	Lead	Zinc	*Authors*
Cholburi	5·2	61·2	6·13	230	Siriruttanachai (1980)
Chanthaburi	3·5	91·5	11·06	444	Siriruttanachai (1980)
Ang Sila, Cholburi	8·9	117·4	15·20	572	Hungspreugs & Siriruttanachai (1981)

contained levels of trace elements which would indi ate the existence of potential public health problems. Concentrations of mercury were particularly low and did not, in any case, approach a level which v ould give rise to public health concerns. All other elements were also at acceptable levels, including cadmium, chromium and lead, all of which may have profound health effects on humans at high concentrations. Interspecies differences, of course, exist with respect to element accumulation: for example, oysters concentrate copper and zinc far more efficiently than do mussels or clams. However, even in oysters the observed metal concentrations are at acceptable levels for human consumption.

It therefore appears that the previous concerns, particularly involving lead in bivalves from Thailand, may be allayed. Whilst certain areas of Thailand may be exposed to metallic contamination (e.g. see Suckcharoen *et al.*, 1978; Polprasert, 1982), the present results imply that this pollution is not sufficiently widespread to endanger public health from the consumption of locally cultured bivalves. It may be added here finally that the high levels of mercury reported for predatory fish in the Andaman Sea (Menasveta & Siriyong, 1977) are a worldwide phenomenon which is probably related more closely to food chain amplification of the element (and its increase in concentration with age in fish) than to local pollution.

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Annex 5

Analysis of Length and Weight Characteristics of Green Mussel, *Perna viridis* from Thailand*

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Abstract

The following parameters were measured (females and males separately) in 1,760 individuals of the green mussel, *Perna viridis* (Mytilidae): size (length, height), weight (total, flesh + shell, shell, flesh wet, flesh dry). Size/weight relationships were determined as well as the relationships within various weight units. The analysis suggests that the weight unit "flesh + shell" should be used as a standard unit for total weight. With this unit taken as weight, the exponent "b" of the size/weight relationship varies between 2.55 and 2.87, depending whether "length" or "height" is used as dimension unit. The sex ratio in the sample was 44% male to 56% female. Sexual growth dimorphism was not observed.

Introduction

In fisheries research, measuring length and weight are standard tasks and the data obtained are the backbone of many models used in

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fish population dynamics. The applications reach from growth estimates to the prediction of potential catch or harvest.

The properties of weight data obtained from fish are generally such that the data on total weight can be used directly in most of the models applied. To define a biologically meaningful weight for marine invertebrates is, however, in some cases difficult and needs careful evaluation of the purpose of data collection. Quite clearly, when assessing the availability of food for human consumption, the total weight of an animal with large parts of its body consisting of hard structures (e.g., carapace or shell) is relatively meaningless. On the other hand, to measure a more appropriate weight might often be impracticable.

Molluscs are a typical example of this problem. The present study analyses the length and weight characteristics of the green mussel *(Perna viridis)* which plays an important role in the shellfish industry of Thailand and other countries in Southeast Asia.

The objectives of this work were to establish the quantitative relationships of a standard set of weight units both among themselves and in comparison to morphometric characteristics such as length and height.

Materials and Methods

The data analyzed in this paper were generated in the context of research on the green mussel culture industry in Thailand, jointly organized by the International Center for Living Aquatic Resources Management (ICLARM) and the Department of Fisheries (DOF) of Thailand. It was part of a four-year project: "Applied Research on Coastal Aquaculture in Thailand".

The research reported here was carried out over a period of 15 months from April 1984 through June 1985. Two important green mussel farming areas were selected for sampling: Ban Laem, Phetchaburi Province, in the northwestern part of the Gulf of Thailand and Samae Kao, Chachoengsao Province, in the northeastern part of the Gulf. These sites were visited monthly and data collected on biological and economic aspects of the green mussel and its related processing industry.

In addition, live green mussel samples were collected every month directly from boats at the landing sites and brought back to Bangkok, where they were kept overnight in water tanks.

On the following day, any green mussel found dead was removed from the tanks. Out of the remaining mussels, subsamples totaling 120 specimens were selected for further investigation (80 mussels from Ban Laem and 40 mussels from Samae Kao). The investigation aimed at obtaining quantitative data on size, weight and sex of every individual.

A total of 1,760 records was available, each comprising eight variables defined as follows:

- Length: maximum shell length along the anterior/posterior axis; measured with callipers to the nearest 0.1 mm.
- Height: maximum shell length along the dorsal/ventral axis; measured with callipers to the nearest 0.1 mm.
- Total weight: weight of mussel immediately after removal from the tank with completely closed shell. (Any animal found to have lost some of its cavity water prior to weighing was replaced by another mussel.) Weight's were recorded on an analytical scale, in grams.
- Flesh weight: weight of the soft parts of the mussel including adductor muscles. Flesh was removed from the shell and adherent water was blotted off prior to weighing.
- Shell weight: weight of the shell after removal of the soft parts.
- Flesh & shell weight (FL & SH): computed by summing the individual weights recorded for Flesh and Shell.
- Flesh dry weight (Dry wt): the soft part of the mussel (Flesh) was dried in an oven for 48 hours at 70°C. Weighing was done directly after removal of the samples from the oven to avoid an artificial weight increase from humidity.
- Sex: the color of the gonads was used for sexing; orange for females, cream for males. In case of doubt, animals were listed as unidentifiable.

Throughout this paper, all relationships were analyzed by least-square regression of the form

$$y = a + b \cdot x \qquad \text{...}1)$$

The predictive power of the computed functions were assessed from the following parameters: S_b: standard error of the regression coefficient b; S_y: standard error of estimate; r^2: coefficient of determination; n: number of observations included in the regression; % outliers: number of observations excluded from analysis (in per cent of total N = 1,760).

Size-weight relationships are generally expressed by a non-linear function of the form

$$W = a \cdot L^b \qquad \text{... 2)}$$

These size and weight data were analyzed with the logarithmic transformation:

$$\log W = \log a + b \cdot \log L \qquad \text{... 3)}$$

with W being the weight and L the size (length or height).

The use of a logarithmic transformation introduces a systematic bias into the calculations which has to be counteracted by means of a correction factor (Sprugel 1983). This is done by multiplying "a" in equation (2) with a correction factor (CF) of the form:

$$CF = \exp\,(SEE^2 \cdot 2^{-1}) \qquad \text{... 4)}$$

where SEE is the standard error of estimate (S_y) multiplied by $\log_e 10$ (= 2.303) to convert the base-10 S_y to a base-e standard error of estimate.

