MINISTRY OF AGRICULTURE
AND FOOD SECURITY
DEPARTMENT OF FISHERIES MALAYSIA

JIRCAS

Proceedings of the

JIRCAS-FRI
30 Years Anniversary Symposium

"Findings from ecological and aquaculture research mainly focused on mangrove estuary areas in Peninsular Malaysia"

FRI Penang
20 November 2025

First Edition 2026

Editor:

Wan Norhana Md. Noordin

Published by:

Fisheries Research Institute (FRI)

1960 Batu Maung

Penang, Malaysia

Tel: +604–626 3925 / 26

Fax: +604–626 2077

Email: fri_helpdesk@dof.gov.my

Cataloguing-in-Publication Data

Perpustakaan Negara Malaysia

A catalogue record for this book is available from the National Library of Malaysia

eISBN 978-967-2946-63-2

Contents

Opening Remarks

Ladies and Gentlemen,

Distinguished guests, colleagues, and friends,

On behalf of the Japan International Research Centre for Agricultural Sciences (JIRCAS), I am honoured to welcome you to the JIRCAS-FRI Joint 30 Years Anniversary Symposium. This event marks the conclusion of a long-standing and fruitful collaboration between JIRCAS and the Fisheries Research Institute (FRI) of Malaysia, and we are delighted to celebrate this milestone with all of you.

Over the past three decades, our joint efforts have significantly contributed to ecological and aquaculture research, particularly in the mangrove estuary areas of Peninsular Malaysia. These studies have deepened scientific understanding and supported sustainable development and local livelihoods.

As this collaborative project comes to a close, this symposium provides a valuable opportunity to reflect on our shared achievements, exchange insights, and explore future directions for research and cooperation. We are especially pleased to host this event in Penang, which represents the heart of our fieldwork and partnership.

I would like to express my sincere appreciation to our colleagues at FRI for their unwavering support and collaboration throughout the years, and to all presenters and participants for joining us in this meaningful occasion. We look forward to engaging in discussions and to building upon the legacy of this partnership in new and evolving contexts.

Thank you very much.

November 20, 2025

Director, Fisheries Division, JIRCAS

Dr. Satoshi HONDA

Welcoming Remarks

Distinguished delegates from JIRCAS, former researchers, colleagues, ladies and gentlemen,

It is a pleasure to welcome all of you to this special symposium. A particularly warm welcome to our former researchers who contributed so much to our joint efforts. Welcome back to FRI! This symposium marks a significant event, celebrating a remarkable and enduring partnership. For the past 30 years, JIRCAS and FRI have collaborated in the fields of ecology and aquaculture research in brackish water areas. This three-decade relationship has been advancing our understanding and capacity in these crucial domains. We at FRI consider ourselves fortunate to have had this collaboration. We have gained valuable experience and expertise from JIRCAS researchers, which has shaped our research direction and built lasting institutional capacity.

I'm so happy to see many familiar faces today. Among us are FRI researchers who have been a part of this journey since the collaboration was first initiated. Thank you for joining us today Ms Chee, Dr Alias, your dedication and hard work are a testament to the success of this partnership.

I understand that the presentations today will be divided into two sessions ecology study and aquaculture research in brackish water estuary. I believe this approach will facilitate fruitful discussions, and I hope this symposium proceeds successfully as planned.

Thank you once again to everyone for your presence and contributions.

November 20,2025

Senior Director, Fisheries Research Institute

Dr Azhar HAMZAH

SESSION 1

Presentation 1

JIRCAS / Malaysia Brackish Water Mangrove Ecosystems Project

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*Corresponding author: phaikean@hotmail.com

Abstract: Fisheries contribute significantly in providing protein as food to Malaysians as well as to populations in many developing countries. Fisheries and aquaculture also support the livelihoods of coastal communities and generate income and revenue. In April 1995, the Japan International Research Center for Agricultural Sciences (JIRCAS) and Malaysia started the project “Brackish Water Mangrove Ecosystems” to evaluate productivity in mangrove areas and to identify criteria for the sustainable management and utilization of fisheries in these areas. The Department of Fisheries Malaysia, the Forestry Department of Malaysia, and the University of Malaya together with scientists from JIRCAS are participants in this project. Initial studies of this JIRCAS / Malaysia project focused on biomass and diversity of the capture fisheries in the Matang mangrove area in Perak. Management of the Matang mangrove forest for timber and charcoal started in 1908, and this forest reserve has since been known as the best managed mangrove forest reserve in the world. However, mangroves are not only utilized for timber and charcoal production but they also serve as important nursery and feeding grounds for commercial fish species. Later studies were conducted on the complex food web of the mangrove ecosystem. These studies show that the food pathway, starting from mangrove leaf detritus, passes through the diverse fish and invertebrate species in the mangrove ecosystem. These species are in turn preyed upon by larger fish and higher-level predators. Comparative studies were also conducted in the smaller, exploited Merbok mangrove area in Kedah. Data and new information collected from these studies are needed to support the effective management of sustainable capture fisheries based on the ecosystem approach and the process of continuous improvement. Data collected also support the development of aquaculture of important commercial species. This project provides a platform for data, knowledge, and information exchange. It also provides technical training for Japanese and Malaysian scientists through numerous seminars and study visits.

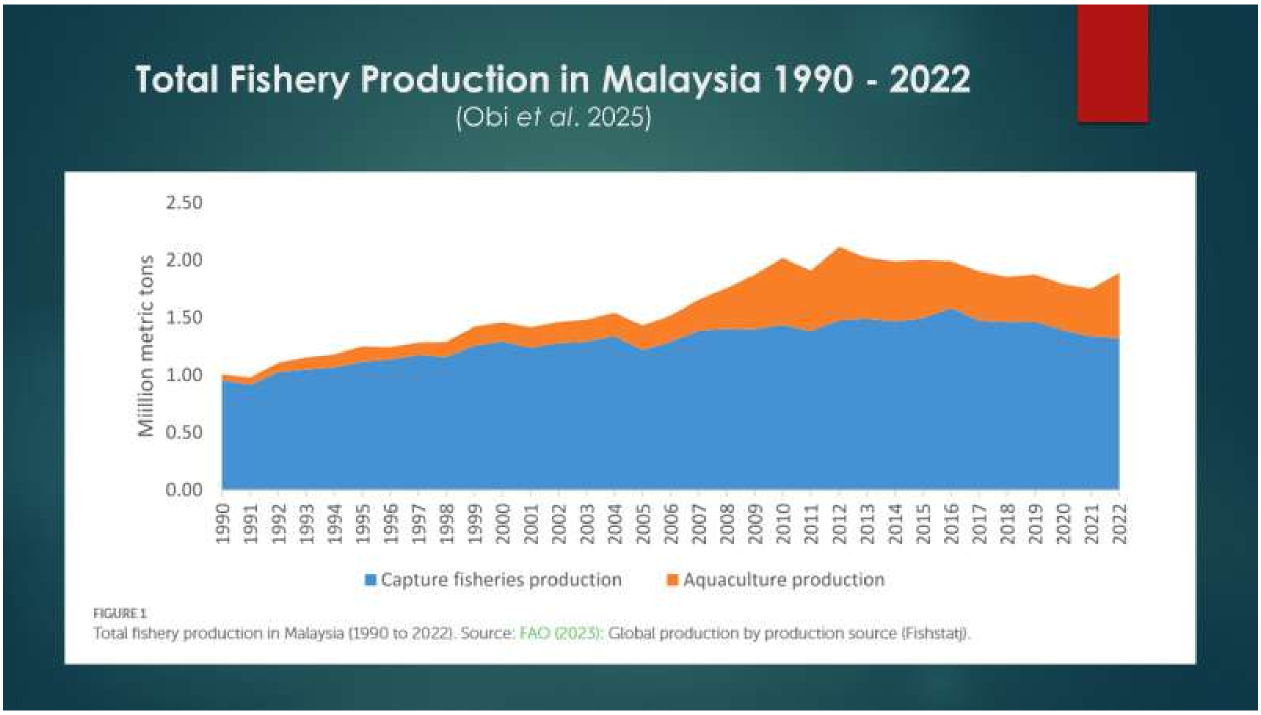
Keywords: Mangrove ecosystems, Sustainable fisheries, Brackish water, Food web, Matang mangrove forest.

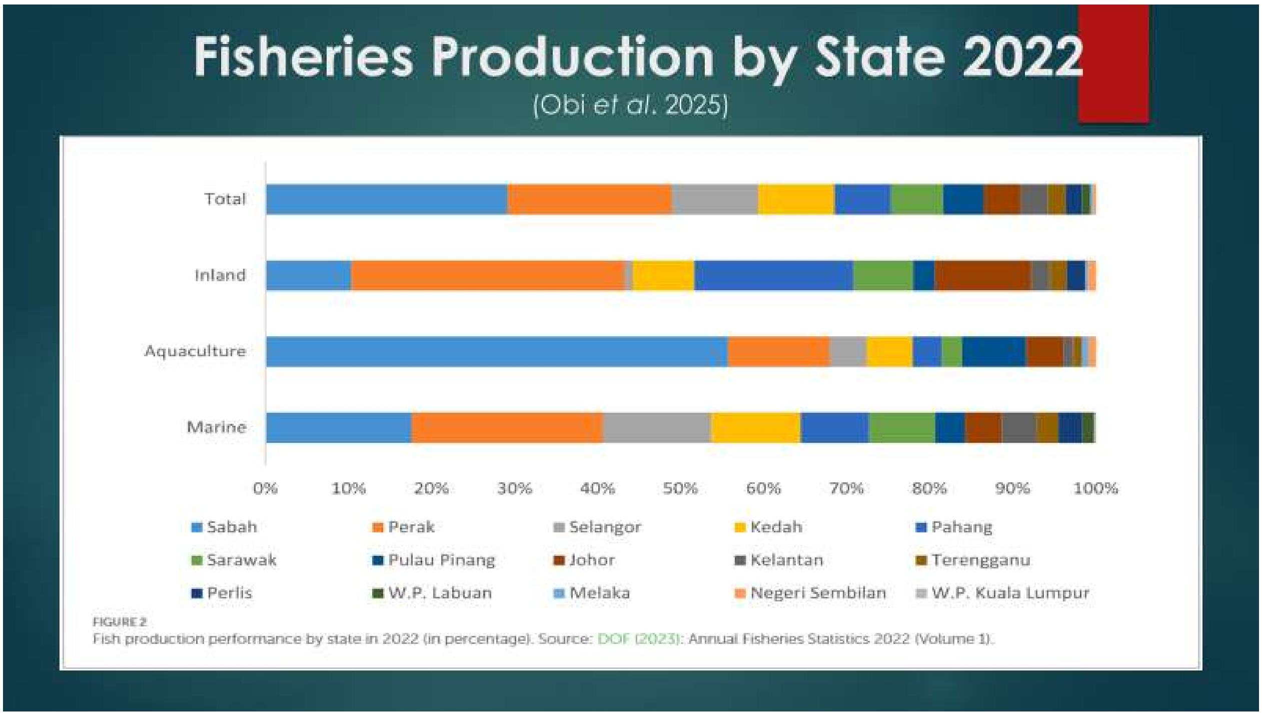
Abstrak**:** Perikanan memberi sumbangan yang signifikan dalam menyediakan sumber protein sebagai makanan kepada rakyat Malaysia serta kepada penduduk di banyak negara membangun. Sektor perikanan dan akuakultur juga menyokong sumber pendapatan dan mata pencarian komuniti pesisir pantai, di samping menjana hasil dan pendapatan kepada negara. Pada April 1995, Japan International Research Center for Agricultural Sciences (JIRCAS) dan Malaysia telah memulakan projek "Brackish Water Mangrove Ecosystems" bagi menilai produktiviti di kawasan paya bakau serta mengenal pasti kriteria untuk pengurusan dan pemanfaatan perikanan secara lestari di kawasan tersebut. Jabatan Perikanan Malaysia, Jabatan Perhutanan Malaysia dan Universiti Malaya bersama para saintis dari JIRCAS merupakan peserta dalam projek ini. Kajian awal projek JIRCAS/Malaysia ini memberi tumpuan kepada biomassa dan kepelbagaian perikanan tangkapan di kawasan paya bakau Matang, Perak. Pengurusan Hutan Simpan Paya Bakau Matang untuk tujuan pengeluaran kayu dan arang telah bermula sejak tahun 1908, dan hutan simpan ini kemudiannya dikenali sebagai hutan paya bakau yang terbaik pengurusannya di dunia. Walau bagaimanapun, paya bakau bukan sahaja dimanfaatkan untuk pengeluaran kayu dan arang, malah turut berfungsi sebagai kawasan asuhan dan kawasan pemakanan penting bagi spesies ikan komersial. Kajian seterusnya telah dijalankan terhadap jaringan makanan yang kompleks dalam ekosistem paya bakau. Kajian-kajian ini menunjukkan bahawa laluan makanan yang bermula daripada detritus daun bakau akan melalui pelbagai spesies ikan dan invertebrata dalam ekosistem tersebut. Spesies-spesies ini seterusnya menjadi mangsa kepada ikan yang lebih besar dan pemangsa pada aras trofik yang lebih tinggi. Kajian perbandingan turut dijalankan di kawasan paya bakau Merbok yang lebih kecil dan telah dieksploitasi di Kedah. Data dan maklumat baharu yang diperoleh daripada kajian-kajian ini amat diperlukan untuk menyokong pengurusan perikanan tangkapan secara lestari berasaskan pendekatan ekosistem serta prinsip penambahbaikan berterusan. Data yang dikumpulkan juga menyokong pembangunan akuakultur bagi spesies komersial penting. Projek ini menyediakan satu platform bagi pertukaran data, pengetahuan dan maklumat. Ia juga menyediakan latihan teknikal kepada saintis Jepun dan Malaysia melalui pelbagai seminar dan lawatan sambil belajar.

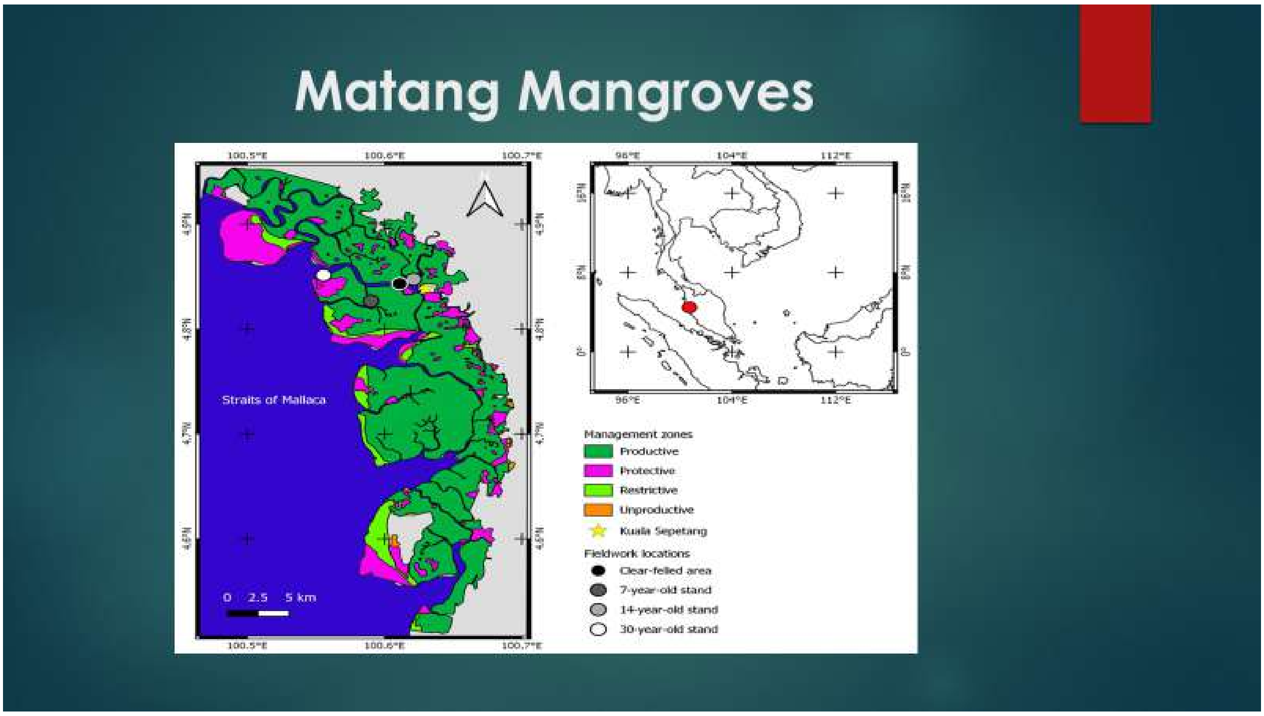
Brackish water mangrove ecosystems project

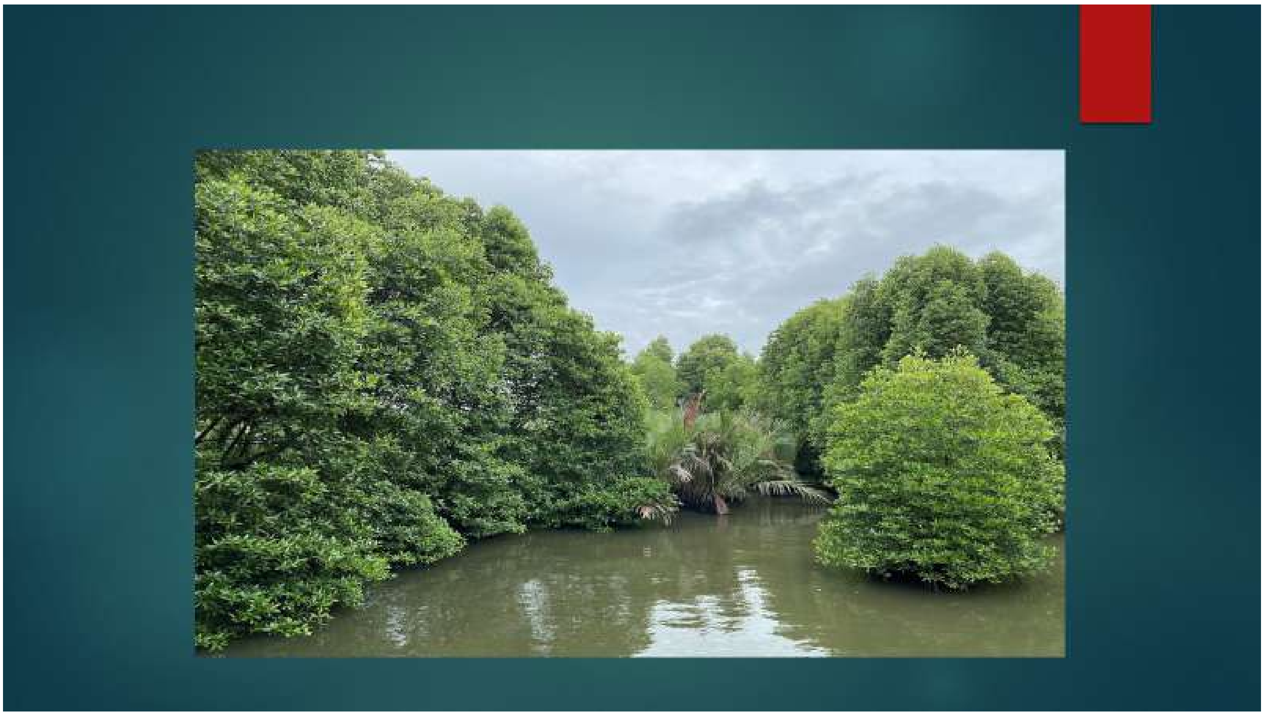
CHEE PHAIK EAN

Map of Peninsular Malaysia


Total Fishery Production in Malaysia 1990 - 2022
(Obi et al. 2025)
Miillion metric tons
2.50
2.00
1.50
1.00
0.50
0.00
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022
Capture fisheries production
Aquaculture production
FIGURE 1
Total fishery production in Malaysia (1990 to 2022). Source: FAO (2023): Global production by production source (Fishstatj).