The computation of the regression constants a and b was always done in two runs to detect and eliminate outliers by means of residual analysis. The first run used all 1,760 data pairs available. The resulting (preliminary) values of "a" and "b" allowed the calculation of an estimate of y (= $\hat{y}$) for every given value of x. From this, "standard residuals" (STR) were computed for every observation using the formula

$$STR = R \cdot S_R^{-1} \qquad \text{... 5)}$$

where R are the residuals ($y - \hat{y}$) and S_R is the standard deviation of the computed residuals.

STR expresses the deviation of a single data point from the regression line in units of its own standard deviation. If the measurements of size and weight are unbiased, STR is a random variable following (ideally) a normal distribution with mean zero. Any strong deviation from this rule would suggest the inapplicability of the least-square regression technique in the analysis of a given data set.

The distribution of the STR-values was inspected graphically by plotting their frequencies along an x-axis reaching from -10 to +10. Any observation resulting in a standard residual exceeding ±3 was considered an outlier (Chatterjee and Price 1977). Regression analysis was then performed a second time with outliers excluded. The number of outliers are given with every analysis (in % of the total available N = 1,760) to provide an estimate of possible additional source of variation.

Results

The various relationships presented below pertain to mussels ranging in length from 38 to 109 mm and in height from 19 to 42 mm. Any extrapolation to a size beyond these ranges has to be viewed with some precaution.

The results of the regression of length on height and vice versa are summarized in Table 1.

Table 1. Morphometric relationships of *Perna viridis* ("% outlier" denotes number of records in per cent excluded from analysis.)

Function	$Y = a + b \cdot X$	
X-Variable Y-Variable	Length Height	Height Length
a	5.38	- 0.1404
b	0.3467	2.37
S_b	0.0037	0.0258
S_y	1.6768	4.4767
r^2	0.836	0.834
n	1,742	1,748
% outlier	1.02	0.68

Table 2 shows the results of the relationship between the length of green mussel and various forms of weight. To check whether the computed values of "b" were significantly different from b = 3, a value of t* was calculated using the formula:

$$t^* = |b - 3| \cdot S_b^{-1} \qquad \ldots 6)$$

The tabulated value of the t-statistics (student distribution) for df > 1,000 and a 1% error level was $t_{\infty,0.01} = 2.576$.

Table 2. Length/weight relationships of *Perna viridis* ("% outlier" denotes number of records in per cent excluded from analysis; reference value of t-distribution: $t_{\infty,0.01}$ = 2.576).

Function	$Y = a \cdot X^b$				
X-Variable Y-Variable	Length Total	Length FL & SH	Length Flesh	Length Shell	Length Dry Wt
a	2.22 E-4	2.41 E-4	2.17 E-4	0.69 E-4	0.89 E-4
b	2.70	2.55	2.37	2.72	2.18
S_b	0.0196	0.0250	0.0349	0.0274	0.0466
S_y	0.9552	0.0701	0.0986	0.0764	0.1315
r^2	0.916	0.856	0.725	0.850	0.555
n	1,744	1,747	1,7541,743	1,754	
% Outlier	0.91	0.74	0.34	0.97	0.34
t*	15.33	17.87	18.01	10.23	17.65

The t*-values listed in Table 2 are all larger than the tabulated value of 2.576; thus, at the 1% error level, "b" is significantly different from 3. This shows that green mussel growth, when using the anterior/posterior axis as unit of length, is not isometric.

Table 3 summarizes the results of the height/weight relationships. It is interesting to note that the regression of height on total weight (i.e., shell + flesh + cavity water) results in a value of b = 2.98 which is not significantly different from 3 at the 1% level. The value of b in the height/shell relationship was also quite close to but significantly different from 3.

Table 3. Height/weight relationships of *Perna viridis* ("% outlier" denotes number of records in per cent excluded from analysis; reference value of t-distribution: $t_{\infty,0.01}$ = 2.576).

Function	$Y = a \cdot X^b$				
X-Variable Y-Variable	Height Total	Height FL & SH	Height Flesh	Height Shell	Height Dry wt
a	8.69 E-4	7.48 E-4	8.66 E-4	2.04 E-4	3.28 E-4
b	2.98	2.87	2.56	3.09	2.35
S_b	0.0232	0.0262	0.0400	0.0260	0.0523
S_y	0.0591	0.0663	0.1026	0.0655	0.1345
r^2	0.905	0.873	0.702	0.891	0.535
n	1,744	1,742	1,748	1,738	1,754
% outlier	0.91	1.02	0.68	1.25	0.34
t*	0.77	5.14	10.87	3.41	12.49

Tables 4 and 5 give an overview of how the various weight units are related to each other when fitted by a linear function of the form given in equation (1).

Even though the regression parameters "a" and "b" can be used to convert one unit of weight into another one, the relatively low

Table 4. *Perna viridis:* Summary of regression coefficients for the conversion of total weight to lower weight units. ("% outlier" denotes number of records in per cent excluded from analysis.)

Function	$Y = a + b \cdot X$			
X-Variable Y-Variable	Total FL & SH	Total Flesh	Total Shell	Total Dry wt
a	1.028	0.969	- 0.008	0.292
b	0.53	0.19	0.34	0.03
S_b	0.0038	0.0030	0.0021	0.0007
S_y	1.5981	1.2363	0.8660	0.2986
r^2	0.917	0.711	0.938	0.479
n	1,736	1,748	1,727	1,728
% outlier	1.36	0.68	1.88	1.82

Table 5. *Perna viridis:* Summary of regression coefficients for the conversion of Flesh & Shell, Shell, and Flesh to lower weight units. ("% outlier" denotes number of records in per cent excluded from analysis.)

Function	$Y = a + b \cdot X$					
X-Variable Y-Variable	FL & SH Shell	FL & SH Flesh	FL & S Dry v	Shell Flesh	Shell Dry wt	Flesh Dry wt
a	- 0.292	0.292	0.137	1.199	0.297	0.069
b	0.61	0.39	0.06	0.54	0.09	0.16
S_b	0.0034	0.0034	0.0011	0.0086	0.0021	0.0020
S_y	0.7914	0.7914	0.2419	1.2614	0.2950	0.1817
r^2	0.949	0.882	0.663	0.697	0.498	0.793
n	1,745	1,745	1,724	1,746	1,725	1,727
% outlier	0.85	0.85	2.05	0.80	1.9	1.88

coefficient of determination (r^2) in some of the cases is proof of the large variations in these relationships.

Another way to perform weight conversion is to express a given weight as a fraction (in %) of the next larger units. This is demonstrated in Table 6. The values listed are the fractions (means, in %) of the weight in the corresponding row in comparison to the weight unit indicated in the column headings. Also given are the standard deviations to estimate confidence intervals in the conversion.

Of the 1,760 samples, 735 were males and 945 were females. In 80 cases, the sex could not be identified beyond doubt. The sex ratio was 44% male to 56% female.

To test whether sexual dimorphism occurred, the mean length and height of both females and males was computed separately and the results compared. They showed no significant difference at the 1% error level.

Table 6. *Perna viridis:* Summary of various weights expressed in mean per cent of higher weight units (second value denotes standard deviation.)

	Total	FL & SH	Flesh
FL & SH	58.00 ± 7.65		
Shell	33.75 ± 4.32	58.55 ± 5.97	
Flesh	24.25 ± 5.73	41.45 ± 5.97	
Dry wt	4.40 ± 1.47	7.51 ± 2.04	18.02 ± 3.62

As the dry weight of the green mussel meat is strongly affected by the condition of the gonads, the mean dry weights per month were plotted along a time axis for both females and males. Even though the course of both curves was synchronized, males had a consistently higher dry weight than females.

Discussion

When recording the weight of mussels, much attention has to be paid to the time between the moment the animal is removed from the water and the actual weighing. Mussels keep water within their shell for some time. As Table 6 shows, the average weight of this water makes up 42 per cent of the total initial weight, with extreme cases as high as 50 per cent.

Table 7 summarizes previously published values of the coefficients "a" and "b" for *Perna*. The values of "b" show considerable variation, ranging from 2.37 (Lee 1985) to 2.86 (Narasimham 1981).

Table 7. Compilation of the coefficients "a" and "b" of the allometric length/weight relationship in *Perna* from various locations. (Adapted from published data.)

Species	Location	a	b	Length units	Source
Perna viridis	Hong Kong	1.12E-03	2.37	mm	Lee (1985)
	India, Goa	5.13E-04	2.50	mm	Parulekar et al. (1982)
	India, Kakinada Bay	1.63E-04	2.86	mm	Narasimham, K.A. (1981)
	Malaysia, Penang	2.22E-04	2.76	mm	Choo and Speiser (1979)
	Singapore	9.81E-02	2.79	cm	Cheong and Chen (1980)
	Thailand, upper Gulf	7.07E-02	2.78	cm	Chonchuenchob et al. (1980)
Perna canaliculus	New Zealand, Ahipara	2.14E-04	2.80	mm	Hickman (1979)

This might partly be explained through the influence of ecological factors such as density, shore level, etc. Such ecological differences were demonstrated by Hickman (1979) who compared wild stocks and raft-grown populations of *Perna canaliculus*.

Another source of variation, however, might be the effect that the cavity water has on the final result. As the figures in Table 2 show, the value of "b" may range from 2.55 to 2.70 for the same animal, depending on the amount of water included in the measurement of weight.

The factor "cavity water", therefore, introduces a considerable error into the data analysis. This also becomes obvious when expressing the weight of the mussel meat (Flesh) in per cent of "total weight": this can be anything between 24% and 41%, depending on how much water the mussel lost prior to weighing. To avoid this problem, "total weight" should be defined (and measured) as the weight of the green mussel with its shell forced open (by severing the adductor muscle) and drained of water.

The exponent "b" of the size/weight relationship in *Perna viridis* is generally different from 3 as shown in Tables 2 and 3. Growth analysis of green mussel based on a model that involves the parameter "b" should, therefore, be checked on its assumption concerning the value of the exponent "b". If a model applied assumes b = 3 and does not provide for any adjustment for a different exponent, it would be more appropriate to use "Height" as the reference length with b = 2.87 as the coefficient of the size/weight relationship. This value comes at least close to the (assumed) value of b = 3.

Acknowledgements

The authors wish to thank the fishermen and green mussel processors of Baan Laem and Samae Kao for their kind cooperation in letting us collect data and samples. We also acknowledge the assistance of the technicians of the Brackishwater Fisheries Division, Department of Fisheries, Thailand, in analyzing the samples. Finally, sincerest thanks are expressed for the financial assistance provided by the German Government through the Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ).

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Annex 6

Commercial Cockle Farming in Southern Thailand*

Reprinted from: Siri Tookwinas. 1983.
ICLARM Translations 7, 13 p.
E.W. McCoy, translator. 1985.

Abstract

Thailand has cultured cockles or arc shells (*Anadara granosa* Linnaeus) since 1900 at which time the traditional farm area was 1-1.5 ha. Seeds were collected from nearby culture beds. In 1973, seeds were imported from Malaysia for culture in Satun Province in the southern part of Thailand. The culture beds were expanded to 160 ha and the culture method was modified and developed. However, commercial cockle farming is beset with problems which should be solved with further research.

Introduction

Cockles are bivalve molluscs which commonly inhabit muddy seashores. Culture of these molluscs in Thailand began about 75 years ago at Bang Tabun Subdistrict, Baan Laem District, Phetchaburi Province. The cockle seeds were collected and reseeded in a bamboo fenced area (Chomdet and Poocharoen 1979). The fencing was 50 cm high and enclosed an area of 5-10 rai (one rai = 1,600 m^2). The farmers sifted seed from natural beds for sowing in the culture area. The culture period was one to two years. Later, cockle farming spread to other districts in the Province and into Samut Songkhram Province.

Cockle farming was conducted by this method until 1972, when severe water pollution occurred in the inner Gulf of Thailand. The source of pollution was waste water released from the sugar factories on the Mae klong and Phetchaburi Rivers. The waste polluted the freshwater resources of the two rivers and ultimately the brackishwater. The pollution was particularly harmful for cockles because they could not move to nonpolluted areas. The cockle beds in Phetchaburi and Samut Songkhram Provinces eventually became polluted and unsuitable for cockle production. Cockle production decreased and subsequently a shortage of cockles for consumption occurred. Since cockles were a highly favored product in Thailand, some people began to import cockles from Malaysia where production was said to exceed consumption. In 1973, some farmers began production of cockles by sowing cockle spat (approximately 10,000 pieces/kg) at Tam Malang Bay, Muang District, Satun Province (Tookwinas 1981).

The cockle farming in Satun Province was relatively large scale. The culture area for each farm was 200-900 rai (Tookwinas 1981). The culture method was the same as used in Malaysia. Malaysians were involved in all operations on a partnership basis. Malaysians either shared investments or operated the farms. They assisted with site selection, seed purchase, seed sowing, sorting and thinning, harvesting and marketing. Due to the ease of operation of a cockle farm, the labor requirements were limited. Labor was used for seeding, thinning, harvesting and guarding. The cockles were not fed. The farming operation normally could return a cash income about 5-10 times that of input costs (variable cash costs). Cockle farming spread rapidly throughout the southern part of Thailand to the provinces of Trang, Ranong, Nakhon Si Thammarat, and Surat Thani. After five to six years of culture a serious problem developed. The culture beds gradually deteriorated and growth rate decreased while mortality rate increased.