Fisheries Production by State 2022
(Obi et al. 2025)
Total
Inland
Aquaculture
Marine
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Sabah
Perak
Selangor
Kedah
Pahang
Sarawak
Pulau Pinang
Johor
Kelantan
Terengganu
Perlis
W.P. Labuan
Melaka
Negeri Sembilan
W.P. Kuala Lumpur
FIGURE 2
Fish production performance by state in 2022 (in percentage). Source: DOF (2023): Annual Fisheries Statistics 2022 (Volume 1).


Matang Mangroves
Straits of Mallaca
0 2.5 5 km
Management zones
Productive
Protective
Restrictive
Unproductive
Kuala Sepetang
Fieldwork locations
Clear-felled area
7-year-old stand
14-year-old stand
30-year-old stand



Charcoal kiln in Kuala Sepetang

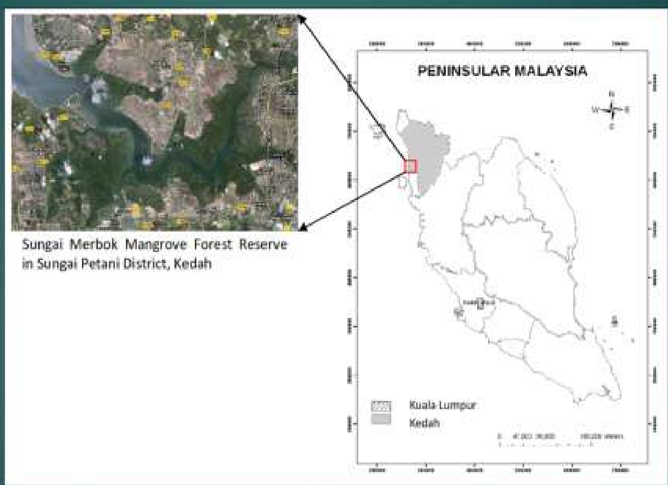
Small scale traditional capture fisheries

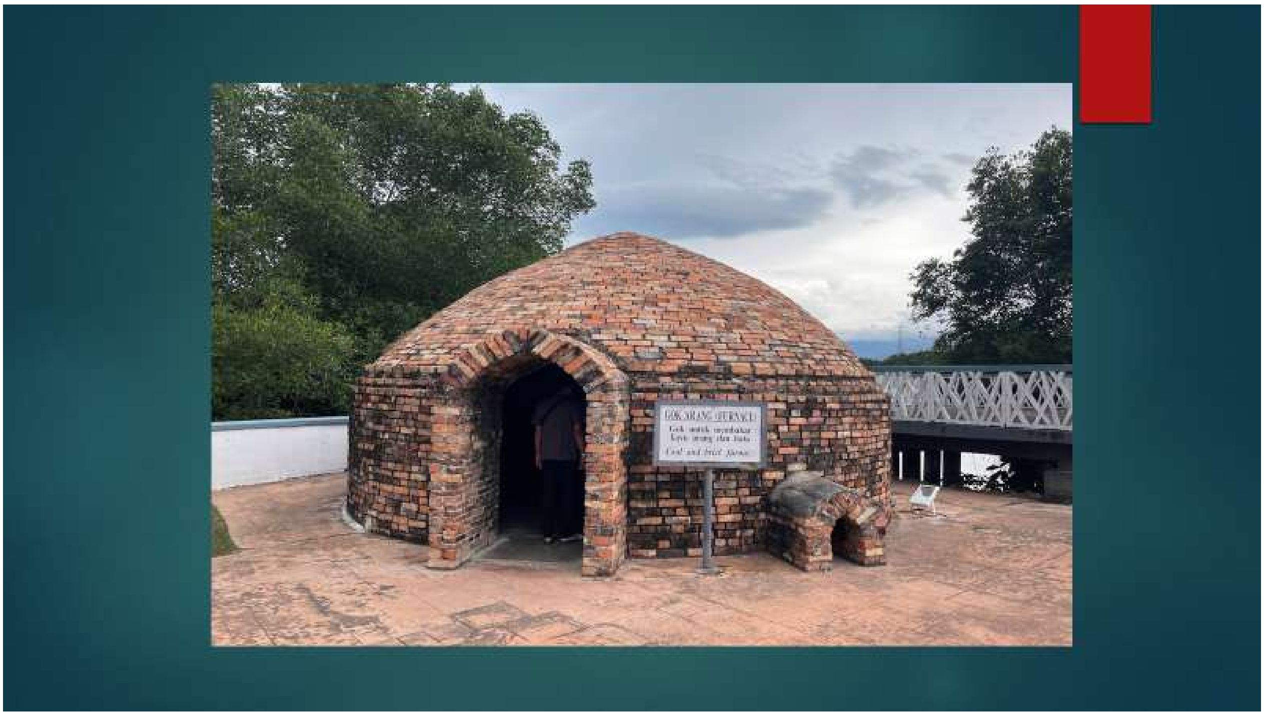
Coastal capture fisheries

Aquaculture: finfish, shrimps and bivalves

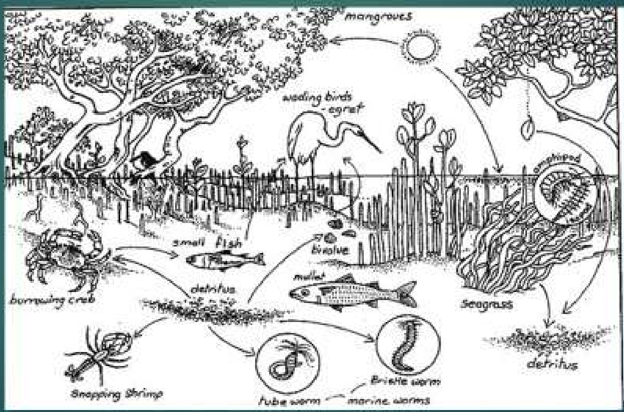

Kuala Sepetang, Perak


Fish cages in Kuala Sepetang


PENINSULAR MALAYSIA
Sungai Merbok Mangrove Forest Reserve in Sungai Petani District, Kedah
Kuala Lumpur
Kedah



Mangrove Food Web



Spatial distribution of hyperbenthic crustaceans in mangrove estuaries
(Hanamura *et al.*, 2007)

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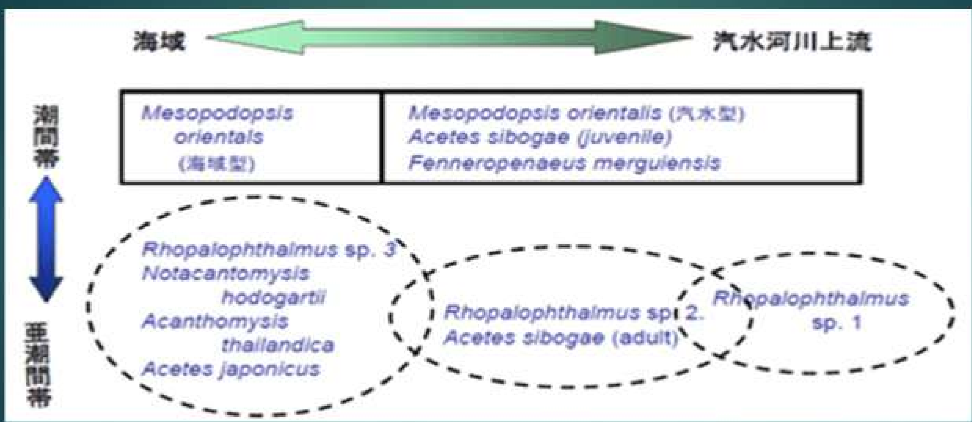
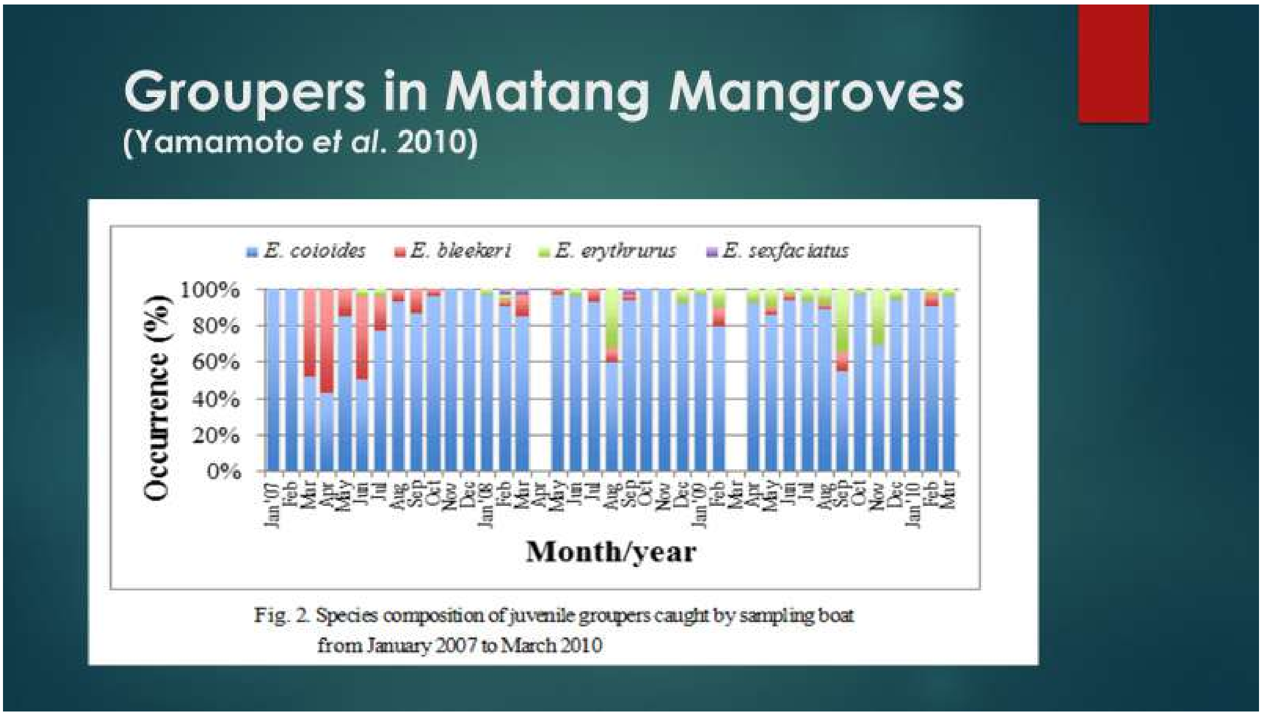



Groupers in Matang Mangroves
(Yamamoto *et al*. 2010)
E. coioides
E. bleekeri
E. erythrurus
E. sexfaciatus
100%
80%
60%
40%
20%
0%
Occurrence (%)
Jan '07 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan '08 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan '09 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan '10 Feb Mar
Month/year
Fig. 2. Species composition of juvenile groupers caught by sampling boat from January 2007 to March 2010

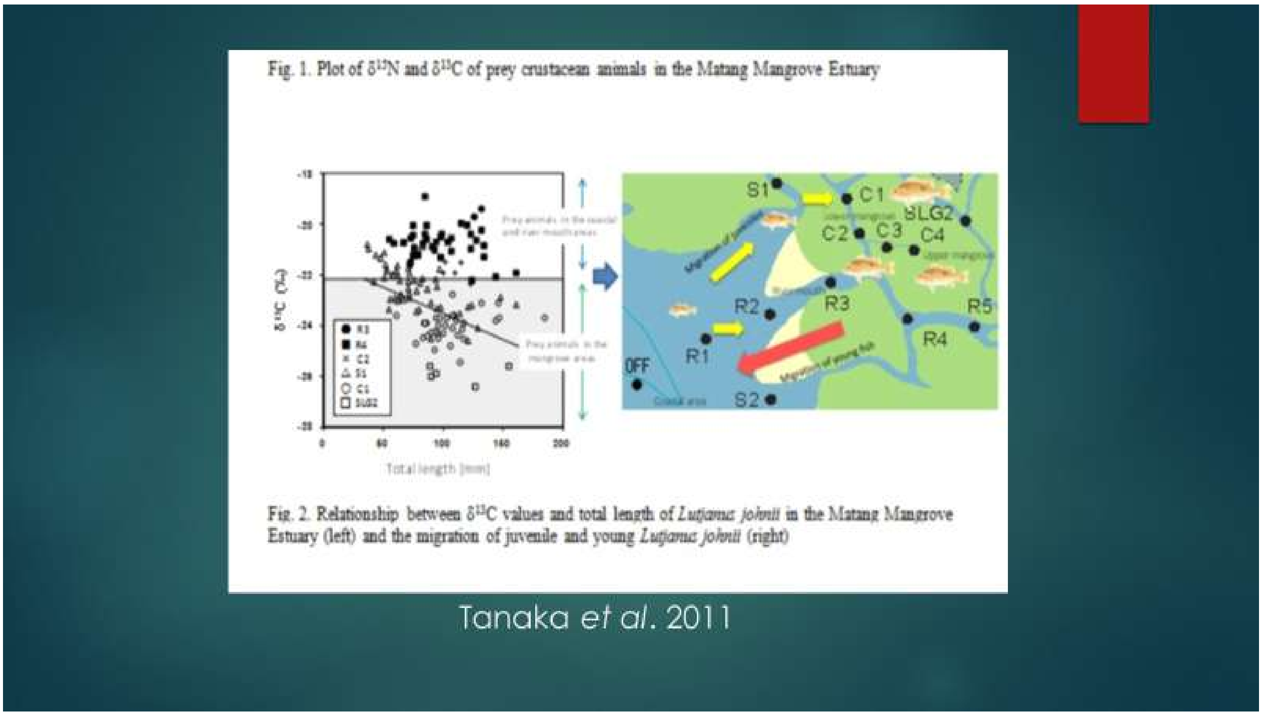


Fig. 1. Plot of $\delta^{15}N$ and $\delta^{13}C$ of prey crustacean animals in the Matang Mangrove Estuary
$\delta^{13}C$ (‰)
Total length (mm)
0
50
100
150
200
S1
C1
BLG2
C2
C3
C4
R2
R3
R5
R1
R4
OFF
S2
Fig. 2. Relationship between $\delta^{13}C$ values and total length of *Lutjanus johnii* in the Matang Mangrove Estuary (left) and the migration of juvenile and young *Lutjanus johnii* (right)
Tanaka *et al*. 2011

From the Project

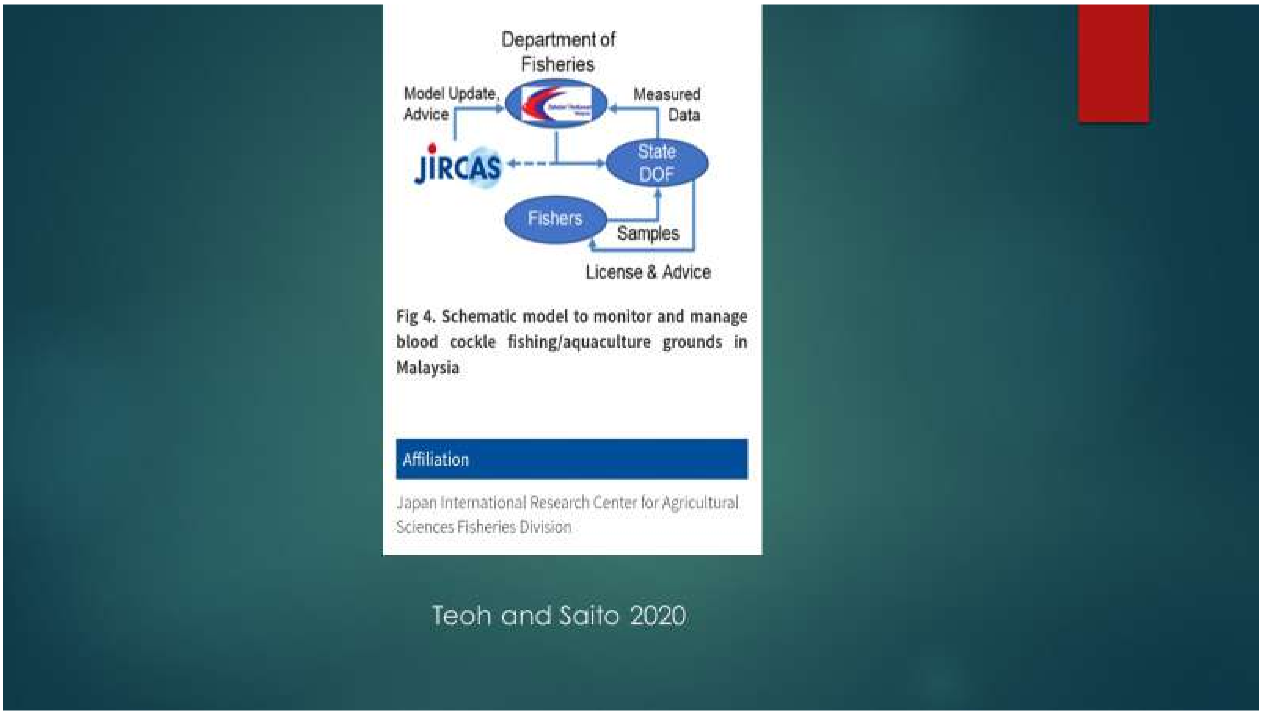
RECOMMENDATIONS FOR ECOSYSTEM BASED MANAGEMENT – HABITAT PROTECTION, PROTECT ION OF NURSERY AREAS, COASTAL DAMAGE REDUCTION, POLLUTION REDUCTION

COMMUNITY INVOLVEMENT, LONG TERM CAPACITY BUILDING IN CO MANAGEMENT SYSTEMS

MODEL FOR MANGROVE AND MANGROVE ASSOCIATED FISHERIES USING FIELD AND EXPERIMENTAL DATA ?

FUTURE OF MANAGEMENT OF SMALL SCALE FISHERIES

1. COMMUNITY DRIVEN, TECHNOLOGY ENABLED, EDUCATING AND EMPOWERING FISHERS (INCLUDE WOMEN) FOR LONG TERM SUSTAINABILITY
2. ENHANCEMENT OF FISHERIES MANAGEMENT, ENFORCEMENT OF FISHERIES ACT 1985
3. BETTER DATA AND CONTINUOUS IMPROVEMENT
4. REGIONAL AND INTERNATIONAL COOPERATION E.G. WITH SEAFDEC, ASEAN, JIRCAS FOR KNOWLEDGE AND DATA EXCHANGE, EXPOSURE AND TRAINING


Department of Fisheries
Model Update, Advice
Measured Data
JIRCAS
State DOF
Fishers
Samples
License & Advice
Fig 4. Schematic model to monitor and manage blood cockle fishing/aquaculture grounds in Malaysia
Affiliation
Japan International Research Center for Agricultural Sciences Fisheries Division
Teoh and Saito 2020


Local Success Stories in Community Based Management
"TAGAL" COMMUNITY BASED FISHERIES OF RIVERINE FISHERIES
SG KILIM, LANGKAWI ECOTOURISM PROJECT

Examples of sustainable fisheries (Certified by Marine/Aquaculture Stewardship Council)

BEN TRE CLAM (*MERETRIX LYRATA*) FISHERY IN VIETNAM

COMMUNITY BASED AND MANAGED BY LOCAL COOPERATIVES

TUNA FISHERIES IN INDONESIA POLE AND LINE AND HANDLINE FOR SKIPJACK AND YELLOWFIN

MALAYSIAN SHRIMP FARM IN SABAH, SANKINA AQUACULTURE, TOGETHER WITH WWF MALAYSIA, FISHERIES DEPT SABAH, WAS ASC CERTIFIED IN JUNE 2023. THIS SITE IS ADJACENT TO MANGROVES

Presentation 2

Blood cockle research of the Northwest Coast of Peninsular Malaysia in relation to the 2011 mass cockle mortality event and a prolong catch drops after 2015

ALIAS MAN*

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**Corresponding author: aliasman001@gmail.com*

Abstract: The farming of the Blood Cockle (*Tegillarca granosa*) in the Northwest Coast of Peninsular Malaysia (NWCPM) have been identified as one of the potential means to sustainable supply of cheaper protein to the locals as well as providing sustainable livelihood for the culturists. In 2008, Selangor, one of the important cockle state producers of NWCPM, launched "Kebun Kerang", an initiative to extensively culture the cockle in the shallow-coastal zones of the state. To complement the initiative, various cockle research programs have been implemented from 2009 to 2015. During the study period, the production from Selangor rose from 1,830 tons in 2006 to 41,410 tons in 2010, but plunged to only 26,510 at 2011. In 2015, only 3,330 tons of cockles were produced from Selangor, and the catch remained low until 2024 where only 160 tons of cockles were harvested. The problem of declining catch started with a mass mortality event that occurred in 2011. A specific research program was triggered to elucidate the potential factors that have caused the mass mortality event, but was only implemented in 2015 after funding was provided. After 2015, the low-landing of the cockle from NWCPM was never recovered. This paper reviewed the earlier works as well as exploring new potential factors that might have caused the mass mortality in 2011 as well as the catch reduction after 2015. Among the new parameters studied were growth, mortality and carrying capacity. The renewed analysis on the growth discovered a bigger asymptotic length (L∞) of the cockle, which is 78mm. This was fifty percent higher than the previous size which are around 50mm. However, the rate of growth and total mortality were about the same as before. Analysis on the catch and effort data of the cultured cockle, revealed that the catch per unit effort (CPUE) were highly varied for the same effort levels. This indicated that the environmental conditions were not at equilibrium or at changing phase, resulting in a changing in the carrying capacity as the environment changes. A matrix of cause-and-effect model factors was developed to determine potential factors that have caused the mass mortality and the prolong catch reduction of the cockle. Coastal erosion was identified as the potential factors that have eroded the important intertidal cockle habitat as well as their food supply. Apart from climate change that gradually changed the current speed and the waves energy at the intertidal zones, enormous and rapid sand mining in the straits was identified as the most contributing factors that aggravated further the destruction of the cockle beds.

Keywords: Blood cockle, population dynamics, ecosystem model and simulation, mass mortality, coastal erosion, offshore sand mining.

Abstrak: Penternakan kerang darah (*Tegillarca granosa*) di Pantai Barat Laut Semenanjung Malaysia (NWCPM) merupakan salah satu kaedah berpotensi untuk membekalkan protein yang murah kepada pengguna tempatan serta sumber ekonomi kepada penternak. Pada tahun 2008, Selangor, salah satu negeri pengeluar kerang penting di NWCPM, melancarkan "Kebun

Kerang", satu inisiatif untuk memternak kerang secara meluas di zon pantai cetek di negeri itu. Bagi melengkapkan inisiatif itu, pelbagai program penyelidikan telah dilaksanakan dari 2009 hingga 2015. Sepanjang tempoh kajian, pengeluaran kerang telah meningkat daripada 1,830 tan pada 2006 kepada 41,410 tan pada 2010, tetapi menjunam kepada hanya 26,510 pada 2011. Dalam 2015, hanya 3,300 tan kerang sahaja yang didaratkan, dan hasil tangkapan kekal rendah sehingga 2024 dengan hanya 160 tan. Pola penurunan bermula dengan peristiwa kematian besar-besaran kerang yang berlaku pada tahun 2011. Satu kajian telah dilaksanakan untuk menentukan faktor-faktor yang menyebabkan kejadian ini, tetapi hanya dapat dilaksanakan pada tahun 2015 selepas mendapat pembiayaan. Selepas 2015, tangkapan rendah kerang daripada NWCPM tidak pernah pulih. Kertas kerja ini mengkaji kerja-kerja terdahulu serta meneroka faktor potensi baharu yang mungkin menyebabkan kematian beramai-ramai pada 2011 serta pengurangan tangkapan selepas 2015. Antara parameter baharu yang dikaji ialah pertumbuhan, kematian dan daya tampung. Analisis yang diperbaharui pada pertumbuhan mendapati panjang asimptotik ($L\infty$) kerang yang lebih besar, iaitu 78 mm. Ini adalah lima puluh peratus lebih tinggi daripada saiz sebelumnya iaitu sekitar 50 mm. Walau bagaimanapun, kadar pertumbuhan dan jumlah kematian adalah lebih kurang sama seperti sebelum ini. Analisis terhadap data tangkapan dan usaha kerang yang dikultur, mendedahkan bahawa tangkapan seunit usaha (CPUE) sangat berbeza untuk tahap usaha yang sama. Ini menunjukkan bahawa keadaan persekitaran tidak berada pada keseimbangan atau pada fasa yang berubah-ubah, mengakibatkan perubahan dalam kapasiti tampung apabila persekitaran berubah. Satu matriks faktor model sebab-akibat telah dibangunkan untuk menentukan faktor-faktor berpotensi yang telah menyebabkan kematian besar-besaran dan tangkapan kerang rendah yang masih berlanjutan. Hakisan pantai dikenal pasti sebagai faktor berpotensi yang telah menghakis bekalan makanan mereka serta habitat penting kerang di zon intertidal. Selain daripada perubahan iklim yang secara beransur-ansur mengubah kelajuan arus dan tenaga ombak di zon intertidal, perlombongan pasir berskala besar dan berpanjangan di Selat Melaka dikenal pasti sebagai faktor yang mempercepatkan lagi proses kemusnahan habitat kerang.

Introduction

Blood Cockle (*Tegillarca granosa*) was found predominantly in the intertidal zones of mangrove areas, especially in the Northwest Coast of Peninsular Malaysia (NWCPM). In Malaysia the culture of the cockle began in 1948 in Bagan Panchor, a fishing village off Kuala Jarum Mas, Perak (Department of Fisheries (DOF), 1957). The culture began with an experiment with the sowing of seed cockles obtained from the nearby natural bed, on to a patch of muddy foreshore in the village. The experiment was a great success as the young cockles registered phenomenal growth rates in the newly laid out areas compared with those in the natural bed. Since that time the culture of cockles spread rapidly throughout the mangrove areas of the NWCPM, especially in Perak with historical landing started as early as 1952. The landings of the cockle from Perak however were first reported in the Annual Statistic 1957 (DOF, 1957). Several other states in the NWCPM were also participated in the culture of the cockle.

Landings or yield of the cockle were first reported under capture fisheries, but from 1984 onward, the landings were reported as part of the aquaculture production. Landings attained its highest in 1980 where about 119,200 tons of cockles were landed (**Figure 1**). The farming of the cockle in the NWCPM have been identified as one of the potential means to sustainable supply of cheaper protein to the locals as well as providing sustainable livelihood for the culturists. In 2008, Selangor, one of the important cockle state producers of NWCPM, launched "Kebun Kerang", an initiative to extensively culture the cockle in the shallow-coastal zones of the state (Manikavasagam, 2008). To complement the initiative, various cockle research programs have been implemented from 2009 to 2015. During the study period, the production from Selangor rose from 1,830 tons in 2006 to 41,410 tons in 2010, but plunged to only 26,510 at 2011. In 2015, only 3,330 tons of cockles were produced from Selangor, and the catch remained low until 2024 where only 160 tons of cockles were harvested. Similar decline of catches was also reported from other states in the NWCPM. A major drop was recorded in 2015, where only 15,770 tons was landed as compared to 40,420 tons landed in 2014, a drop of sixty percent. By 2024, only 15,860 tons of cockle was landed.

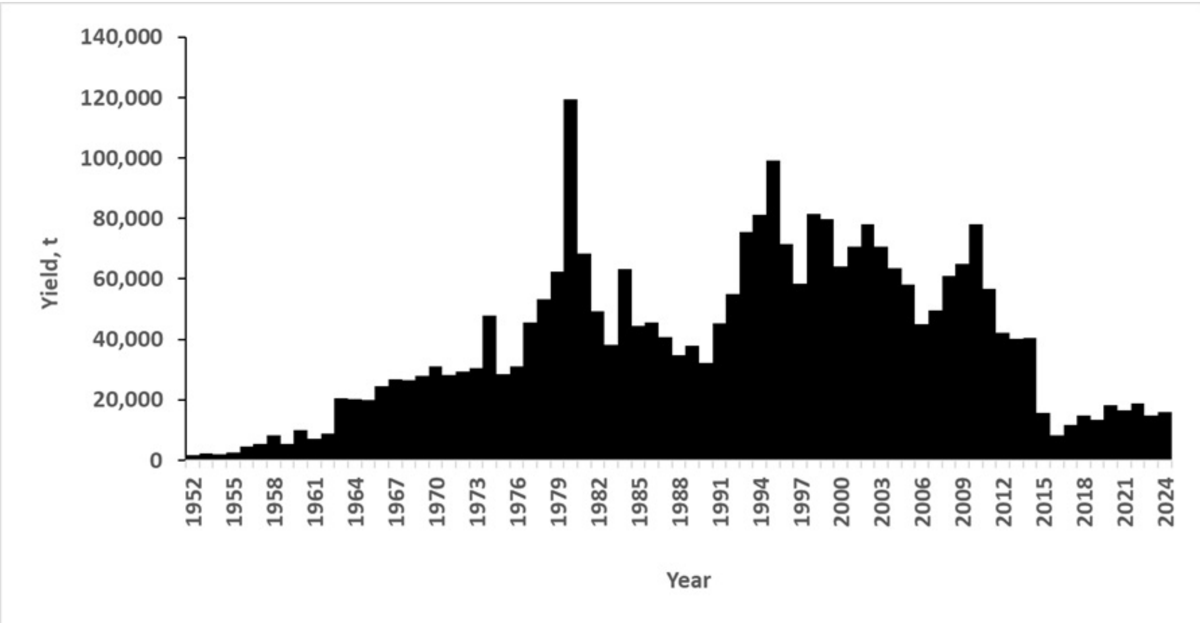

Figure 1: Landings of blood cockle of the NWCPM, from 1952 to 2024.

The problem of declining catch started with a mass mortality event that occurred in 2011. A specific research program was triggered to elucidate the potential factors that have caused the mass mortality event, but was only implemented in 2015 after funding was provided.

Research was focused on growth, mortality, spawning seasons, cockle's larvae density and distribution, phytoplankton density and distribution, pollution, diseases, seabed profiling and fisheries economics. Earlier findings indicated that in general, all the parameters were within the ranges of normal cockle culture, except ammonia was found to be high in areas nearby river mouths (Man and Siow, 2015). However, the high-content of ammonia brought by the river to the cockle's ground was quite temporal and spatial in nature. If ammonia is persistently high, not only cockle would not survive, other coastal fisheries species would also be affected, however, only cockle was affected. Based on the nature of rapid mass mortality of the cockle in 2011 followed by a prolonged low cockle production, a more permanent factors are more likely to be the causative factors. From a mass-balance ecosystem model (Ecopath), ccockles main food comprises of phytoplankton (MPB, 60%) and mangrove detritus (40%). An ecosystem simulation (Ecosim) on the removal of mangrove detritus resulted in forty percent reduction of the cockle's biomass (Alias, 2010). Similarly, proportional to the diet of the cockle, a prolong removal of the MPB could also reduce sixty percent of the biomass of the cockle.

As the low-landing of the cockle from NWCPM was never recovered after 2015, this paper reviewed the earlier works as well as exploring new potential factors that might have caused the mass mortality in 2011 as well as the catch reduction after 2015. Among the new most potential causative parameters studied were density, distribution, growth, mortality and carrying capacity of the cockles. This is in view of suspected change in the environment setting that could have caused the change in the carrying capacity.

Materials and Methods

Analysis of Catch, Revenue and Effort

Catch data from Annual Fisheries Statistics from 1985 to 2024 were analyzed (DOF, 1955-2024). The catch was from culture, and the efforts were in the form of cultured areas. These data were available online since 1985.

Analysis of Density and Distribution

Cockles thrive on the intertidal soft mud areas. The highest population densities of cockles are found on the soft intertidal muds bordering mangrove swamp forests (Pathansali 1966). Examination of the content of water samples from the benthic layer revealed that they contained large quantities of benthic diatoms and diatoms typically found in shallow coastal waters (Broom 1980). These diatoms, together with foraminiferans, are invariably found in the guts of *A. granosa* (Broom 1982a). In this study, a density-depth relationship was developed to see the density distribution as depth changes in the culture plots. Here density was expressed in term of weight (kg/km²) rather than numbers per unit area. Cockle's data from a monthly swept area method sampling in 2015 of Selangor's culture areas was analyzed.

Analysis of Growth and Mortality

Growth of cockle is subjected mainly to food availability and suitable habitat. There are two important parameters to describe a growth of a known aged fish in the von Bertalanffy Growth Function (VBGF), using FiSAT fisheries software. First is the maximum size of fish can grow (asymptotic length, $L\infty$), and second is the growth coefficient (k), which is the rate of growth. Mortality of cockle are caused by predation (natural mortality, M) and fishing (fishing mortality, F). Based on the age determined from the growth function, a catch-at-age in term on numbers was analyzed to obtain either M or F. To develop the growth and the mortality functions, data from a monthly swept area sampling in 2015 of Selangor's culture areas was analyzed.

Analysis of Carrying capacity

Carrying capacity (K) is described as the maximum weight or number of fish an environment can support, and it depends on the volume and factors like water quality, oxygen levels, and food availability. In the catch and effort fisheries dependent data, the carrying capacity is the coefficient (B_0) described as fish biomass before any fishing is occurred or virgin biomass. In the independent fisheries data, the carrying capacity is expressed as the coefficient in the mortality function. For a newly-recruited fish cohort, the carrying capacity is proportional to the numbers of fish at first captured. At both dependent and independent situation, before capture or harvest, natural mortality as a function of the ecosystem at equilibrium, played important roles in determining what carrying capacity that the environment able to offer to the fisheries, before the fishing (fishing mortality) starts.

In relation to cockle culture or farming in the wild, farmers will first stock the cockle seeds in their respective culture plot. Technically, the stocking density which is an age-based density, should commensurate with the carrying capacity of the cockle's stocking age in that area. Overstocking (over density) will results in mortality adjustment until density match with environment's carrying capacity. For the dependent data analysis, carrying capacity was analyzed using the catch and effort data from NWCPM from 1985 to 2024. In the independent data, carrying capacity was analyzed using the mortality function generated during the mortality assessment, where numbers at age were analyzed from a monthly swept area sampling in 2015.

Results and Discussion

Catch, Revenue and Effort

The catch of cockles cultured in the NWCPM increased from 44,500 tons in 1985 to 99,200 tons in 1995. The catch however was gradually declined to 78,000 tons in 2010, before drastically drop to only 8,300 tons in 2016. The low catch continues after that (**Figure 2**).

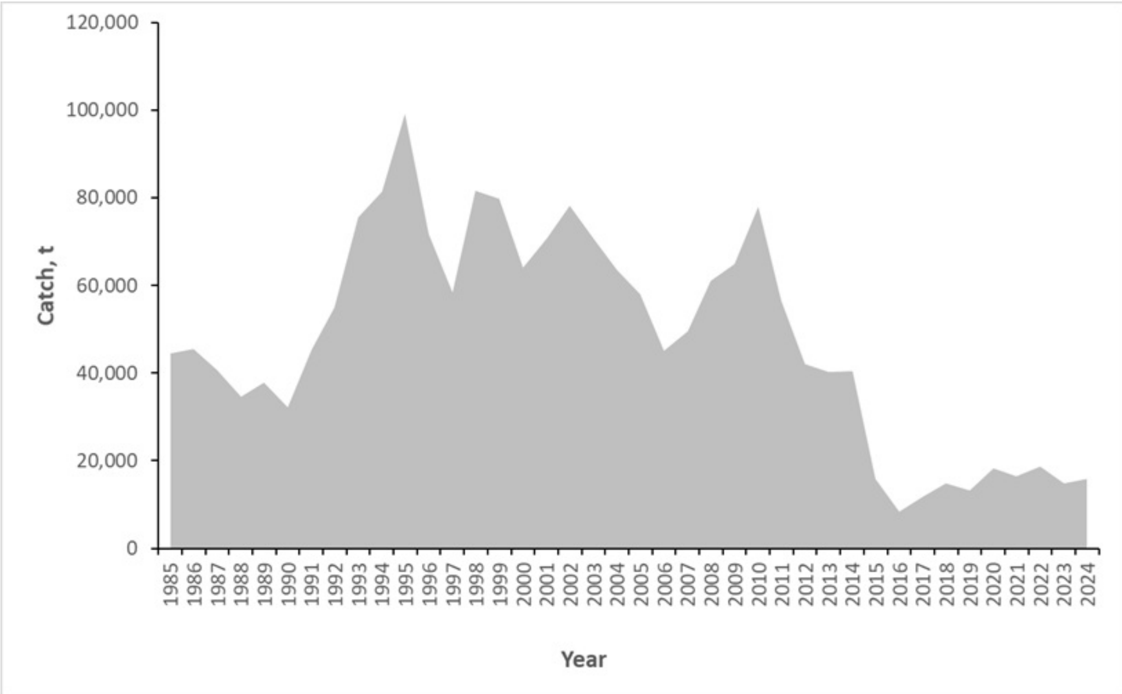

Figure 2: Catch (t) of cockles cultured in the NWCPM from 1985 to 2024.

In term of revenue, despite of low production, the cockle culture remains as a valuable venture. In term of value, the wholesale value of the cockle from the NWCPM gradually rose from RM15 million in 1985 to RM91 million in 2010 before dropped to RM16 million in 2016 due to the shortage supply of the cockle (**Figure 3**). In term of cockle's price, the price of cockle was less than a Ringgit before 2005. From 2006 to 2015, the price was between RM1.08 to RM2.45 respectively (**Figure 4**). After 2016, as the supply became short, the prices were linearly increased at a rate of fifty-three cents per year (**Figure 5**), from RM4.25 in 2016 to RM8.71 in 2024.

In early years of landings, cockle was classified as a third-grade fisheries species in term of price, but from 2016 onward, cockle was no longer a cheap protein source for the many, but an exclusive and highly priced fisheries species, similar to top grade fish species such as groupers.

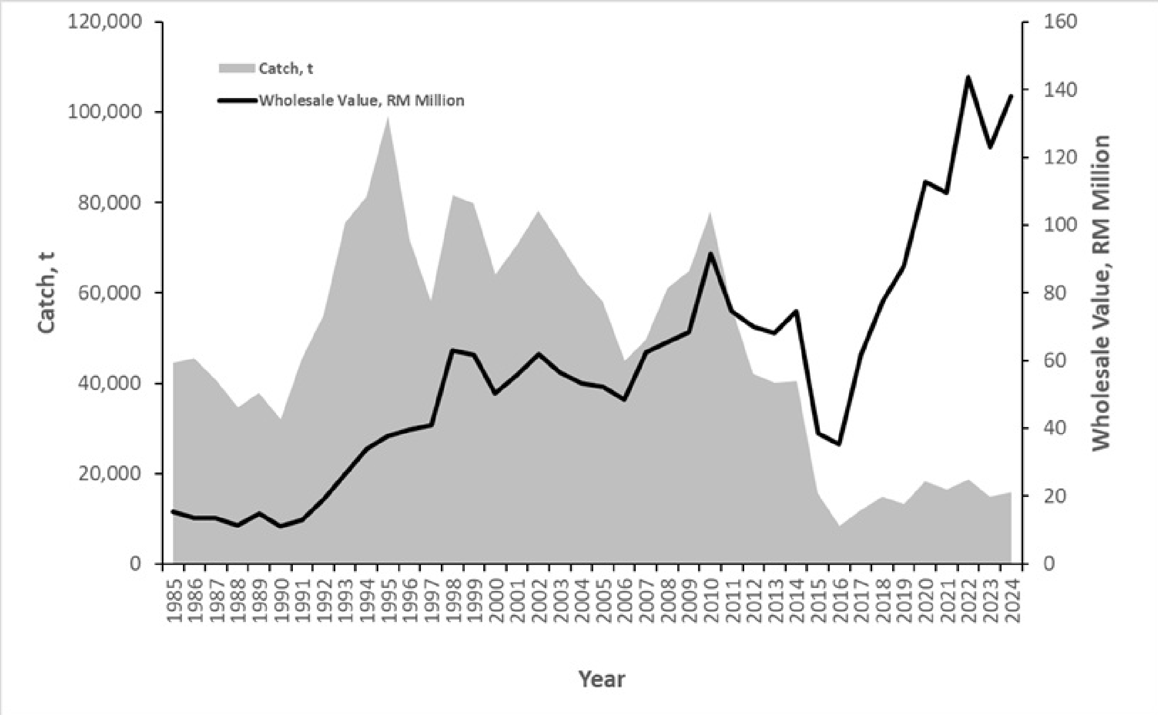

Figure 3: Cockle catch (t) from aquaculture and wholesale value (RM Million) of NWCPM from 1985 to 2024.