Life History of Cockles

The cockles farmed in Malaysia and Thailand are bivalves of the genus *Anadara,* Family Arcidae. They are not true cockles but more correctly arc shells.

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*Contribution No. 2 of the Satun Brackishwater Fisheries Station, Department of Fisheries, Bangkok, Thailand Contribution No. 2 of the Satun Brackishwater Fisheries Station, Department of Fisheries, Bangkok, Thailand and ICLARM Contribution No. 262.

The cockles found in Thailand include:

Anadara granosa Linnaeus, which is commonly called arc shell or bloody clam. This species is commonly found in fine muddy sand along the shallow coastline. The width of mature shell is 4-5 cm. This is the species cultured in Malaysia.

Anadara (Tegellarca) nodifera (E. Von Martens). This species is like *A. granosa* but the width and height relationship differs. The habitat is similar to that of *A. granosa*. This is one of the species cultured at Phetchaburi Province.

Anadara (Scapharca) trocheli (Dunker). This species is heart shaped. The shell width is 6-7.5 cm. The species is found in relatively large quantities along the western coast of Thailand from Phangnga to Satun Province.

Anadara (Scapharca) satowi (Dunker). The shape of this species is rather square. The shell width is 7.5-10 cm.

Only *A. granosa* and *A. nodifera* are cultured or imported for culturing in Thailand.

Behavior of Cockles

As indicated, cockles generally inhabit the fine muddy shore of the coastline. When cockles are placed in an aquarium with fine mud from the natural beds, they burrow into the mud with the open side up (Fig. 1). In general, the cockles burrow only into the surface of the mud. The shell is then partially opened, one end is used for water and nutrient intake, the other end is the waste outlet. The inlet and outlet can be observed on the mud surface.

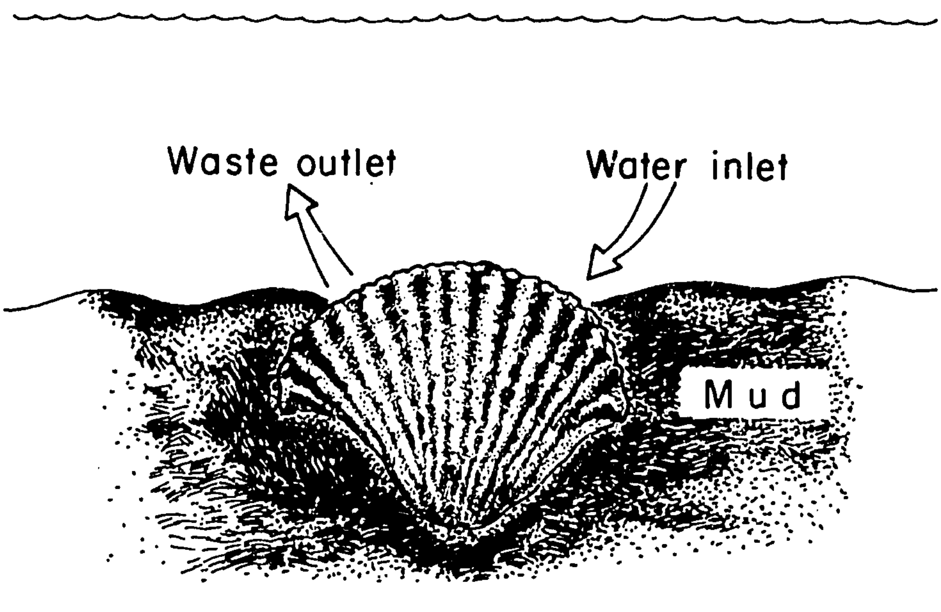

Fig. 1. Position of cockles in mud.

Presumably, when water is suctioned in, small organisms are also taken in, such as phytoplankton, zooplankton and organic matter (detritus). At the same time, the water passed through would carry away the excretionary products. According to a study by Tuaycharoen (1983), the stomach contents of cockles were dominated by phytoplankton. The predominant groups were algae and diatoms, *Chlorella* sp., *Coscinodiscus* sp., *Rhizosolenia* sp. and *Nitzchia* sp.

Cockles are benthic bivalves. The farmers wonder whether migration of the cockles occurs by self or wave action. Some farmers believe cockles can crawl or move by turning the open side down and projecting the foot for movement. This is the primary reason why farmers at Bang Tabun, Phetchaburi Province surround the growing area with bamboo strips. The strips prevent cockles from migrating to surrounding farms. The author also desired to determine if cockles could or would migrate. A trial was conducted by placing cockles in an aquarium. Half of the aquarium bottom was filled with mud and the other half was not filled. After 10 hours, the cockles placed on the unfilled side migrated to the mud filled side. Cockles can move to find more favorable conditions by projecting the foot.

Suitable Culture Area

Suitable areas for cockle culture is near the mouth of canals or coastline with a salinity not lower than 25 ppt (Tookwinas 1983). Experiments indicate mortality will occur when salinity decreases to 23 ppt. The area should be a wind sheltered bay with a river or canal to bring in nutrients. The bottom slope should not exceed 15 degrees so cockles will not be moved by wind or wave action. The bottom should be mud or silty clay without sand (Fig. 2). A simple method for testing the fineness of the mud