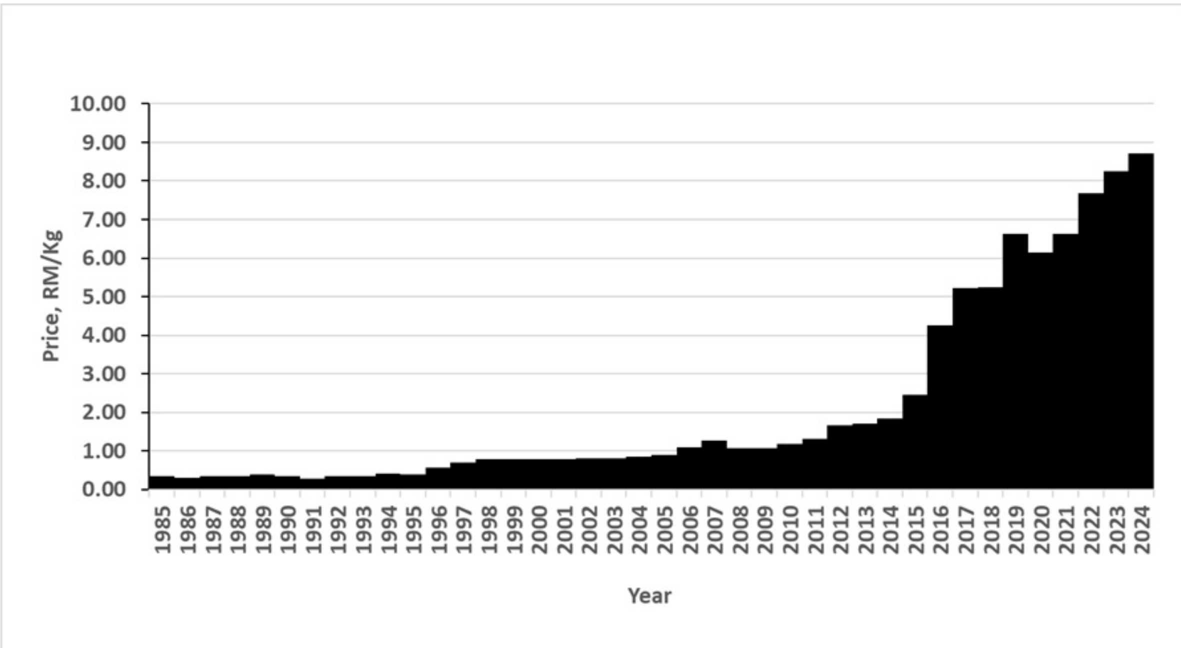

Figure 4: Price of cockle of the NWCPM, from 1985 to 2024.

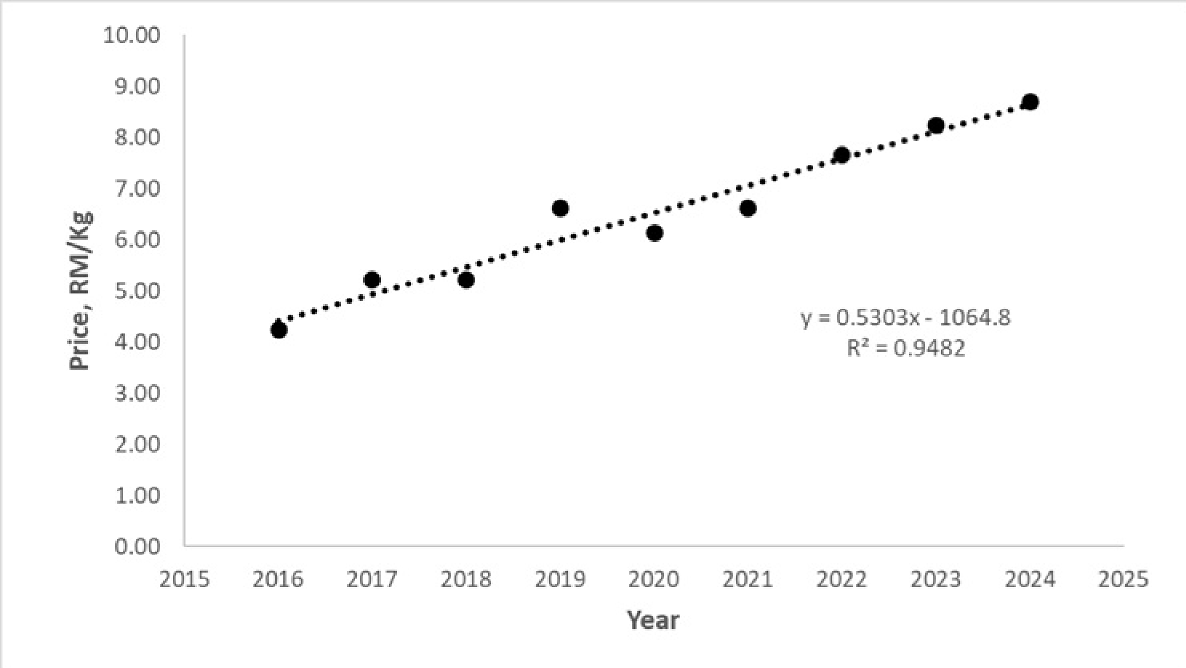

Figure 5: Trend of price increase of cockle of the NWCPM, from 2016 to 2024.

In term of cockle culture areas (effort) as first reported from aquaculture fisheries starting from 1985 (DOF, 1985), the cultured areas were gradually increased from 3,977 hectares in 1985 to 6,205 hectares in 2007, before a tremendous increase in culture areas to 9,355 hectares in 2008, largely by the extensive cockle culture in Selangor (**Figure 6**). The total cultured areas rose to the highest in 2012, where about 10,730 hectares have been reported (DOF, 2012). Due to a massive declining catch starting in 2011, the cultured areas were later reduced, beginning 2013. In 2024 the cultured areas were only 4,995 hectares left.

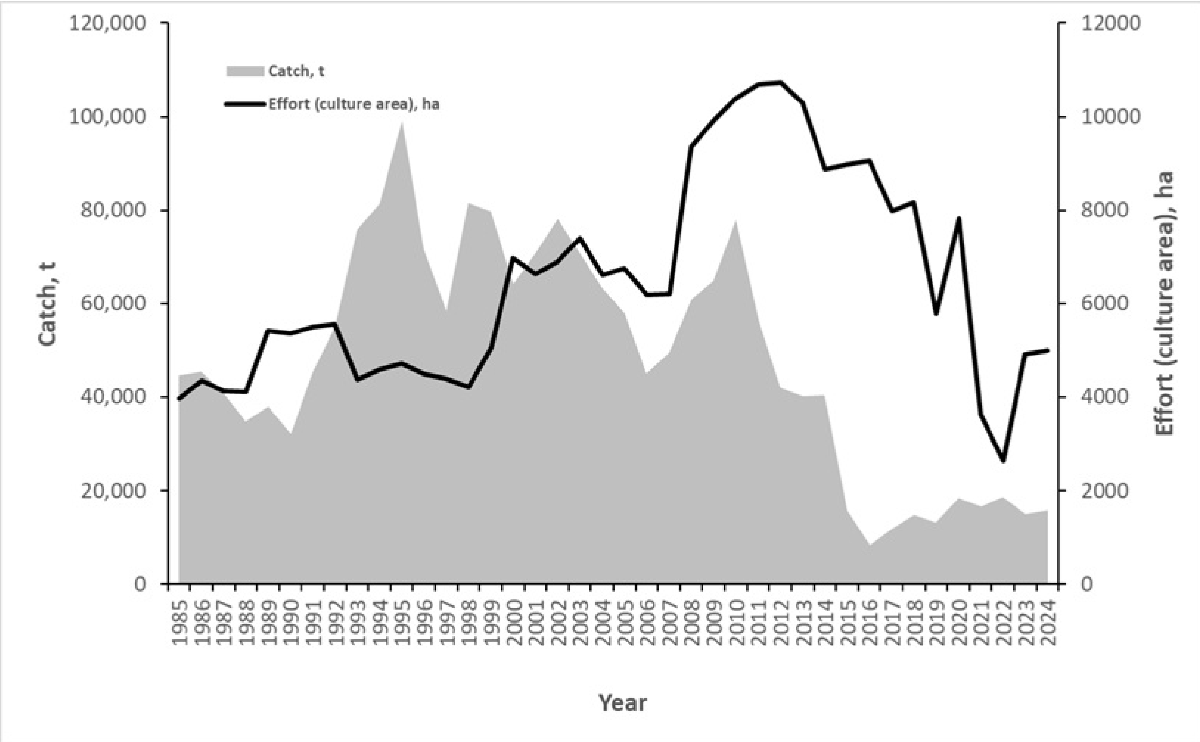

Figure 6: Catch (t) and Effort (culture area, ha) of NWCPM from 1985 to 2024.

Density-depth relationship

It was found that a strong density-depth bell-shaped model of normal relationship exists, where the maximum density lies at depth 1.25 meters. Based on the model, positive values of density ranges from 5 meters depth to 2.5 meters elevation (**Figure 7)**. The density-depth relationship indicated that the highest density of cockle was in the subtidal zones. The relationship also shows that cockle cannot grow at subtidal zones at depth more than 5 meters and at intertidal zones at elevation of more than 2.5 meters. Even though the sampling were done in the subtidal zones, this finding was not in contradiction with Pathansali (1966) and Broom (1982a) who studied cockle's population on the intertidal zones, discovered that cockle's highest densities were at the low elevation areas.

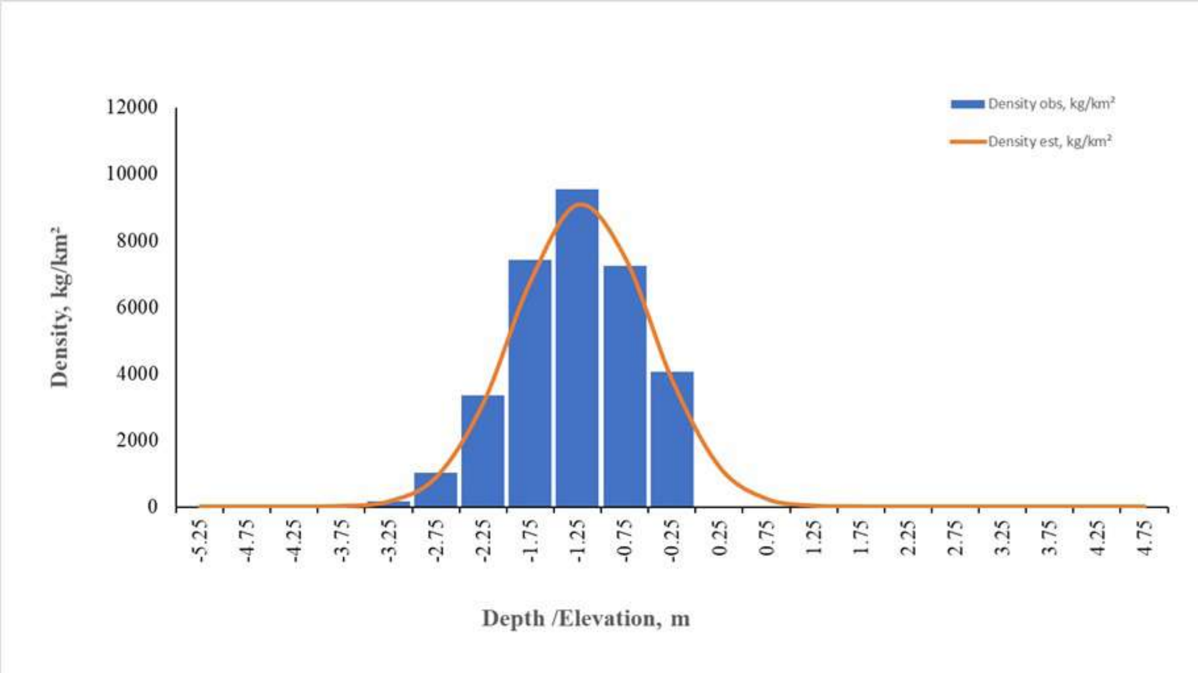

Figure 7: Depth-Density relationship for Selangor's cockle at culture plots.

Growth

Figure **8** shows the VBGF of the cockle cultured in Selangor. There were two obvious cohort per year, meaning that there were two main recruitment seasons per year for cockle in the NWCPM. Therefore, the growth function should be passing through yearly cohorts, connecting current cohort with previous year cohort of the same recruitment season. Before using FiSAT software for the estimation of VBGF, the length frequency data were first converted to Bhatacharrya's cohort discrimination. Using the restructuring frequency, the VBGF is plotted as shown in the figure.

Another new approach was using the maximum L∞ with high response surface score. Based on observations on the size of the cockle captured from the culture as compared to the wild, the size of cultured was much smaller than from the wild. The maximum size sampled from the culture ground of Selangor in 2015 was only 50mm, while the observed size of cockle from the wild attained the size of 70 mm. Based on the above approaches, the L∞ was estimated to be 78 mm, while the growth rate was estimated to 0.51 per year (**Figure 8**).

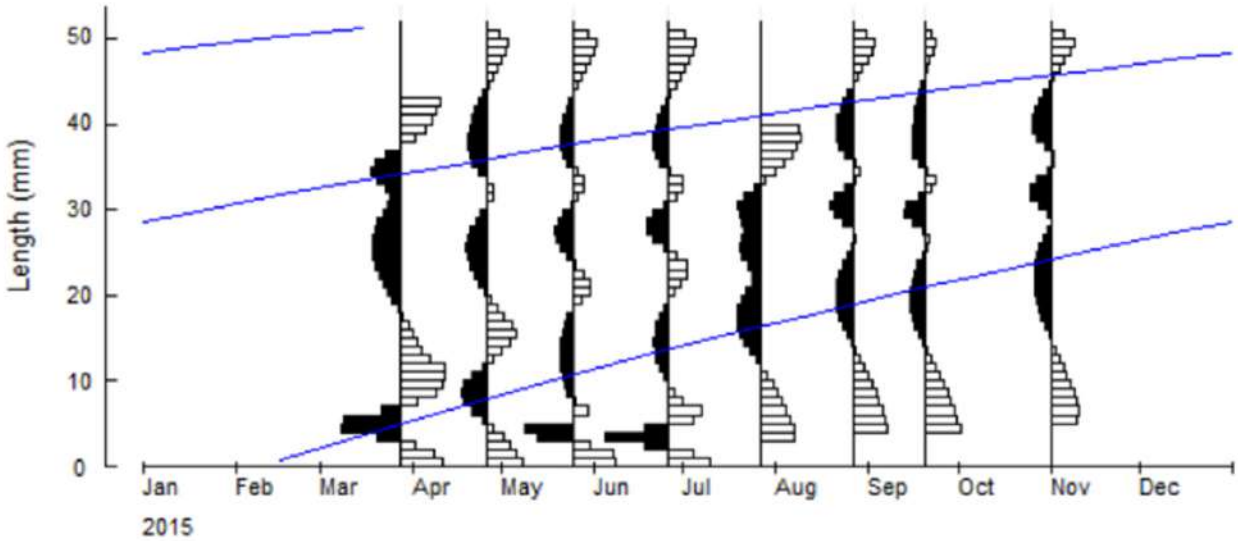

Figure 8: Estimated von Bertalanffy growth function (L∞=78mm, K= 0.51 y^{-1}).

Mortality

Mortality of cockle is mainly caused by predation (natural mortality, M) and harvest (fishing mortality, F). Table 1 below shows the estimated values of natural mortality, fishing mortality and carrying capacity for three different cohorts in the samples, from March to October, 2015. The newest cohort was recruited in February 2015 (201502), the previous six-month cohort was recruited in August, 2014 (201408), and the much older cohort was recruited in February, 2014 (201402). As newly recruited, the 2015 cohort has not reached the harvest size of 25mm, therefore mortality was only limited to predation. The natural mortality (M) was estimated to 3.18. Fishing mortality (F) for the August and February 2014 cohorts were estimated to 5.95 and 7.91 respectively.

Table 1: Cockle's mortality and carrying capacity by cohort

cohort	Z	Z	M	F	carrying capacity	t=9mth (25mm)
201502	M	3.17647	3.17647	0.00000	469184	13.05875121
201408	M+F	9.12301	3.17647	5.94654	1055085	13.86913168
201402	M+F	11.08166	3.17647	7.90519	40384993	17.51396881

Carrying Capacity

From Table 1, the carrying capacity (at the size of 25mm and at the age of 9-month-old) of 201502, 201408 and 201402 cohorts were estimated 469,184, 1,055,085 and 40,384,993 individuals respectively. This indicated that the carrying capacity has significantly dropped during the study period (**Figure 9**).

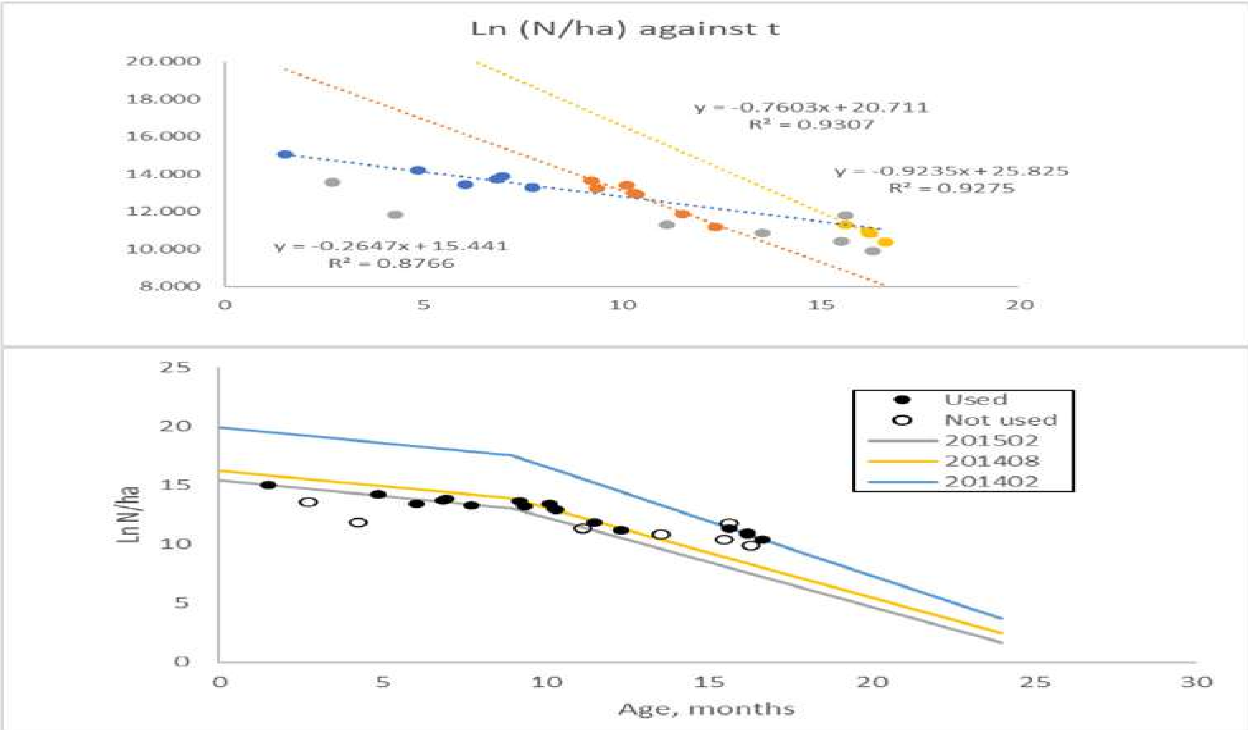

Figure 9: Declining carrying capacity as observed from cockle cohort's analysis.

The collapse of cockle fisheries in the NWCPM: what have caused it?

In order to identify the most causative factors, a matrix table of impacting and impacted factors was developed. The matrix was specifically focus on the problem of mass mortality and level of possibility that each factor could implicate (Table 2).

Table 2: Matrix of factors associated with the mass mortality and the collapse of the cockle fishery in the NWCPM

Impacting factors		**Impacted factors I**	**Impacted factors II**	**Mass Mortality of Cockles**	**Changes and Recovery**
Factors	**Scale and magnitude**	**Salinity and current speed**	**Habitat destruction and food supply disruption**		
Pollution	Low	No significant change in the salinity and current speed	No visible damage to the intertidal zones but the phytoplankton supply might have a small disruption	Less likely to have cause mass mortality of cockle	Gradually affected, but cockle fishery can be improved by eliminating the polluting elements
	High	No significant change in the salinity and current speed	No visible damage to the intertidal zones but might disrupt the phytoplankton supply	Many reports have claimed that cockle culture beds polluted by ammonia kills cockle, but not at the scale of mass mortality	Gradually affected, but cockle fishery can be improved by eliminating the polluting elements
Parasites	Low and High	No changes	Not affected	Cockles might die due to parasites, but not at a scale of mass mortality	Gradually affected, but cockle fishery can be improved by eliminating the parasites
Salinity from Rain	Normal	No significant change in the salinity and current speed	No visible damage to the intertidal zones and the phytoplankton supply is also not disrupted	No mass mortality of cockle is expected	No change in the fishery
	Heavy and prolong rain during full/ new moon, creating large volume of rain water during flood tides	Significantly lower the salinity	No visible damage to the intertidal zones, growth of some phytoplankton species might be affected, but low-salinity species might thrive	No mass mortality of cockle is expected	Small-temporary disruption in the growth of the cockles due to food supply disruptions
		Increased current speed during ebb tides, especially in the mangrove estuaries	Erosion of the fine mud at the intertidal zones by strong tidal current especially at riverbanks, causing the phytoplankton and mangrove detritus washed away	Significant destruction of cockle's habitat and prolong reduction in food supply could cause high cockle mortality in mangrove estuaries	The mortality disruption is temporary and the fishery will resume after rainy season over

Coastal erosion by climate changes	Gradual but slow	Gradual change in the salinity and current speed at all places in the straits, causing coastal erosions	Gradual changes to the intertidal zones due to erosion and the phytoplankton supply is also gradually disrupted	Reduced carrying capacity, but no mass mortality of cockle is expected	Slow and permanent loss of the fishery
Coastal reclamations	Gradual or rapid	Gradual or rapid loss of intertidal zones	Gradual or rapid loss of the cockle habitat due to loss of intertidal zones. Cockles can no longer be cultured here	No mass mortality of cockle is expected as no cockle is cultured	Complete or partial loss of aquaculture and fishing activities and access to fish landing sites (DID, 1997)
Coastal erosion by sand mining	Sustainable amount of sand removal, replaced over times	No significant change in the salinity and current speed at all places in the straits	No visible damage to the intertidal zones and the phytoplankton supply is also not disrupted	No mass mortality of cockle is expected	No disruption in the growth of the cockles
	Enormous amount of sand removal in short period of times, replaced by large amount of sea water	No changes in the salinity, but abrupt increased in the tidal current speed at the northern part of the straits and strong waves	Erosion of the fine mud at the intertidal zones by strong tidal current and waves, causing the microphytobenthos and mangrove detritus washed away	Sudden habitat destruction and reduction in food supply could cause mass mortality, while prolong habitat destruction and reduction in food supply could reduce the carrying capacity in the long run	Rapid and permanent loss of the fishery. Destruction of aquatic ecosystems and adverse effects on aquaculture systems (DID, 1997)

Fish density and catch are subjected to carrying capacity and exploitation rate. Carrying capacity is determined largely by food availability and habitat suitability, subjected to environmental setting such as tidal current and waves. Increase in exploitation beyond the optimum level (over-exploitation), would results in declining catch. Fishing at the optimum level would produce the maximum yield (Maximum Sustainable Yield, MSY).

In the carrying capacity issue, tidal current and waves change either naturally, humanly, or both. When the tidal current and waves increase beyond certain magnitude, both cockle food (MPB) and habitat (soft-mud) will easily be washed away. This species of MPB is easily resuspended during mid-ebb tide (Broom, 1982a) and by a strong tidal current and waves (Cahoon and Safi, 2002). If this change stays, a new environmental setting is established, and cockle will not thrive, similar to the sandy coast in the East

Coast of Peninsular Malaysia, where environment with strong tidal current and waves is not suitable for cockle as well as other mangrove species.

A reduction in carrying capacity indicated that the cockle's preferred habitat has deteriorated, and the cockle could no longer thrive in this new environment. The abrupt deterioration of the cockle's habitat could be associated with climate changes and coastal development. Depending on the scale and duration of development, coastal development can cause abrupt high-impact on the sensitive fisheries habitat as compared to the climate changes, which is more gradual and low-impact in nature. It was observed that the reduction in cockle's carrying capacity was of abrupt type rather than gradual. From the matrix table (Table 2), offshore sand mining has been identified as the most potential cause for the abrupt coastal erosion, and the cockle's carrying capacity reduction.

The coastal erosion whether of abrupt or gradual, can be determined by analyzing satellite images. Sand mining activities and the magnitude of sand harvested is difficult to be assessed from satellite image. However, its associated coastal land reclamations can be monitored from satellites. **Figure 10** showed the rapid coastal erosion at cockle's bed in Selangor, and **Figure 11** showed huge coastal reclamation in Malacca. Both coastal erosion and sand mining occurred about the same time with the 2011 mass mortality of cockle, followed with the collapsed of the fishery.

Figure 10: Coastal erosion at cockle's beds in Selangor, where mangrove has been uprooted (2015) as soft mud washed away, and a muddy coast ecosystem (2009) is replaced by a sandy beach ecosystem (2022).

Figure 11: Coastal reclamation in Malacca, from sea sand mining in the Straits of Malacca (2012 to 2024). No reclamation was observed in 2004.

In view of the increasing incidences of coastal erosion and increasing pace of development in the coastal zone, the National Coastal Erosion Council (NCEC) has requested the government to formulate erosion control guidelines for development projects in the coastal zone. In 1997, Department of Irrigation and Drainage (DID) has come out with a guideline to control the coastal erosion in the country (DID Malaysia, 1997). The guideline "Guidelines on Erosion Control for Development Projects in the Coastal Zone" was aimed at ensuring the proper planning and sustainable development of the coastal zone. The Guidelines described in detail the data requirements and the scope of impact evaluation for the various types of development activities in the coastal zone namely shorefront development, backshore development, land reclamation and offshore sand mining and river mouth dredging.

For the offshore sand mining, the Guidelines described that the offshore sand mining activities change the bathymetry of the seabed, which can alter beach dynamics, waves and swell patterns, as well as coastal current circulation, which may lead to erosion or sedimentation. Mining activities can influence the coastal processes through erosion of beaches from drawdown due to the backfilling of the dredge pit during calm period, interception of sediment movement by the dredged pit, which results in sand depletion onshore or downdrift, removal of protection afforded by offshore banks, which leads to bigger waves impinging on the coast, changes in the waves refraction pattern, which concentrates waves energy at a particular place; and destruction of aquatic ecosystems and adverse effects on aquaculture systems.

Coastal land reclamation development activities based on offshore sand mining have been rampant in the straits nowadays. While the reclamation has its own environmental impacts but limited to the nearby ecosystems, the offshore sand mining could impact a much wider ecosystem. Deepening the existing narrow-shallow parts of the straits in the SWCPM would alter the hydrology processes in the entire straits. The One-Fathom Banks (OFB), which is a large sand barrier at the center of the straits that separates the NWCPM from the SCWPM, together with the narrow part of the straits, forming a bottle-neck serving as a flood gate that slowing down the current and waves from the Bay of Bengal. Therefore, the shallower and narrower Straits of Malacca (SOM) together with the OFB since the ice age, played important roles in keeping the NWCPM waters calm, and establishing the muddy estuarine coastal ecosystem, the most productive fisheries ecosystem. The mangrove rich ecosystem of NWCPM have supplied more than 70 percent of the landed fish to the whole country since the fisheries statistics started recording in 1952. Altering the coastal processes in the NWCPM would risk the food security of the country.

Conclusions

The renewed analysis on the growth discovered a bigger asymptotic length (L∞) of the cockle, which is 78 mm. This was fifty percent higher than the previous size which are around 50 mm. However, the rate of growth and total mortality were about the same as before. Analysis on the catch and effort data of the cultured cockle, revealed that the catch per unit effort (CPUE) were highly varied for the same effort levels. This indicated that the environmental conditions were not at equilibrium or at changing phase, resulting in a changing in the carrying capacity as the environment changes. A matrix of cause-and-effect model factors was developed to determine potential factors that have caused the mass mortality and the prolong catch reduction of the cockle. Coastal erosion was identified as the potential factors that have eroded the important intertidal cockle habitat as well as their food supply. Apart from climate change that gradually changed the current speed and the waves energy at the intertidal zones, enormous and rapid sand mining in the straits was identified as the most contributing factors that aggravated further the destruction of the cockle beds.

Recommendations

The future of the cockle fishery depends on:

a) how our cockle beds ecosystem adjusted to the new physical hydrodynamics of the straits as the results of the sand mining.
b) how we protect the important fisheries habitats, especially mangrove ecosystem, shallow subtidal and intertidal zones (by managing the flow of the straits, such that any sand mining would not alter the flow in any way)

As precautionary approach, in order to protect the critical fisheries habitat in the NWCPM, the sand mining in the SOM that damage the cockle beds needs to be stop until evidences prove otherwise.

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Presentation 3

Biodiversity As Seen from Environmental DNA: A Sungai Merbok Case Study

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Abstract: The Sungai Merbok Estuary in Kedah, Malaysia, is a vital, ecologically sensitive tropical mangrove ecosystem that supports significant commercial aquaculture of fish and oysters. Understanding the microbial community structure, particularly the phytoplankton, is essential for sustainable management and mitigating threats like Harmful Algal Blooms (HABs). This study employs a high-resolution Environmental DNA (eDNA) metabarcoding approach targeting the 18S rRNA region to establish a molecular baseline of phytoplankton biodiversity along a 4 km stretch of the river. The primary objectives were to: (1) comprehensively inventory the diatom and dinoflagellate communities inhabiting the estuary; and (2) specifically identify the presence and relative abundance of known HAB-forming species potentially toxic to human health (Shellfish Poisoning) or aquaculture stock. Monthly water samples were collected from November 2021 to December 2024. Following eDNA extraction, high-throughput sequencing of the 18S marker was performed. The analysis successfully revealed a rich and dynamic community profile, with numerous diatom and dinoflagellate taxa identified. Crucially, the metabarcoding approach provided sensitive molecular detection of multiple genera associated with HABs, including *Blixaea quinquecornis*, *Margalefidinium fulvescens*, and several species of the toxic genus *Alexandrium* sp. the causative agents of Paralytic Shellfish Poisoning (PSP). This research demonstrates the efficacy of 18S eDNA metabarcoding as a rapid, high-resolution tool for ecological monitoring in complex tropical estuaries. The resulting comprehensive species inventory and the early molecular detection of key harmful species provide an essential biodiversity baseline for the effective management and conservation of this valuable mangrove-associated aquaculture region.

Keywords: Sg. Merbok, e-DNA, Harmful algae, metabarcoding, rRNA

Abstrak: Muara Sungai Merbok, Kedah, Malaysia merupakan ekosistem paya bakau tropika yang penting dan sensitif dari segi ekologi, serta menyokong aktiviti akuakultur komersial yang signifikan melibatkan ikan dan tiram. Pemahaman terhadap struktur komuniti mikrob, khususnya fitoplankton, adalah penting bagi pengurusan lestari serta mitigasi ancaman ledakan alga berbahaya (Harmful Algal Blooms, HAB). Kajian ini menggunakan pendekatan metabarkod DNA persekitaran (eDNA) beresolusi tinggi yang mensasarkan rantau 18S rRNA bagi mewujudkan garis dasar molekul kepelbagaian biodiversiti fitoplankton sepanjang 4 km kawasan sungai tersebut. Objektif utama kajian adalah untuk: (1) menjalankan inventori komprehensif komuniti diatom dan dinoflagelat yang mendiami muara; dan (2) mengenal pasti secara khusus kehadiran serta kelimpahan relatif spesies pembentuk HAB yang diketahui berpotensi toksik kepada kesihatan manusia (Keracunan Kerang) atau stok akuakultur. Persampelan air bulanan telah dijalankan dari November 2021 hingga Disember 2024. Selepas pengekstrakan eDNA, penjujukan berkapasiti tinggi penanda 18S telah dilaksanakan. Analisis berjaya mendedahkan profil komuniti yang kaya dan dinamik, dengan pelbagai taksa diatom dan dinoflagelat dikenal pasti. Pendekatan metabarkod ini turut membolehkan pengesanan molekul secara sensitif terhadap beberapa genus yang dikaitkan dengan HAB, termasuk *Blixaea quinquecornis*, *Margalefidinium fulvescens*, serta beberapa spesies daripada genus toksik *Alexandrium* sp., yang merupakan agen penyebab Keracunan Kerang Paralitik (Paralytic Shellfish Poisoning, PSP). Kajian ini menunjukkan keberkesanan metabarkod eDNA berasaskan penanda 18S sebagai alat pemantauan ekologi yang pantas dan beresolusi tinggi dalam ekosistem muara tropika yang kompleks. Inventori spesies yang komprehensif serta pengesanan awal molekul terhadap spesies berbahaya utama menyediakan garis dasar biodiversiti yang penting bagi pengurusan dan pemuliharaan berkesan kawasan akuakultur yang berkaitan dengan ekosistem paya bakau yang bernilai ini.

Introduction

Comprehensive biodiversity assessment is fundamental for understanding ecosystem structure, function, and resilience, particularly in complex tropical estuarine and mangrove systems. Biodiversity monitoring in these ecosystems remains a significant challenge due to the complexity of species assemblages, the presence of cryptic taxa, and the limitations of conventional survey methods. Traditional approaches, such as morphological identification, trawling, netting, and benthic surveys, are labour-intensive, expensive, and often intrusive or destructive to the habitats they aim to protect Munian et al., 2024). Moreover, these methods typically struggle to detect rare, cryptic, or early life-stage organisms, and may fail to capture the full spectrum of biodiversity (Wang et al., 2024), especially in ecosystems with high species richness such as mangrove estuaries. These limitations hinder comprehensive ecological assessments and reduce the effectiveness of conservation planning, highlighting the need for integrative and sensitive approaches capable of capturing biodiversity across multiple trophic levels.

Sungai Merbok in Kedah, Malaysia, represents one of the region's most ecologically significant mangrove-associated estuarine systems. Characterized by extensive mangrove forests and diverse aquatic habitats, the estuary provides essential ecosystem services including coastline protection, nutrient cycling, and nursery, feeding, and spawning grounds for a wide array of aquatic organisms (Alongi, 2008; Nagelkerken et al., 2008). These natural functions directly support the socioeconomic livelihoods of local communities through aquaculture activities involving oysters, seabass, and groupers. Despite its status as a permanent forest reserve and recognition as a global hotspot for mangrove species richness, the estuary faces increasing anthropogenic pressures such as eutrophication, sedimentation, pollution, aquaculture expansion, and overfishing, all of which threaten its ecological integrity.

The primary challenge in managing this megadiverse ecosystem lies in the limitations of traditional biodiversity assessment. In particular, microscopic organisms such as phytoplankton are difficult to monitor using conventional methods, yet they play critical roles in primary productivity, nutrient cycling, and higher trophic dynamics. Certain phytoplankton taxa can also form harmful algal blooms (HABs), posing risks to aquaculture sustainability and food safety (Anderson et al., 2021; Zin et al., 2020). Similarly, invertebrate communities, which underpin estuarine food webs, are often underrepresented in conventional surveys. Consequently, there is an urgent need for advanced molecular monitoring tools to augment previous checklists and establish a robust, high-resolution biodiversity baseline.

To address these challenges, environmental DNA (eDNA) metabarcoding has emerged as a powerful, non-invasive molecular approach for ecosystem-wide biodiversity assessment (Munian et al., 2024). By integrating DNA barcoding with high-throughput sequencing of genetic material shed into the environment, this technique enables the simultaneous detection of multiple taxonomic groups from a single water sample. In this study, phytoplankton communities were assessed using the nuclear small subunit ribosomal RNA gene (18S rRNA, targeting the V4 and V9 hypervariable regions) and the ITS region for diatoms and dinoflagellates, while invertebrate biodiversity was characterized using the mitochondrial cytochrome c oxidase subunit I (COI) gene and 12S rRNA marker. The combined use of these markers enhances taxonomic resolution and facilitates a more comprehensive biodiversity profile than traditional methods allow.

Within this context, the present study seeks to establish a robust molecular baseline for the Sungai Merbok estuary. The primary objectives are: (i) to inventory the complex biological communities within the estuary, ranging from phytoplankton and invertebrates to fish assemblages, thereby creating a comprehensive molecular database; and (ii) to evaluate the efficacy of eDNA markers in providing holistic biodiversity profiles, detecting HAB-forming taxa, and identifying species of conservation importance along the estuarine gradient. By embedding these objectives into a modern methodological framework, this research highlights the potential of eDNA metabarcoding to advance biodiversity monitoring in tropical mangrove estuaries. Ultimately, the findings contribute to a deeper ecological understanding and the development of evidence-based conservation strategies for this vital tropical ecosystem.

Materials and Methods

Study Area

The study was conducted in the Sungai Merbok Estuary, Kedah, a tropical mangrove system spanning approximately 30 km. To ensure a comprehensive assessment, the Sampling stations (**Figure 1**) were distributed along the estuarine gradient to capture spatial variation in community composition associated with salinity, nutrient availability, and anthropogenic pressures. The estuary, part of the Sungai Merbok Mangrove Forest Reserve, encompasses approximately 40,000 ha of mangrove habitat and provides critical ecological services such as nursery grounds for fish, coastline stabilization, and support for local fisheries. Field sampling was carried out during the dry season, specifically in February 2018 for fish and through a multi-year monthly monitoring program from 2021 to 2024 for phytoplankton.