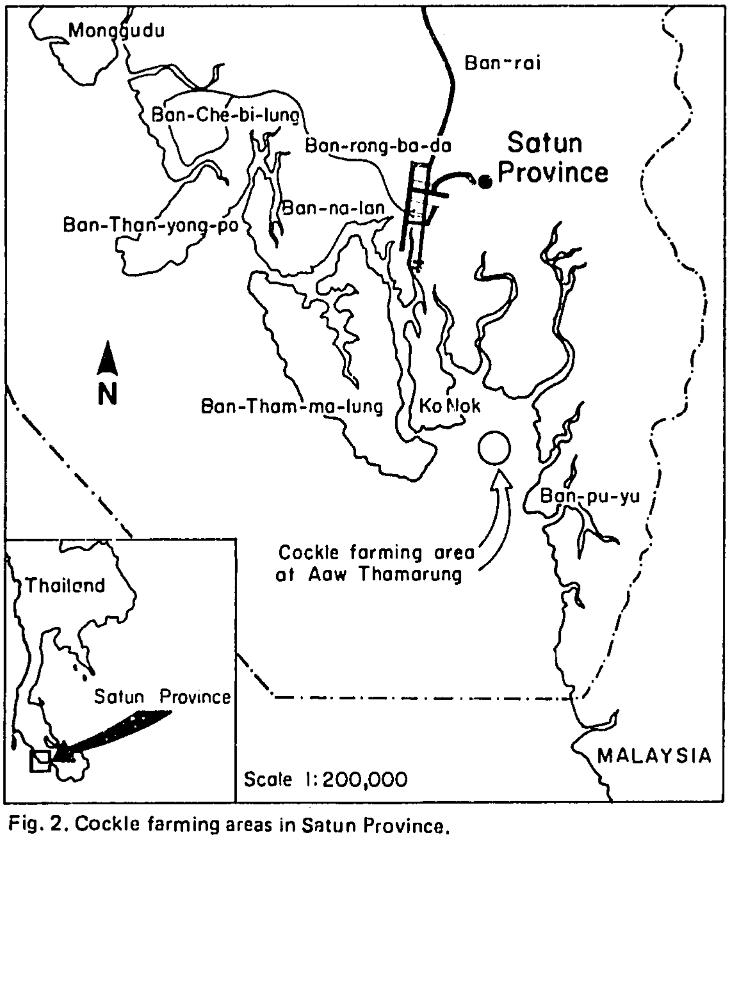

Fig. 2. Cockle farming areas in Satun Province.

is as follows: put a small amount of mud in one hand, then rub with the thumb of the other hand. If sand is present, it can be felt. The mud layer should not be less than 0.5-1.0 m deep. The mud should not have a strong smell. Water depth should be between 0.5 and 1.0 m (mean sea level) and the exposure period should be two to three hours a day (Fig. 3). In addition, the culture area should be secure from predators.

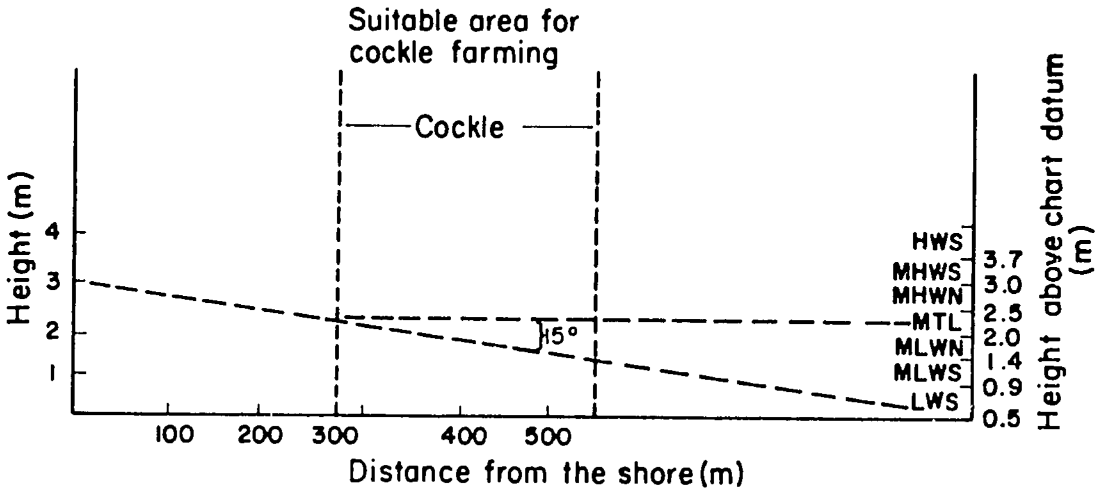

Fig. 3. Distance from the shore and tidal zone suitable for cockle farming (from Boonruang and Janekarn 1983). HWS (high water spring); MHWS (mean high water spring); MHWN (mean high water neap); MTL (mean tide level); MLWN (mean low water neap); MLWS (mean low water spring); LWS (low water spring).

Seed Bed and Spat Collecting Season

SEED BED

As previously mentioned, cockles originally were widely cultured in Phetchaburi and Samut Songkhram Provinces. The area had sufficient seed (size approximately 2,000/kg) to supply the local production. However, in 1972, water pollution destroyed not only cockles but many other aquatic animals in the area. The culture and seed beds deteriorated and were no longer suitable for production. Cockle production virtually ceased for four to five years. During the last few years, production has restarted and seed has been collected. Data are not available to indicate the amount of seed available at Phetchaburi.

In 1979, Satun Province had about 3,800 rai in cockle production but no reported spat settlement has occurred. In January 1983, a report from Nakhon Si Thammarat, where cockle farming also exists, indicated that spatfall had occurred. Many spat, size 170-200 pieces/kg, could be collected. The spat collection area was about 2-3 km from the culture area in Nakhon Si Thammarat Bay. The seed bed at Nakhon is a very hopeful sign for continued cockle culture in Thailand.

MALAYSIA SEED BED

Cockle seed has been imported from Malaysia (Pathansali 1977). In 1977, about 200 t were imported. Cockle seed beds in Malaysia are primarily in Bagan Fermal and Balik Pulau of Penang State, and Kuala Selensing, Kuala Jarum Mas and Bagan Sungei Jelukang of Perak State (Fig. 4).

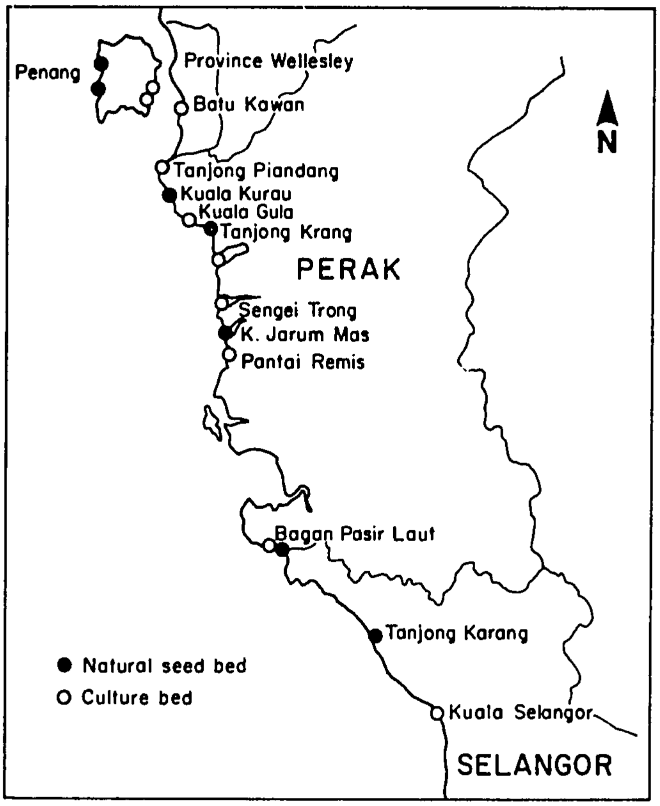

Fig. 4. Cockle culture areas in Malaysia (from Pathansali 1961).