Field Sampling and eDNA Filtration

At each of the predetermined sampling sites, water was collected during high tide to maximize the capture of both resident and transient species. One-liter surface water samples were collected from the bow of the boat using sterile bottles to prevent contamination. To ensure the integrity of the environmental DNA, all equipment,

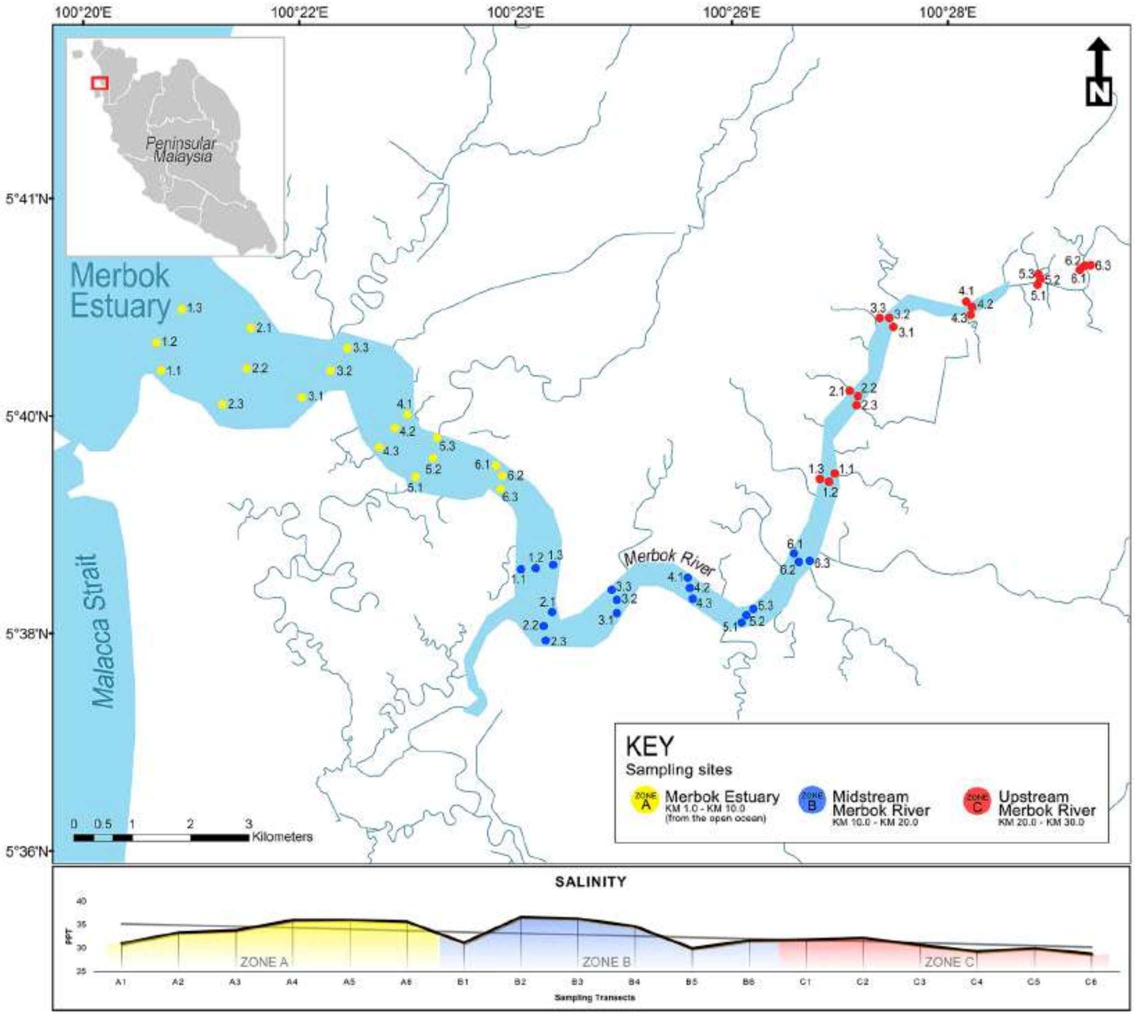

Figure 1: The sampling localities along Sungai Merbok with reference of salinity readings

including bottles and funnels, was sterilized with a 10% bleach solution and rinsed with distilled water between sites. For the phytoplankton study, water was filtered immediately or within hours using membrane filter 0.20µm (Membra-flo®, Johnson), while the fish study utilized Sterivex-GV filter units with a 0.22 µm membrane. Filters were then preserved in lysis buffer and stored at low temperatures (-20°C to -80°C) until laboratory extraction.

DNA Extraction and PCR Amplification

DNA extraction was performed using the DNeasy Blood and Tissue Kit for the invertebrates' samples and Power Water kit for the phytoplankton (both from Giagen, Germany), following modified protocols to maximize DNA yield. To target multiple taxonomic groups, distinct primer sets were employed: the cytochrome c oxidase subunit I (COI) gene for a wide range of bony fish, and the internal transcribed spacer (ITS) region for phytoplankton, particularly diatoms and dinoflagellates including harmful algal bloom (HAB) species.

Sequencing and Bioinformatics

The libraries were prepared via a two-step PCR process, the amplicons were pooled, purified, and sequenced on the Illumina MiSeq platform. The resulting raw sequences underwent a rigorous bioinformatics pipeline, including quality filtering, chimera removal, and clustering into Amplicon Sequence Variants (ASVs) or Molecular Operational Taxonomic Units (MOTUs). Taxonomic assignment was conducted by matching these sequences against curated global databases like GenBank and local reference libraries to identify species presence and abundance.

Data Availability

The sequencing data generated in this study will be deposited in a public repository (e.g., NCBI Sequence Read Archive) upon acceptance of the manuscript. Accession numbers will be provided in the final published version. Additional data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

This study was conducted using environmental water samples only and did not involve the capture, handling, or experimentation on live organisms. As such, no specific ethical approval was required. All sampling and laboratory procedures were carried out in accordance with relevant institutional guidelines and regulations.

Results and Discussion

The application of eDNA metabarcoding in the Sungai Merbok Estuary successfully captured a high-resolution snapshot of the ecosystem's biodiversity, revealing a far more complex community structure—including cryptic and low-abundance taxa—than previously documented through conventional morphological surveys (Munian et al., 2024; Stat et al., 2017). Collectively, the 12S and COI markers detected 178 fish species from 127 genera and 68 families (**Figure 2**), marking a 40% increase in species richness compared to traditional capture records from the last decade. The most speciose orders identified were Perciformes, Carangiformes, and Gobiiformes, which align with the dominant taxa expected in tropical mangrove environments. Notably, the high sensitivity of the eDNA assays allowed for the detection of threatened species of high conservation importance, such as the Endangered blacktail reef shark (*Carcharhinus amblyrhynchos*) and the Near Threatened blacktip reef shark (*Carcharhinus melanopterus*), neither of which had been recorded in the study area through previous traditional surveys.

The spatial analysis of these communities revealed that fish diversity is not homogenous along the estuarine gradient. Higher species richness and diversity indices were estimated in the midstream and upstream zones, particularly in Zone B, which is characterized by pristine mangrove cover and lower anthropogenic disturbance. While the study successfully identified numerous estuarine residents and marine-dependent species, it also detected “exogenous” DNA from stenohaline freshwater taxa, such as cyprinids and channids, as well as coral reef endemic species. These findings suggest that water movements, tidal currents, and downstream flow can transport genetic material from adjacent habitats into the estuary, a factor that must be considered when interpreting localized diversity patterns (Harison et al., 2019).

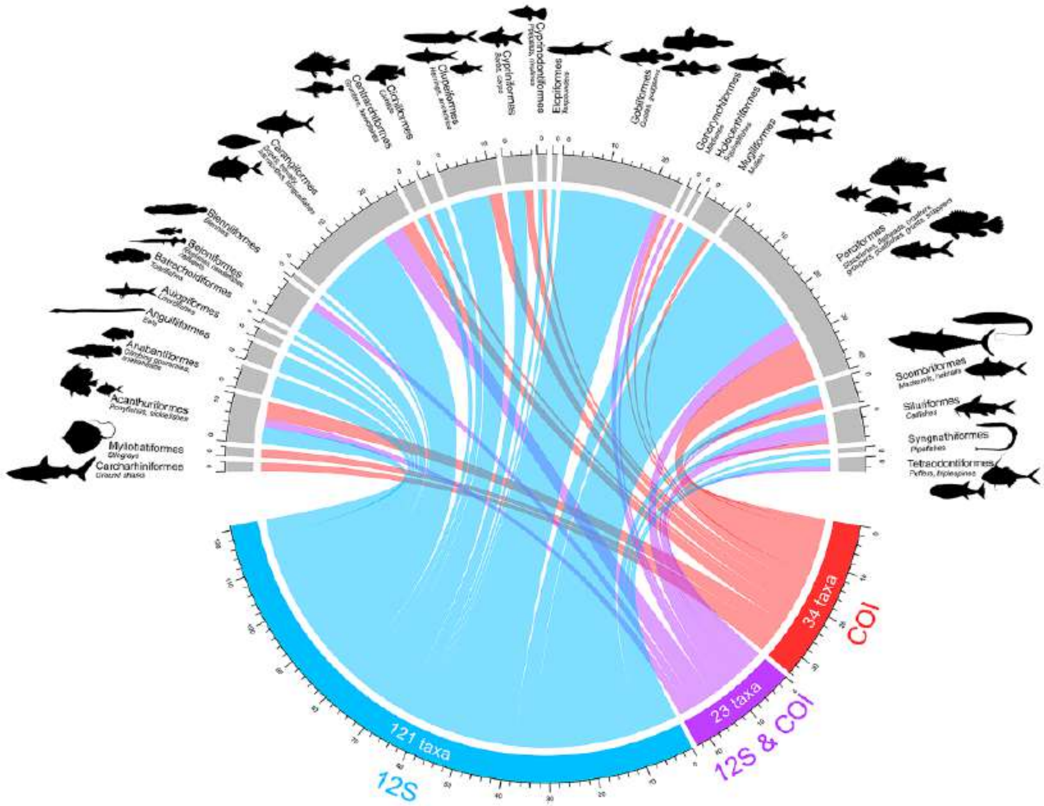

Figure 2: *Circlize* plot showing assays being mapped to the 25 orders detected by eDNA metabarcoding.

At the foundation of the food web, the 18S rRNA eDNA metabarcoding provided a robust molecular baseline for the phytoplankton community. The study identified a rich and dynamic system with over 80 genera, where spatial variation was clearly defined by salinity and nutrient gradients; diatoms showed higher abundance upstream, while dinoflagellate presence increased toward the downstream zones. Crucially, the 18S marker demonstrated superior sensitivity as an early-warning tool by detecting low-abundance Harmful Algal Bloom (HAB) taxa, including *Alexandrium spp.* and *Margalefidinium fulvescens*, which were entirely missed by microscopic analysis. These results underscore the management implications of the JIRCAS–FRI partnership, demonstrating that eDNA metabarcoding can support sustainable aquaculture and food safety by enabling the early detection of ecological threats before they reach critical thresholds.

The results demonstrate that eDNA metabarcoding can effectively capture spatial biodiversity patterns and detect ecologically important taxa in Sungai Merbok. The detection of HAB-related phytoplankton and diverse invertebrate assemblages highlights the potential application of this approach for routine ecosystem monitoring, early warning systems, and aquaculture management (Tuttle et al., 2021; Pawlowski et al., 2018). In line with previous studies from Sungai Merbok, this study reinforces the value of eDNA metabarcoding as a non-invasive, cost-effective tool for biodiversity surveillance in tropical estuaries. However, eDNA signals should be interpreted with caution due to potential DNA transport and incomplete reference databases. Integrating molecular data with environmental parameters and conventional surveys will further enhance the reliability and applicability of this approach for long-term management and conservation.

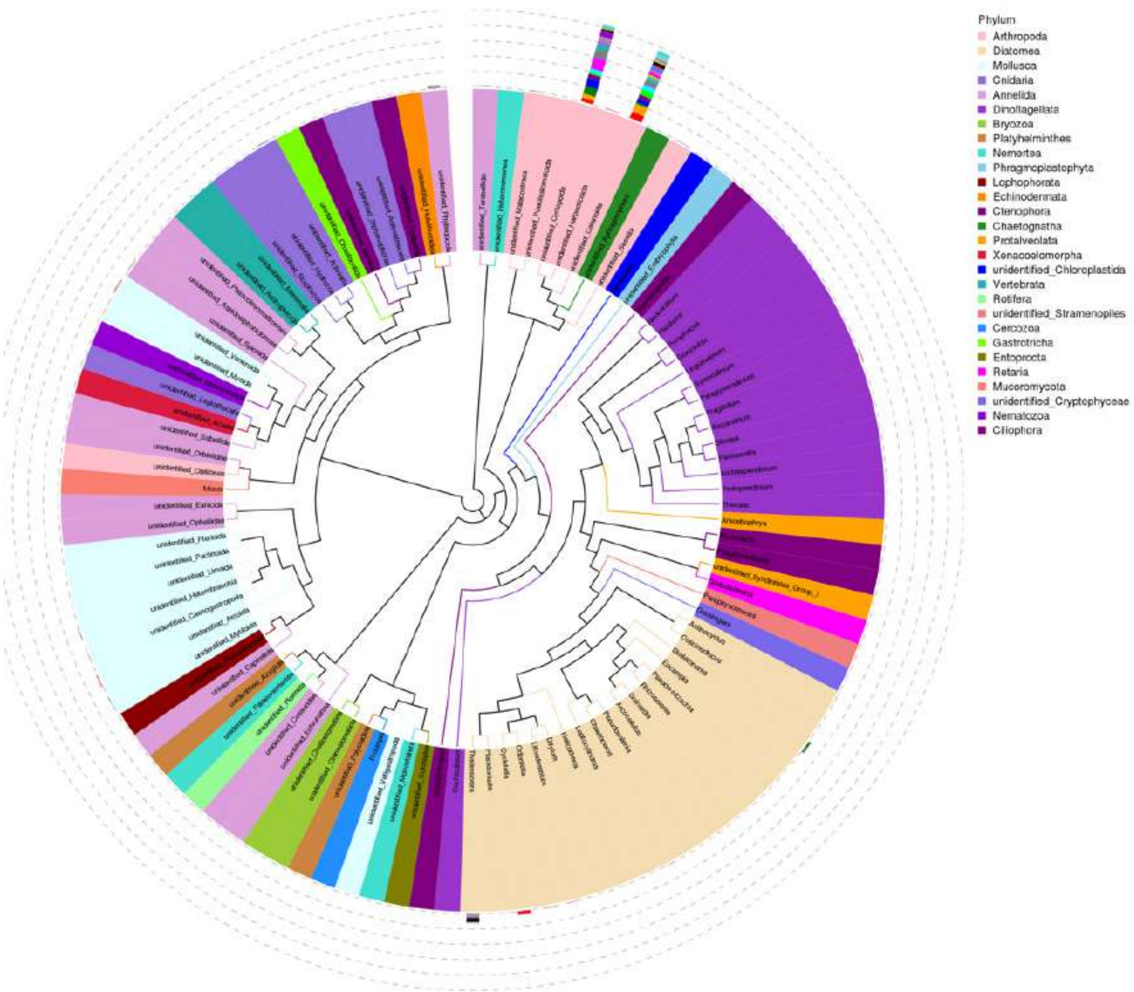

Figure 3: Phylogenetic relationships of 100 representative genera derived from 18S V4 sequence analysis. Distinct colours denote the 28 identified phyla, emphasizing the high taxonomic resolution achieved at the genus level. Key target groups, including diatoms and dinoflagellates, are labelled to show their relative distribution across the eukaryotic tree of life.

Conclusions

Overall, this study demonstrates that integrated eDNA metabarcoding using 18S rRNA and COI markers provides a robust and holistic assessment of phytoplankton and invertebrate biodiversity in the Sungai Merbok estuary. The findings establish a valuable molecular baseline for future monitoring and support the use of eDNA as a complementary tool for ecosystem-based management in tropical estuarine environments.

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SESSION 2

Presentation 4

Site Selection and Seasonal Adaptation in Bivalve Aquaculture: Lessons from Two Research Collaborative Projects in Malaysia

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Abstract: This study reviews two phases of joint research on bivalve aquaculture conducted by JIRCAS and the Fisheries Research Institute Malaysia (FRI), in which the author participated as a JIRCAS researcher from FY2010 to 2025. Phase I (FY2011–2015) focused on blood cockle (*Tegillarca granosa*) farming along the Selangor coast. Field observations suggested that mass mortality events were associated with freshwater inflow during heavy rainfall, resulting in low salinity and elevated inorganic nitrogen levels. These findings led to practical measures, including the development of a simple morphology-based growth index for site assessment and a resource recovery program implemented by the Department of Fisheries and FRI. Phase II (FY2021–2025) shifted to tropical oyster (*Magallana* spp.) cultivation in the Merbok Estuary. Seasonal monitoring revealed that dry-season conditions favoured growth, whereas rainy-season freshwater inflow reduced salinity and dissolved oxygen, causing stress and limiting feeding activity. Technical innovations included IoT-based environmental monitoring and the development of upwelling systems to enhance young oyster growth. A common conclusion across both phases was the critical role of adaptive management, emphasising site selection and risk mitigation. Given the strong influence of seasonal fluctuations on bivalve growth and survival, real-time monitoring and flexible site selection are essential for sustainable production. Looking ahead, as Malaysia's seafood demand is projected to rise with economic growth, this adaptive approach will contribute to food security, strengthen coastal livelihoods, and improve aquaculture resilience under climate variability.

Keywords: Bivalve aquaculture, Site selection, Seasonal variation, IoT-based monitoring, Sustainable production

Abstrak: Kajian ini mengulas dua fasa penyelidikan bersama mengenai akuakultur kerang-kerangan yang dijalankan oleh JIRCAS dan Institut Penyelidikan Perikanan Malaysia (FRI), di mana penulis terlibat sebagai penyelidik JIRCAS dari FY2010 hingga 2025. Fasa I (FY2011–2015) memberi tumpuan kepada penternakan kerang darah (*Tegillarca granosa*) di sepanjang pantai Selangor. Pemerhatian lapangan menunjukkan bahawa kejadian kematian besar-besaran berkait rapat dengan aliran air tawar semasa hujan lebat, yang menyebabkan penurunan kemasinan dan peningkatan tahap nitrogen tak organik. Penemuan ini membawa kepada langkah praktikal, termasuk pembangunan indeks pertumbuhan berasaskan morfologi untuk penilaian tapak dan program pemulihan sumber yang dilaksanakan oleh Jabatan Perikanan dan FRI. Fasa II (FY2021–2025) beralih kepada penternakan tiram tropika (*Magallana* spp.) di Muara Merbok. Pemantauan bermusim menunjukkan bahawa keadaan musim kering menggalakkan pertumbuhan, manakala aliran air tawar semasa musim hujan mengurangkan kemasinan dan oksigen terlarut, menyebabkan tekanan dan mengehadkan aktiviti pemakanan. Inovasi teknikal termasuk pemantauan alam sekitar berasaskan IoT dan pembangunan sistem upwelling untuk meningkatkan pertumbuhan tiram muda. Kesimpulan umum daripada kedua-dua fasa ialah peranan penting pengurusan adaptif, dengan penekanan kepada pemilihan tapak dan pengurangan risiko. Memandangkan pengaruh besar turun naik bermusim terhadap pertumbuhan dan kelangsungan hidup kerang-kerangan, pemantauan masa nyata dan pemilihan tapak yang fleksibel adalah penting untuk pengeluaran yang lestari. Melangkah ke hadapan, apabila permintaan makanan laut Malaysia dijangka meningkat selaras dengan pertumbuhan ekonomi, pendekatan adaptif ini akan menyumbang kepada keselamatan makanan, mengukuhkan mata pencarian pesisir, dan meningkatkan daya tahan akuakultur di bawah variabiliti iklim.

Introduction

Bivalve aquaculture plays a vital role in providing sustainable sources of high-quality protein in tropical coastal regions (Willer and Aldridge, 2020). However, its success is strongly influenced by natural environmental conditions, making it highly vulnerable to seasonal fluctuations between dry and rainy periods (Hamli et al., 2019; Yurimoto et al., 2024a). These seasonal changes affect key water quality parameters such as salinity, dissolved oxygen, and food availability, which in turn impact growth rates, survival, reproduction, and overall productivity of farmed species (Saffian et al., 2020; Yurimoto et al., 2024a, b; 2025c, f). In Malaysia, where bivalve farming is concentrated along estuarine and coastal mudflats with phytoplankton rich, the challenges posed by monsoonal rainfall and riverine runoff are particularly significant (Amiruddin et al., 2011; Chor et al., 2022; Yurimoto et al., 2014; 2021b; 2024a). Heavy rainfall events can lead to sudden drops in salinity and introduce organic matter and pollutants from around peatlands, creating stressful conditions for bivalves (Ramli et al. 2013; Ramli et al. 2014; Shimoda et al., 2016; 2020; Alam et al., 2025). Conversely, the dry season often provides stable and favourable conditions for growth in the estuary area, highlighting the need for adaptive management strategies that account for these cyclical variations (Teoh et al., 2016; Hamli et al., 2019; Yurimoto et al., 2025a, f).

This paper reviews these challenges through a two-phase approach: (1) investigating the causes of production instability in blood cockle farming and developing practical tools for farmers (Yurimoto et al., 2014; Teoh et al., 2016; Shimoda et al., 2016; 2020; Saito and Teoh, 2020; Saito et al., 2023), and (2) introducing technological innovations such as IoT-based monitoring and improved nursery systems for tropical oyster farming (Nasir and Mumtazah, 2020; Yurimoto et al., 2025c, d, e). Additionally, this study emphasizes the critical role of site selection and environmental monitoring in developing a robust framework for resilient and sustainable bivalve aquaculture (Yurimoto et al., 2025a). Such a framework is intended to address Malaysia's increasing demand for seafood while enhancing regional food security within the ASEAN context (Willer and Aldridge, 2020).