SPAT COLLECTING SEASON

According to farmers in Nakhon Si Thammarat Bay, spat (approximately 170-200/kg) were collected in January 1983. Cockles of this size are five to six months in age. The spat survey at Sapum Bay, Phuket Province (Boonruang and Janekarn 1983) indicated that spat were 18 mm in size in December, almost the same as the Nakhon seed. These data indicate the spawning season in both areas must occur around June-August.

Pathansali (1977) reported the spawning season in Malaysia was in May-September and spat (1 mm) collection was in June-November. Spawning and collection periods varied due to the environmental effects such as salinity and tide. In Malaysia (Pathansali 1977), spat settlement was on fine muddy bottoms with a low slope, around the mouth of rivers or the mangrove coastline. Settlement period was at the beginning of high or low tide during neap tide (about the 8th-10th day of waxing or waning). The spat settlement occurred at 28 to 30 ppt salinity.

Purchasing Cockle Seed for Culture

Cockle farmers in the south of Thailand import seed from Malaysia; therefore, the quantity available and price in Malaysia strongly influence cockle farming in Thailand. Cockle farmers in the south of Thailand thus join with Malaysians who provide the seed by buying in Malaysia. An interview in

1980 by the author disclosed that the Malaysian government required farmers to form a cooperative for seed collection in the village area. Sale was by bidding thus price was dependent on quantity collected and demand by producers. The price, in 1961, was about M$0.12/kg. In 1982, the price of cockle seed (1,300/kg) was M$1.6/kg* and in 1983, M$5.5/kg* (2,500/kg). The farmers in Thailand have to purchase seed through competitive bidding. In addition, seed exported to Thailand was subject to an 8% tax on the selling price.

Predators, Disease and Parasites

Predators, disease and parasites are significant problems for all types of aquaculture. Shellfish, because of external anatomy, have fewer problems than other types. Some of the major problems are as follows.

HUMAN PREDATORS

Humans are the most significant predators in the culture area. The culture area is large and near shore, thus theft is a constant problem. Theft is accomplished by use of hand dredges or even boat dredges even though watchmen are employed to guard the production area.

FISHING IN THE CULTURE AREA

Bottom trawling in the culture area using push nets can press the cockles into the mud or disturb the growing area. Cockles may be killed by siltation or burial. The push nets can also destroy the cockle larvae suspended in the water. Other small-scale fishing equipment such as fish traps, gill nets, and hand lines are not a direct problem but the users of the gear can easily steal cockles.

OTHER PREDATORS

Fig. 5 shows predators which damage or drill cockles. These are drilling gastropods—*Natica maculosa* (moon snail) and *Thais carinifera.* These gastropods can consume cockles. Also, starfish and catfish *(Plotosus anguillaris)* can eat small cockles. At times also a small crab is found within cockles between the shell and meat. The crab has a carapace with width of about 0.25 cm. Generally there is only one crab in a cockle. No references, Thai or English, have been found to classify this crab. In addition, no references have been found reporting the relationship, symbiotic or parasitic, of the cockles and crab.

WATER POLLUTION

Cockles are benthic animals that migrate very slowly, thus pollution can have a major effect on the production area. Red tide, caused by blooms of phytoplankton, can create oxygen and nutrient depletion in the water. If red tide occurs in the culture area, the sediment can accumulate on the mud surface and create an oxygen depletion and nutrient deficiency that will cause mortality in the cockles. The red tide phenomena is caused by blooming of two phytoplankton species—*Trichodesmium* sp. and *Noctiluca* sp.

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*M$2.32 = US$1 as of December 1982.

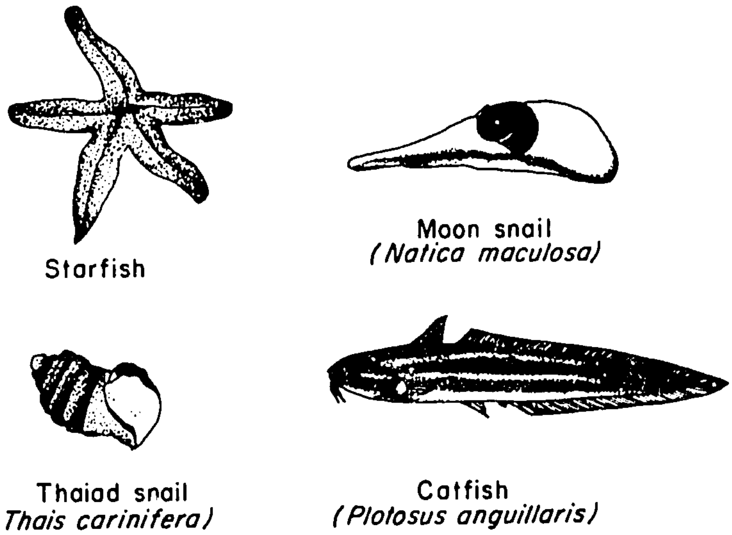

Fig. 5. Cockle predators.

Management and Farm Operation

SEED TRANSPORT AND STOCKING DENSITY

Size of cockle seed for culture varies from 1,000-10,000 pieces/kg. Handling during transport is very important. In general, farmers importing seed from Malaysia transport at night. The seed are packed in sacks weighing 60-80 kg. The sacks are sprayed with seawater at varying times during transport. Sowing of seed is done in the early morning or late evening for a better survival rate. Seeding is always done at neap tide (the 7th-11th day of the waxing moon) when the entire culture area is covered with water. According to farmers who import from Malaysia, the mortality was not greater than 15% (by weight). The farmers use a metal dinner plate for sowing the seed and attempt to spread them evenly over the area. Stocking is dense for the first three months for convenience in determining growth rate. Only a portion of the growing area is stocked. Interviews with producers indicate 540 kg (30 tins) to 1,080 kg (60 tins) per rai are stocked (Tookwinas 1981). After three to six months, the cockle will be redistributed over the entire growing area.

GROWTH RATE

In the cockle farm operation, the farmer checks growth rate and density on a monthly basis. The check is to insure that crowding does not occur that could decrease growth rate or cause mortality.

The farmer uses a mud ski, a plank about 0.9 m wide and 1-1.5 m long with the front portion angled up to check cockle density. The farmer propels the plank across the mud at low water spring. The farmer sits on the heel of the left leg and propels the plank with the right leg (Fig. 6). Efficiency in movement depends on the skill of the farmer. When a crowded area is discovered, the farmer will dip up cockles with a wire sieve, screen size 0,5 cm (Fig. 7), and distribute the cockles to a less crowded area.

A survey to determine proper stocking density was done in Satun Province. The proper density for small cockles during the first six months was 400-450/m^2. After one year, the density should be

Fig. 6. Farmer propelling mud ski for harvesting or distributing cockles.