Phase I: Blood Cockle Farming (FY2011–2015)

The first phase of the research focused on blood cockle (*Tegillarca granosa*) farming along the Selangor coast, which had historically been one of Malaysia's most productive aquaculture zones (Saffian et al., 2020; Yurimoto, 2020). This region's extensive mangrove mudflats provided ideal conditions for cockle growth, but the farming system was highly sensitive to environmental fluctuations (**Figure 1**). One of the major challenges identified during this period was the impact of heavy rainfall events associated with the monsoon season (Amiruddin et al., 2011; Yurimoto et al., 2014). The inflow of freshwater from rivers can cause a rapid decrease in salinity, which may trigger spawning in blood cockles, while at the same time creating conditions that are unfavourable for feeding and survival (Pahri et al., 2016; Yurimoto et al., 2021a; 2024b) In 2012, a severe mass mortality event occurred, drawing attention to the vulnerability of the farming system (Yurimoto et al., 2014). Subsequent investigations indicated that these mortality events were not solely attributable to salinity fluctuations. River runoff was suggested to transport peat-derived inorganic nitrogen compounds etc., which contributed to physiological stress in cockles (Ramli et al., 2013; 2014; Teoh et al., 2016; Shimoda et al., 2016; 2020). In addition to water quality issues, long-term coastal erosion was found on the Selangor coasts, reducing the extent of suitable mudflat areas for farming (Ahmad et al., 2021). This shrinkage of habitat further constrained production and increased competition for viable farming plots (Mohamat-Yusuff et al., 2021). To address these challenges, practical solutions were developed. Saito *et al*. introduced a simple physiological condition index that allowed farmers to assess cockle health without breaking shells, enabling on-site monitoring and better management decisions (Saito & Teoh, 2020; Saito et al., 2023). Moreover, the Fisheries Research Institute (FRI) has implemented a stock recovery program aimed at restoring production capacity through measures such as farm restructuring, identification of spat habitats, and the promotion of spawning (Harith et al., 2016; Harith, 2023; Saffian et al., 2020). These efforts marked an important step toward adaptive management strategies for blood cockle aquaculture in Malaysia. Additionally, what all these have in common is the importance of selecting aquaculture grounds.

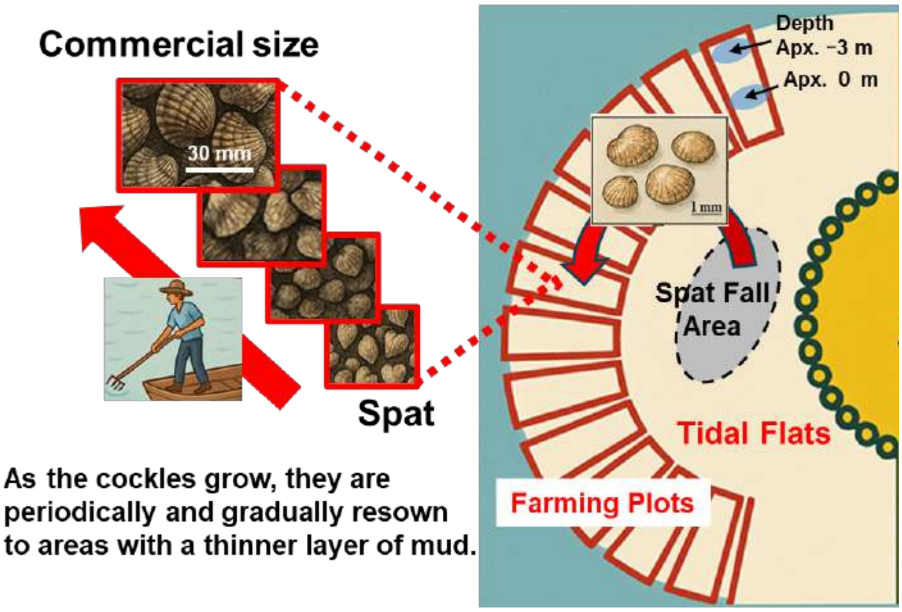

Figure 1: Schematic diagram of the farming process of the blood cockle (*Tegillarca granosa*). After the initial spat settles in the tidal flat area called the 'Spat Fall Area,' they are collected by farmers and transplanted to designated farming plots. To improve growth efficiency, the clams are gradually relocated to areas with thinner sediments according to their growth stage. Several relocations may occur until they reach commercial size. The illustration materials were generated using Copilot.

Phase II: Tropical Oyster Farming (FY2021–2025)

The second phase of the research shifted focus from blood cockles to tropical oysters (*Magallana* spp.), targeting the Merbok estuary in north-western Peninsular Malaysia. This region was selected because of its brackish water environment, which provides favourable conditions for oyster farming (Fatema et al., 2014). However, similar to cockle farming, oyster aquaculture in tropical estuaries is highly sensitive to seasonal changes driven by monsoonal rainfall (Yurimoto et al., 2024a; 2025b). To address these challenges, several technological innovations were introduced. An IoT-based monitoring system was adapted to continuously track key environmental parameters such as water temperature (**Figure 2**). This system allowed real-time observation of environmental fluctuations and provided farmers with actionable data to anticipate stress conditions (Yurimoto et al., 2025c). In addition, an intermediate nursery system was designed to improve the survival and growth of juvenile oysters. By simplifying the upwelling tank structure and optimizing feeding conditions, this system enhanced early-stage growth (**Figure 3**; Yurimoto et al., 2025d, e). On the other hand, seasonal monitoring revealed a clear pattern: the dry season offered stable salinity and oxygen levels, resulting in favourable growth conditions and high feeding activity (Fatema et al., 2014; Yurimoto et al., 2025f). In contrast, the rainy season brought significant freshwater inflow, causing sharp declines in salinity and dissolved oxygen. These changes led to reduced feeding activity and weight loss in oysters, suggesting physiological stress (Yurimoto et al., 2025c, f). Further insights were obtained through vertical water quality monitoring at Merbok. Farmers traditionally suspend oysters about one meter deep in baskets, based on experience, and our data confirmed that this depth is optimal for growth under normal conditions (Yurimoto et al., 2025c). However, seasonal monitoring showed that environmental conditions at this depth vary dramatically between dry and rainy seasons. During the dry season, high salinity and good oxygen levels create a favourable environment for oyster growth. Conversely, the rainy season introduces low salinity and oxygen levels, resulting in stress and poor feeding activity (Fatema et al., 2014; Yurimoto et al., 2025f). Salinity horizontal distribution surveyed by FRI revealed that upstream sites, which are productive during the dry season, become unsuitable during the rainy season (Masazurah et al., unpublished data). Although some farmers already rotate farming sites informally, the research emphasises the need for systematic site-selection methods and predictive tools to scale up production effectively (**Figure 4**). The implications of these findings are critical for aquaculture management. Optimal farming areas in the Merbok estuary shift depending on the season, meaning that a static farming strategy cannot ensure stable production. Adaptive management that integrates environmental monitoring and site rotation is essential for sustainable oyster farming and for meeting Malaysia's growing demand for high-quality seafood (Yurimoto et al., 2025f).

Figure 2: Installation overview of various IoT devices and the internet homepage screen that records them. (a) Weather meter, (b) weather camera, (c) water temperature buoy (arrow), and (d) home page screen displaying live data (Yurimoto et al., 2025c).

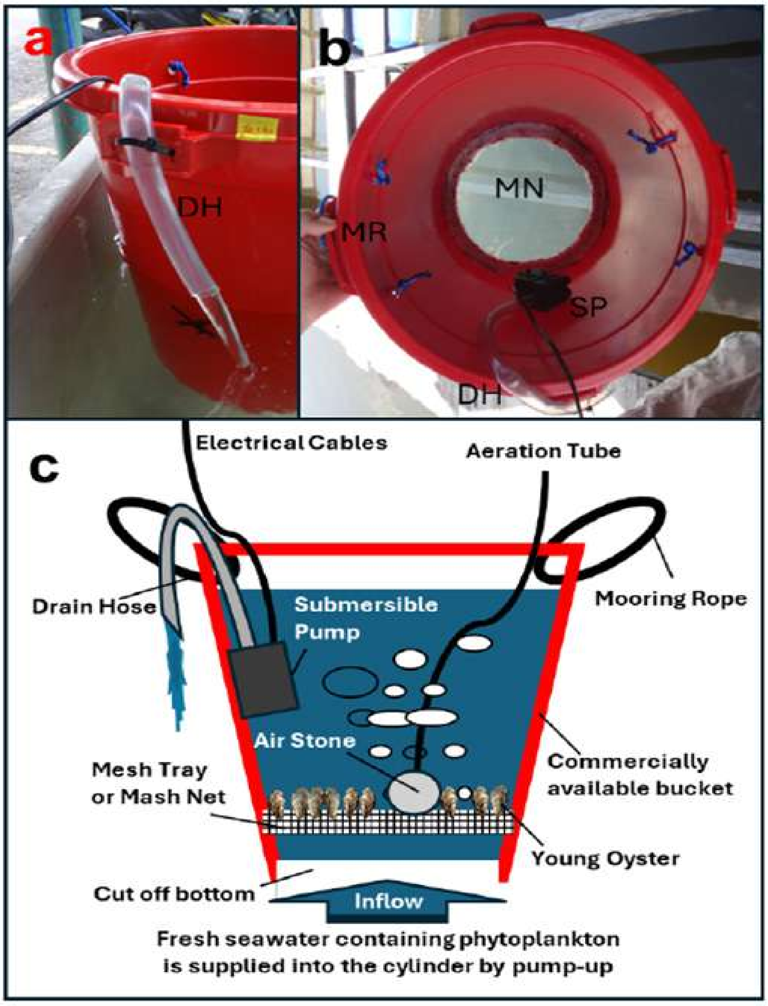

Figure 3: Cylindrical component of the nursery upweller device, fabricated using commercially available materials, and its schematic diagram. (a) Exterior of the cylindrical unit; (b) Interior view; (c) Schematic diagram. Abbreviations: DH – drainage hose; MN – mesh net; MR –mooring rope; SP – submersible pump. A forced-flow nursery upweller device, named the "JF30-upweller," was developed to commemorate 30 years of collaboration between JIRCAS and FRI (Yurimoto et al., 2025e).

Key Findings Across Both Phases

The findings from both research phases underscore several critical factors for advancing sustainable bivalve aquaculture in Malaysia. Foremost, site selection emerged as a decisive element in determining growth performance and survival. Selecting farming locations that align with species-specific requirements and maintain environmental stability is essential for optimising production outcomes. Equally important, water quality strongly influences bivalve health and productivity. Sudden fluctuations in salinity, dissolved oxygen, and food availability—often associated with monsoonal rainfall and riverine runoff—can induce physiological stress, reduce feeding activity, and, in severe cases, lead to mass mortality events. Seasonal variability further compounds these challenges. While dry seasons generally provide favourable conditions for growth, caused by Nutrient supply and phytoplankton stable occurring in the estuary area. Rainy seasons introduce environmental instability that necessitates adaptive management strategies. Ultimately, long-term sustainability depends on integrating site selection with systematic environmental monitoring and flexible farming practices, such as site rotation and predictive tools. These measures are vital for mitigating risks, enhancing resilience, and supporting the continued development of Malaysia's bivalve aquaculture industry.

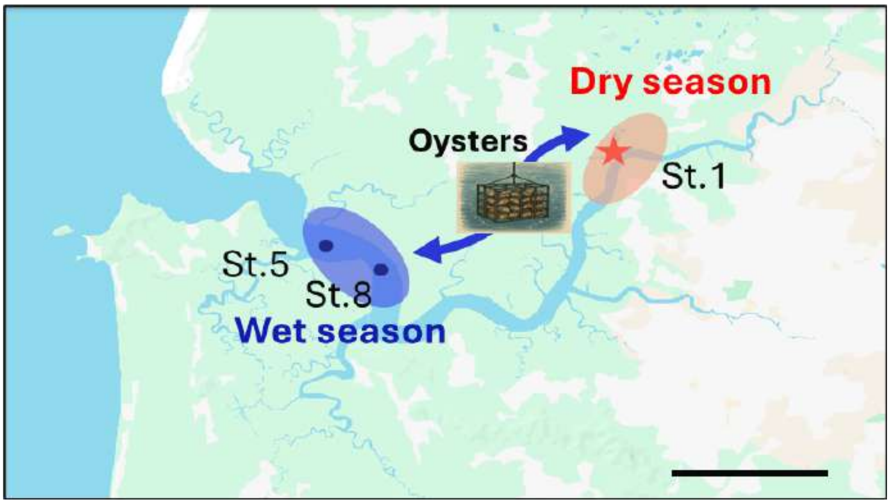

Figure 4: Schematic diagram showing seasonal changes in fishing ground use. During the dry season, aquaculture is conducted in the upstream area (around St.1: red star), while in the wet season, it shifts to the downstream area (St.5 and St.8). Arrows indicate the movement of oyster cages. The station number means for FRI's regular environmental monitoring sites. The map was obtained from Google Earth (https://earth.google.com). This figure was arranged the Fig. 8 in Yurimoto et al., 2025f. Scale bar: 5 km.

Future Prospects

The two research phases highlight key priorities for sustainable bivalve aquaculture in Malaysia. First, site selection is fundamental for optimising growth and survival, requiring alignment with species-specific needs and environmental stability (Chor et al., 2022; Bandira et al., 2021). Second, water quality strongly influences bivalve health. Sudden changes in salinity, oxygen, and nutrients—often driven by monsoonal rainfall and riverine runoff—can trigger stress, reduce feeding, and cause mortality (Yurimoto et al., 2014; 2024a; FAO, 2025). Third, seasonal variability between dry and rainy periods shapes farming outcomes. Dry seasons generally offer favourable conditions in estuary areas, while rainy seasons require adaptive strategies (Willer and Aldridge, 2020; Yurimoto et al., 2025f; FAO, 2025). To ensure resilience, systematic monitoring and flexible farming practices—such as site rotation and predictive tools—are essential (McKindsey, 2013; Alleway et al., 2025). These measures will mitigate risks, enhance productivity, and support long-term industry development.

Conclusion

Sustainable bivalve aquaculture in Malaysia depends on three pillars: careful site selection, seasonally adaptive farming, and continuous environmental monitoring (Chor et al., 2022; Bandira et al., 2021). Phase I revealed that blood cockle farming in Selangor was highly vulnerable to freshwater inflow and peat-derived compounds, causing mass mortality and production instability (Ramli et al., 2013; 2014; Yurimoto et al., 2014; Pahri et al., 2016; Teoh et al., 2016; Shimoda et al., 2016; 2020). Additionally, coastal erosion further reduced suitable mudflat areas (Ahmad et al., 2021). Practical solutions included a non-invasive condition index and resource recovery programs (Saito and Teoh, 2020; Saito et al., 2023; Saffian et al., 2020). Phase II focused on tropical oysters in the Merbok estuary, where dry-season conditions supported growth, while rainy-season freshwater inflow led to low salinity and oxygen, causing stress and poor feeding (Fatema et al., 2014; Yurimoto et al., 2025c, f). IoT-based monitoring and improved nursery systems enhanced early warning and juvenile survival (Yurimoto et al., 2025c, d, e). Vertical profiling confirmed the importance of depth management and systematic site rotation (Yurimoto et al., 2025c, f). Despite these advances, challenges remain. Seasonal patterns were captured, but interannual variability and climate extremes require further study (FAO, 2017). Future research should expand monitoring networks, develop predictive models, and assess economic feasibility and adoption. Integrating science with policy and farmer practices will be critical for building a climate-resilient aquaculture sector (Willer and Aldridge, 2020; FAO, 2017; FAO, 2025). Addressing these gaps will help Malaysia secure food supply, support coastal livelihoods, and maintain competitiveness under changing environmental conditions.

Acknowledgements

This research was made possible through the strong collaboration between JIRCAS and the FRI of Malaysia. We gratefully acknowledge the invaluable support and contributions of our colleagues throughout both phases of the project. For Phase I: Blood Cockle Farming Research Project (FY2011–2015), we extend our sincere appreciation to Dr. Alias Man (counterpart), Dr. Shahunthala Devi, Mr. Ibrahim Johari, and Dr. Wan Norhana Noordin, whose expertise and dedication were instrumental in advancing the research on blood cockle aquaculture. For Phase II: Tropical Oyster Farming Research Project (FY2021–2025), we are deeply thankful to Ms. Masazurah A. Rahim (counterpart), Ms. Roziawati Mohd Razali, Dr. Hadzley Harith, and Dr. Mohd Nor Azman Ayub for their outstanding efforts in developing innovative approaches for tropical oyster farming and environmental monitoring. Additionally, we would like to express our gratitude to Mr. Faizul Mhd Kassim, who supported our research as an assistant for two phases. In addition, we acknowledge the Department of Fisheries Malaysia for their continuous support and cooperation, which enabled the successful implementation of field studies and technology transfer. Finally, the content presented here was adapted from "*Presentation 4: Bivalve farming research in Malaysia (2010–2025): The importance of choosing aquaculture sites*", delivered at the JIRCAS-FRI 30 Years Anniversary Symposium (FRI Penang, 20 Nov. 2025), and edited for inclusion in these proceedings.

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Presentation 5

Coastal oceanographic and environmental studies associated with Malaysia cockle industry. A case study on Malaysia's recovery of cockle resources and the resulting stakeholder benefits

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Abstract: This study examines the decline and subsequent recovery of the Malaysian blood cockle (*Tegillarca granosa*) industry, focusing on the impact of coastal oceanographic and environmental factors. National blood cockle landings plummeted from 78,024.70 Mt in 2010 to 9,596.44 Mt in 2016, prompting urgent research. Investigations in Lekir Bay and other culture areas revealed that sporadic physical, industrial, and plantation activities likely contributed to the decline. To address these challenges, three key technologies were developed and implemented starting in 2017: Mass Blood Cockle Induced Spawning Technology, Blood Cockle Precise Farming Technology, and Technology for Blood Cockle Farm Management for Higher Productivity. These interventions initially led to a rebound in landings, reaching 20,516.37 metric tonnes (Mt) in 2020 and 21,144.97 Mt in 2022. However, a subsequent decline to 15,147.30 Mt in 2023 and 12,240.88 Mt in 2024 was observed, attributed to a shift in farmer interest towards the more lucrative cockle seed trading market. Despite this diversion, cockle seed landings significantly increased, from 20.97 Mt in 2018 to 3,154.24 Mt in 2024. Furthermore, monitoring a 21 Hectare of Cockle farm in Lekir demonstrated substantial improvements in productivity per hectare, rising from 3.74 Mt/Ha in 2021 to 13.96 Mt/Ha in 2025. The results indicate that, with the developed technologies, Malaysia possesses the capacity for sustainable management of its cockle resources.

Keywords: Blood Cockle (*Tegillarca granosa*), sustainable sockle resources.

Abstrak: Kajian terhadap kejatuhan dan kenaikan pendaratan kerang negara telah dijalankan dengan tumpuan utama kepada kesan sekitaran dan pengaruh oseanografi pantai terhadap aktiviti ternakan kerang. Pendaratan kerang negara telah jatuh dari 78,024.70 tan metrik (Mt) pada tahun 2010 ke 9,596.44 Mt pada tahun 2016 memberikan isyarat akan keperluan segera untuk menangani masalah ini. Dapatan kajian di Teluk Lekir telah mendapatkan kejutah fizikal boleh digunakan sebagai mekanisma untuk pembenihan aruhan kerang secara besar-besaran. Bagi mendukung cabaran yang dihadapi, sebanyak 3 teknologi telah dibangunkan meliputi, teknologi pembenihan aruhan kerang secara besar-besaran di lapangan, teknologi kejituan ladang kerang, teknologi pengurusan ladang kerang berproduktiviti tinggi. Pelaksanaan 3 teknologi ini bermula tahun 2017 telah memberikan impak ketara terhadap pendaratan kerang negara sehingga mencatatkan pendaratan sebanyak 20,516.37 Mt pada tahun 2020 dan 21,144.97 Mt pada tahun 2022. Namun kelihatan penurunan pendaratan kerang dewasa pada tahun

2023 dengan catatan 15,147.30 Mt dan 12,240.88 Mt pada tahun 2024 akibat penumpuan lebih kepada aktiviti perniagaan benih kerang. Data pendaratan benih kerang dicatat telah meningkat dari 20.97 Mt pada tahun 2018 ke 3,154.24 Mt pada tahun 2024. Manakala produktiviti kebun kerang Lekir telah meningkat dari 3.74 Mt/Ha pada tahun 2021 kepada 13.96 Mt/Ha pada tahun 2025. Dapatan mencadangkan pembangunan dan pelaksanaan 3 teknologi ini telah memberikan impak yang ketara kepada industri dan pengurusan sumber kerang.