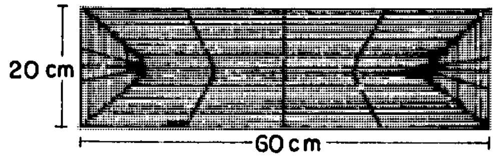

Fig. 7. Wire sieve for sorting young cockles.

reduced to 100-200/m^2. The farmers start to harvest after 18 months when cockles reach about 4 cm and 24 g in weight, 40-50/kg.

In addition to the detection method listed above, an Ekman grab can be used to collect cockles from a boat. In measuring cockles, Vernier calipers were used. Fig. 8 shows dimensions for technical measurement of cockles.

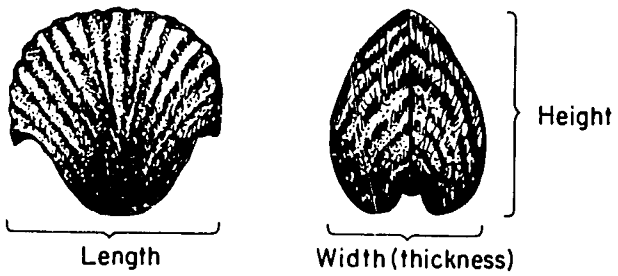

Fig. 8. Dimensions for technical measurement of cockles.

FARM MANAGEMENT

Good management is necessary for any culture of aquatic animals. Detection of disease is much more difficult in aquaculture than for terrestrial animals, Cockle farming is somewhat easier than other aquaculture because it requires less management but gives high returns per unit of capital. Farmers must build a guardhouse in the production area and employ full-time guards to prevent theft of cockles. Provision of a guard is one of the most important management tools. In addition, the farmer has to check for and irradicate predators, such as starfish, from the culture area. Starfish can swiftly reduce the cockle population.

HARVESTING

After 18 months the farmer begins to harvest cockles. At this point, cockles are about 50-60/kg. The farmer employs workers to dredge cockles every day. Daily production will average 6-10 t for an area of 500 rai. After harvest, cockles are transported to Bangkok or Samut Prakan. Equipment used in harvest is an iron frame with strong wire connected along the frame and thin wire across the strong wire making a 2.6-cm mesh size (Fig. 9). The frame is attached to a pole. In dredging, the pole is attached by rope to the front of the boat. One man tilts the pole upright and the forward motion of the boat pulls the dredge. When the dredge is full, the man lifts it into the boat and dumps out the cockles. The boat normally has a central engine and is 6 m long and 2 m wide. The operator holds the pole with his hands and guides it with his legs. The boat circles in an area until harvesting is complete. Boat harvesting continues until density is reduced to 1-3 cockles/m^2.

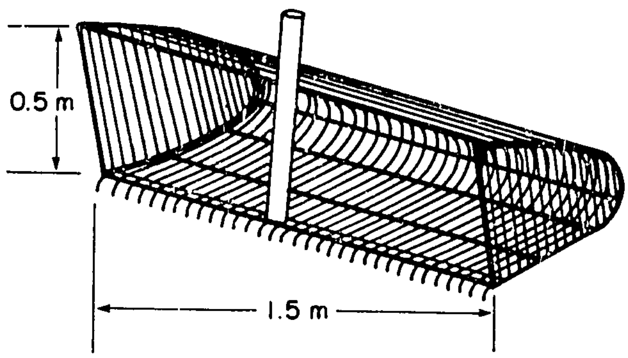

Fig. 9. Rake for harvesting cockles.

MARKETING AND BENEFITS

Intensive cockle farmers in Thailand always arrange forward contracts with wholesalers in Bangkok or in the local area. Since the harvest period is short and the quantity produced is high, the contracts avoid market gluts and consequent low prices. Occasionally when production is not sufficient, the farmer must purchase cockles from Malaysia to fulfill the contract. The wholesalers distribute the cockles to other middlemen. The other middlemen redistribute to dealers who deliver cockles to all sections of Thailand (Fig. 10).

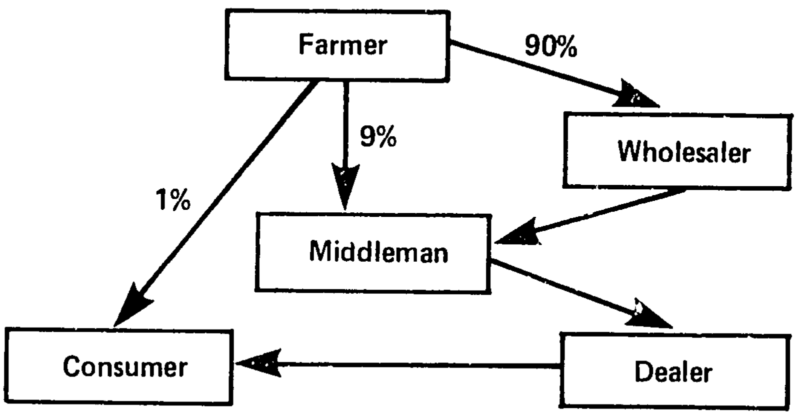

Fig. 10. Cockle marketing system.

The capital requirements and benefits from cockle farming in 1978 are shown in Table 1 (Rabanal et al. 1977).

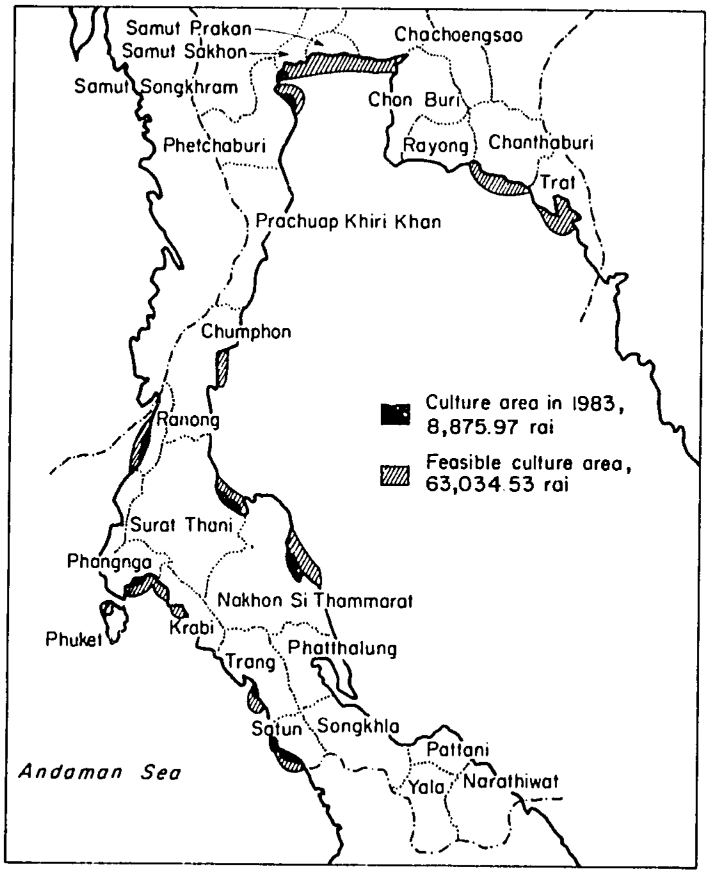

Fig. 11. Present cockle culture areas and feasible areas for expansion.

Table 1. Capital and benefits from cockle farming, 1978.

Item	Cost (Baht*)
Fixed capital	
Equipment, dredge, boats, etc.	55,000
Regular expenses	
Seed (40,000 kg)	93,750
Labor, harvest and transport	2,187
Total	95,937
Income	
Production (109.87 t/6.26 rai @ 1.5 baht/kg)	164,062
Benefits	
Net benefit	68,125
Benefit percentage	17

*15 Baht = US$1 in January-June 1978.

Cockle Farming Area of Thailand

In 1980, cockle farming was conducted in four provinces in Thailand: Samut Sakhon, Phetchaburi, Nakhon Si Thammarat and Satun (Hongskul 1980). Culture area was 4,818 rai. From personal interviews of fisheries officials of many provinces, it appears that the culture area expanded to nine provinces. with an area of 8,876 rai (Table 2 and Fig. 11). A feasibility survey, as well as the author's survey, indicated cockle could be expanded to 21 provinces with a culture area of 71,911 rai (Rabanal et al. 1977; Chomdes and Poocharoen 1979; Hongskul 1980). The feasibility of this expansion requires more study on the technical aspects. Cockle production for 1971-1978 is shown in Table 3; production in 1978 was 16,326 t.

Table 2. Cockle farm areas in Thailand.[1]

Province	Culture area (1980)	Culture area (1981-1982)	Feasible area	Total
Trat	–	–	3,000	3,000
Chanthaburi	–	–	12,000	12,000
Chachoengsao	–	–	1,200	1,200
Samut Prakan	–	–	3,000	3,000
Samut Sakhon	–	–	6,000	6,000
Samut Songkhram	954	250	2,504	2,754
Phetchaburi	672	200	472	672
Chumphon	–	–	1,200	1,200
Surat Thani	–	2,725	11,377	14,102[4]
Nakhon Si Thammarat	–	800	2,200	3,000
Pattani	–	10	?	10[3]
Ranong	44	1,398	10,602	12,000
Phuket	–	–	150	150
Phangnga	–	–	6,500	6,500
Krabi	–	–	1,000	1,000
Trang	–	100	900	1,000
Satun	3,148	2,943[2]	1,380	4,323[5]
Total	4,818	8,876	63,035	71,911

[1]Modified from Hongskul (1980), Table 4.
[2]Includes the permitted area and groups of farmers in the rural poor development project.
[3]Not surveyed for feasible area.
[4]Areas notified by the Department of Fisheries as permitted areas for cockle farming.
[5]Does not include the permitted areas which require improvement.

Problems and Obstacles

Seed shortage is one of the main obstacles to increases in production. Currently, producers must import seed from Malaysia. The imported seed is expensive and sometimes sufficient quantity is not available. The news regarding the seed bed at Nakhon Si Thammarat thus attains greater importance. In addition, cockle seed could be collected from Bang Tabun in Phetchaburi or Khlongton in Samut Songkhram. Thailand seed, if properly utilized and conserved, would be sufficient for cockle farming in Thailand.

Table 3. Cockle production (tonnes) in Thailand, 1971-1978 (from Hongskul 1980).

Province	1971	1972	1973	1974	1975	1976	1977	1978
Phetchaburi	7,332	1,324	2,030	776	1,328	2,448	2,112	1,823
Samut Sakhon	2,802	122	–	–	–	–	–	–
Samut Songkhram	285	1,260	1,890	718	638	745	681	479
Chachoengsao	42	276	–	–	–	–	–	–
Phuket	–	423	390	–	–	17	42	86
Surat Thani	–	288	–	–	–	–	–	–
Chumphon	–	414	545	468	538	–	–	–
Pattani	–	26	–	36	–	94	156	–
Trang	–	4	–	14	24	50	99	165
Satun	–	–	–	1,000	3,600	8,900	13,200	13,467
Songkhla	–	–	–	–	43	–	–	–
Phangnga	–	–	–	–	30	538	267	44
Krabi	–	–	–	–	–	–	89	33
Others	2,121	533	330	110	–	–	–	–
Total	12,581	4,690	5,185	3,131	6,201	12,792	16,646	16,326

DETERIORATION OF CULTURE AREA

Following five to six years of continuous culture, the production area at Che-bi-lung Bay, Muang District, Satun Province had changed. The bottom surface is hard with an accumulation of material including shell of dead cockles. Interview of producers indicated the continuous harvest with the small mesh screen removed only the larger shell. The empty shell remained on the bottom. Additional factors cause the deterioration in culture areas suggesting further research should be performed.

PROBLEMS WITH PERMITS FOR COCKLE FARMING

According to Section 7 of the Fisheries Legislation issued in 1974, a farmer who wishes to engage in cockle farming must follow a certain procedure. First, submit a request to the District Fisheries Officer who passes the request to the Provincial Fisheries Officer who, in turn, submits the request to the Department of Fisheries. The Department of Fisheries will dispatch a Fisheries Biologist to determine the biological feasibility of the area for cockle culture. If the area is feasible, the Provincial and/or District Fisheries Officer will arrange for assembly of the local people to gain approval for the request. After a request is approved for cockle farming, no fishing activity is allowed in the area. In actuality, prospective cockle farmers first seek to gain approval of the local people. Seldom will such approval be granted since the people do not want to give up fishing rights in an area.

LIVE TRANSPORT

As indicated in Fig. 10, farmers transport cockle to wholesalers. The wholesalers in turn sell to other middlemen who distribute throughout the country. These marketing steps require time and cockle may require a few days to reach the consumer. For consumers in the north or northeast it requires an even longer time period. During this transport period the cockles may die. The death loss reduces the quantity available for consumption and price is higher. Transportation needs improvement. At present, cockles are packed in sacks, about 60-70 kg/sack, and sprinkled with seawater before transport. Ten wheel trucks are used and transportation is done in late afternoon or evening. The cockles arrive in Bangkok early in the morning for distribution the next day.

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