Introduction

Study on coastal oceanographic processes have been conducted at several selected sites in Malaysia particularly to explore the coastal oceanographic processes associated with blood cockle (*Tegillarca granosa*) recruitment techniques (Harith, et al., 2013, Harith, et al., 2015, Harith, et al., 2016, Harith, et al., 2017, Harith, 2018, Harith, et al., 2020; Harith, et al., 2021, Harith, et al., 2023). The studies were designed to understand on how coastal oceanographic processes may be used to promote cockle resources at selected sites to examines the decline and subsequent recovery of the Malaysian blood cockle industry. National blood cockle landings plummeted from 78,024.70 metric tonnes (Mt) in 2010 to 9,596.44 Mt in 2016, prompting urgent research. Three technologies have been developed i.e., mass blood cockle induce spawning, cockle precise farming and farm management for higher productivity technology. The mass blood cockle induced-spawning technology consist of three models i.e., Suggested Induce Spawning Ground (SISG), Suggested Induce Spawning Season (SISS) and Suggested Spat Fall Areas (SSFA). Through these three technologies, the productivity of each cockle farm lot was observed and how these technologies could rebound the local cockle spats supplies and the industry livelihood? Thus, several natural mass blood cockles induce spawning projects were launched aimed to boost the local cockle spat resources, among others was the Lekir Bay, Perak and several others selected sites in Johore, Selangor, Penang and Kedah from 2016 till 2019. To do the prove of concept (POC) then replenish the adult cockle stocks when the SISG show its' effect towards local cockle spats landings.

Methodology

Based on the studies conducted at several selected SISG with initial adult cockle stock sprawl in 2018-2019 were observed, several replenish of adult cockle stocks were conducted in 1.5 Mt/SISG to 5.0 Mt/SISG scattered throughout Malaysia as mentioned above from 2022 - 2025. The adult cockles were analysed for their gonad maturity stages prior to the sprawl activities. The sprawl activities were conducted using Department of Fisheries/government agencies vessel for specific SISG site(s). The study results suggested that the natural mass blood cockle induce spawning technology may be conducted to manage the sustainable cockle spats supplies and abundance. Therefore, the abundance of cockle spat supplies at specific area e.g., Lekir Bay, Perak could offer the eligible and selected local participants to do a cockle farming project. The Lekir Cockle Farm project is a Department of Fisheries initiatives launched in October 2020 for 25 cockle culture lots with 21 Ha size (300m x 700m) each separated around 150 m apart from one-lot-to-another (**Figure 1**). A total of 104 selected participants from listed as lower income group (B40) and licensed fisherman addressed in Lekir to participate into this project. The project is a research and development conducted by Fisheries Research Institute. The initial aim of this project was to evaluate the cockle farm management techniques as well as the optimum physical condition and productivity (Harith, 2025).

Each cockle farm lot consist of 8 – 10 participants were conducting the farming activities with the advised from Department of Fisheries. All cockle spats sprawled and landings from each lot were monitor on daily basis from start (in 2020) until 2025 to monitor their productivities, environmental and coastal influences. Since their cockle culture lots were plotted based on scientific study. Thus, the productivity dan farm management data may be used to signify the physical characteristics associated with its water elevation and surroundings. Their cockle farm management were based on study report (Harith, 2025). All data gathered were stored process for their productivities and values.

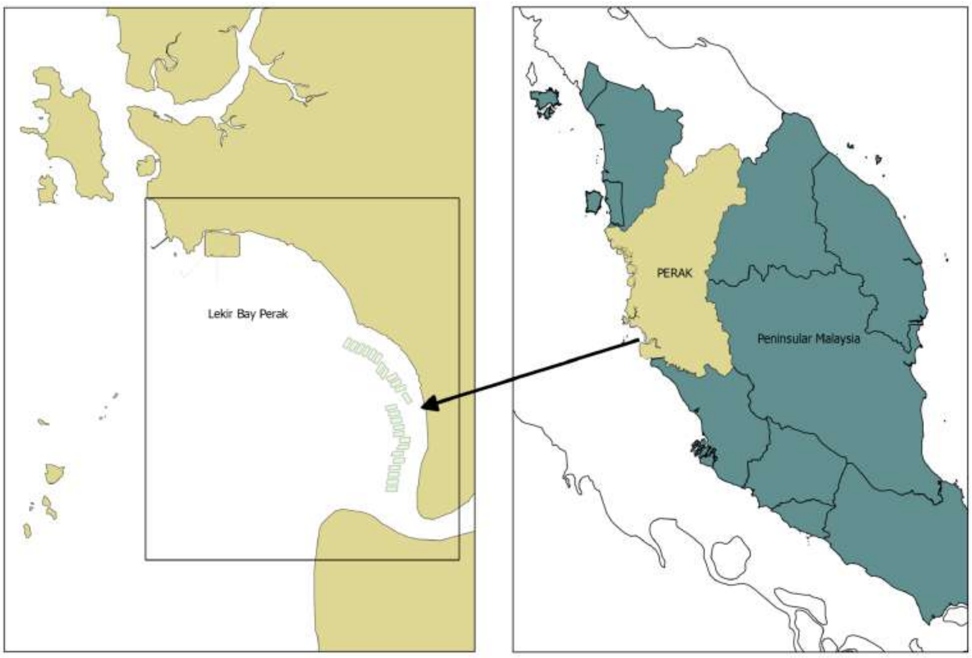

Figure 1: Lekir Cockle Farm Project.

Results and Discussion

The mass natural blood cockle induced spawning technology

The results suggested that the mass natural Blood Cockle induce technology has significantly rebound the local cockle spats from 2016 to 2024 (**Figure 2).** Thus, elevating the national adult cockle landing for the same period. The abundance of cockle spat available from 2018 to 2020 were reflected to the national adult cockle landings from 2019 to 2022. But the downfall of cockle spat in 2020 to 2022 was due to the initial adult sprawled (2018-2019) at selected SISGs with no replenish adult stock. Thus, the results suggested that top up of adult cockle within the SISGs were crucial to sustain the national cockle spat supplies. Replenish of adult cockle were done from 2022 onwards, subsequently increasing the abundance of cockle spats.

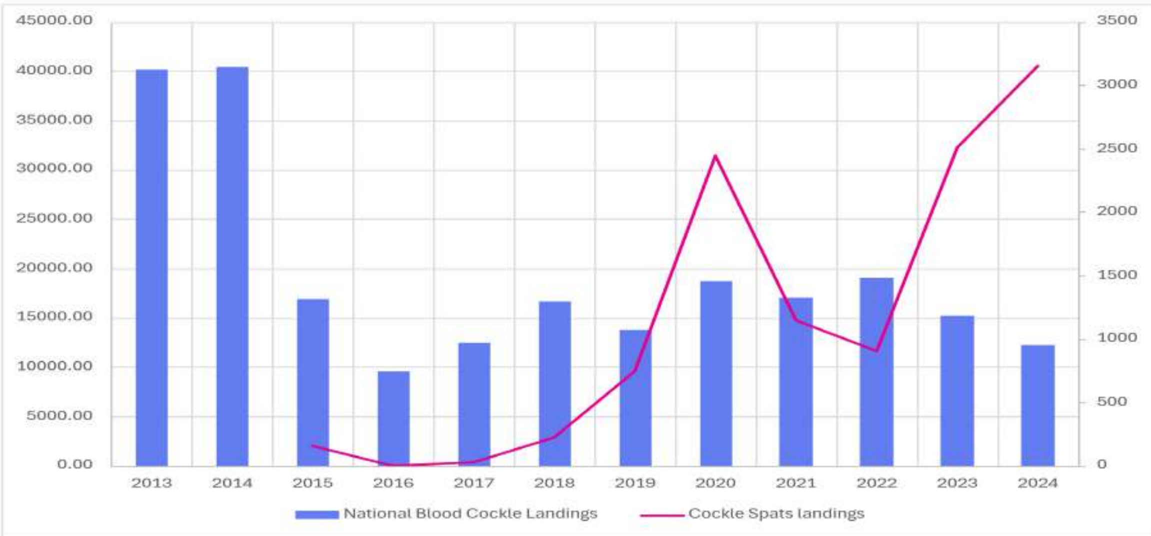

Figure 2: National cockle and spats landings from 2013 - 2024. (Department of Fisheries Malaysia).

While most of the cockle farmers who lives closed to the Suggested Spatfall Areas (SSFA) were found to diversify their focus from farming the cockle spats to trading. This have resulted in the bearish of adult cockle landings clocked in 2023 to 2024 (**Figure 2**). Since the national cockle landing were depleting from 2010 to 2016, alternative studies on how to tackle the cockle resources were initiated (Figure 14). These interventions initially led to a rebound in landings, up to 20,516.37 Mt in 2020 and 21,144.97 Mt in 2022. However, a subsequent decline to 15,147.30 Mt in 2023 and 12,240.88 Mt in 2024 was observed **Figure 2**), attributed to a shift in farmer interest towards the more lucrative cockle seed trading market. Despite this diversion, cockle seed landings significantly increased, from 20.97 Mt in 2018 to 3,154.24 Mt in 2024.

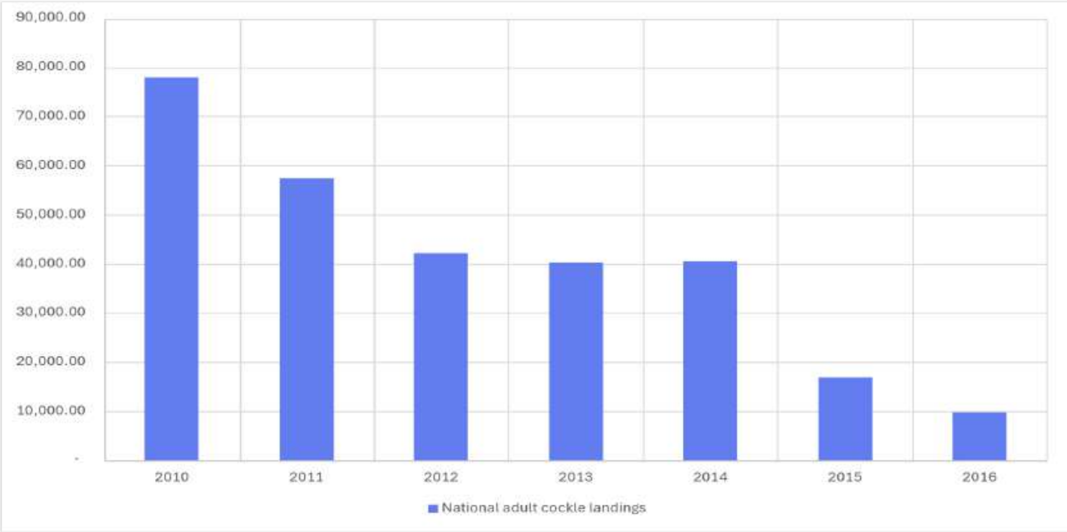

Figure 3: National adult cockle landings from 2010 to 2016. (Department of Fisheries Malaysia).

The cockle precise and farm management technology

Lekir Cockle Farm as mentioned above is a Department of Fisheries initiative project. Several studies were conducted to evaluate the optimum physical associated with cockle culture (Harith, et al., 2013; 2020; 2021; Harith, 2025). The results suggested that the abundance of cockle spats in Lekir Bay were significantly observed from 2018 until 2025. The sustainable cockle spats supply in Lekir Bay helps the cockle farm project to maintain their cockle spats input when part of the sub-lot was harvested (Harith, 2025). Thus, their increase their productivity from year to year (**Figure 4**).

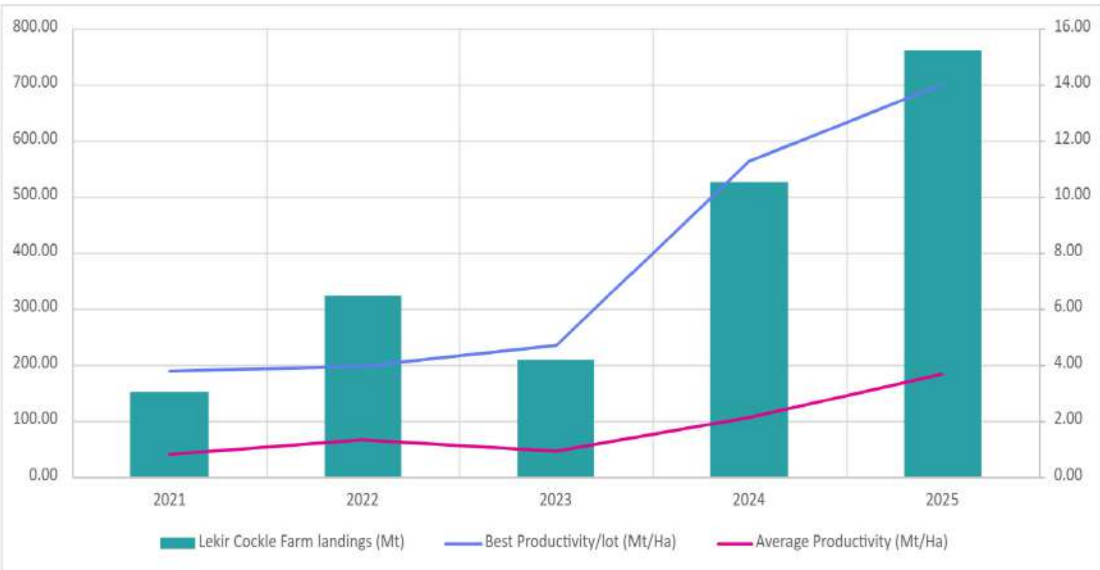

Figure 4: Lekir cockle farm annual landings (Mt), best productivity/lot (Mt/Ha) and average productivity (Mt/Ha).

Each lot were observed to sprawl the cockle spats around 20 Mt to 60Mt annually. Thus, some of these cockle lots were able to land adult cockle of more than 100Mt per year/ lot (**Figure 5**). Furthermore, monitoring a 21 hectare of cockle farm in Lekir demonstrated substantial improvements in productivity per hectare, rising from 3.74 Mt/Ha in 2021 to 13.96 Mt/Ha in 2025 (**Figure 5**).

Economic spillover effects

When sustainable cockle spats can be managed, while the market demand for adult cockle remain stable and the position of cockle farm are at their best state. No excuses that high productivity can be achieved. These can be achieved thru the implementation of 2 technologies i.e., cockle precise farm and management for high productivity.

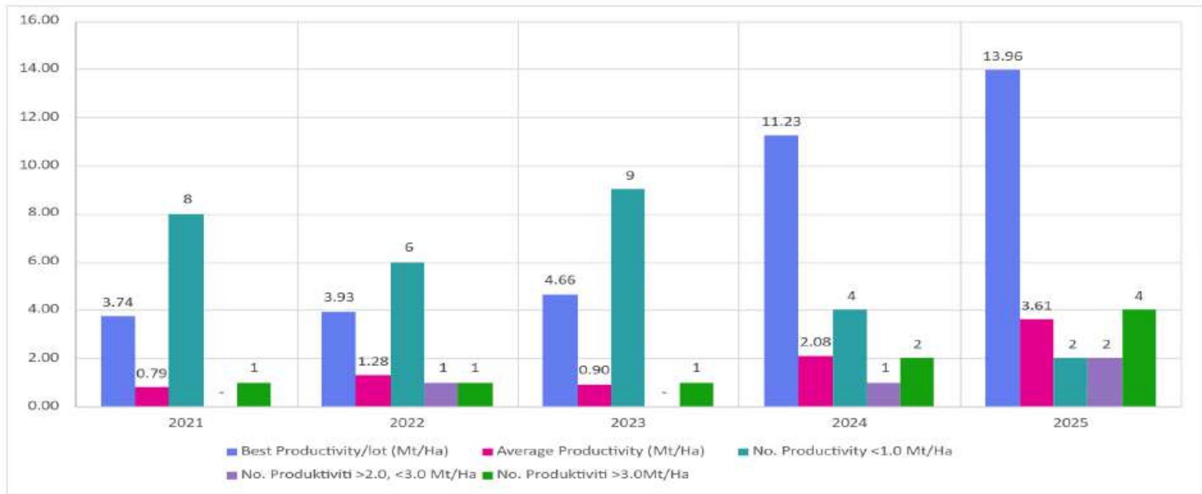

Figure 5: Lekir cockle farm productivity analysis 2021-2025.

Best productivities per lot were seen increased from 3.74Mt/Ha in 2021 to 13.96Mt/Ha in 2025. While average productivities showing the same pattern of increasing from 0.79Mt/Ha to 3.61Mt/Ha in 2025. Number of lot(s) surpassing the key performance index of 3.0Mt/Ha were increased to 4 lots from the champion lot annually (**Figure 5**).

Landing from this project was also seen increased from 150.1Mt in 2021 to 758.346Mt in 2025 (**Figure 6**). The Ex-farm price of the adult cockle in 2021 was RM7.00/Kg valued around RM1,050,700.00 rose to RM10/Kg in 2025 with estimated value of RM7,583,460.00 (**Table 3**). The results suggested that the average returns for each participant rosed from RM1,216.09/month in 2021 rose to RM7,899.44/month in 2025. The highest returned/participant were observed the same pattern, raising from RM5,723.96/month to RM30,546.35/month in 2025 (**Table 4**).

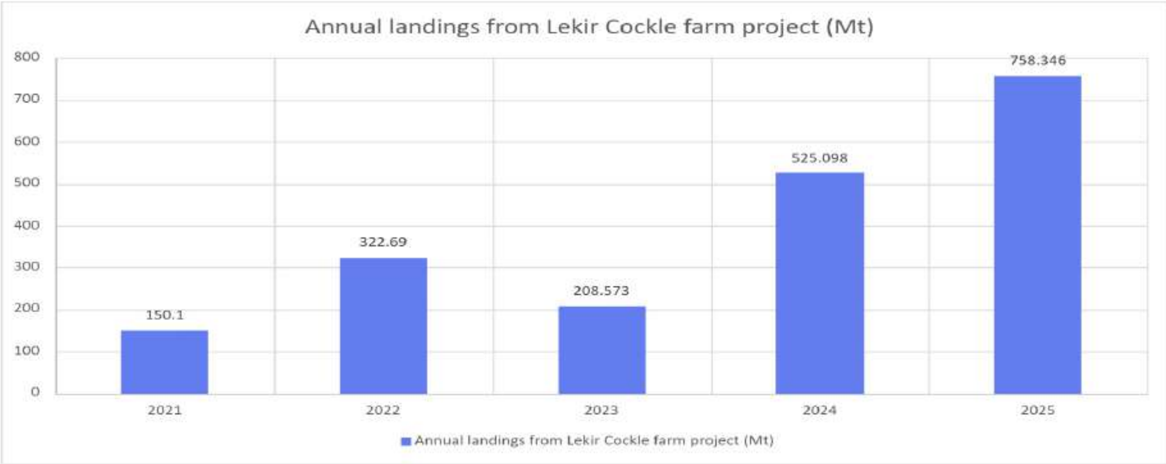

Figure 6: Annual landings from Lekir cockle farm project (Mt)

Table 3: Estimated value (RM), Ex-farm price (RM/Kg) and annual landings.

	2021	2022	2023	2024	2025
Ex-farm price (RM)	7.00	10.00	10.00	10.00	10.00
Landings (Mt)	150.10	322.69	208.57	525.10	758.35
Est value (RM)	1,050,700.00	3,226,900.00	2,085,730.00	5,250,980.00	7,583,460.00

The low productivity gathered from certain lot i.e., lot number 7, 9, 10, 11, 15, 19, and 21, indicates an internal problem associated with attitude, financial management and endurance to do job at sea. These lots have been issued friendly noticed to improve their performance or being replaced. Such an opportunity shouldn't be waste, and it can be benefits to other eligible selected participants in future.

Table 4: Projected returns per participant calculated from annual landings and the number of participants per lot.

Lot KLP		2021		2022		2023		2024		2025
1	RM	1,399.27	RM	1,957.29	RM	-	RM	-	RM	-
2	RM	-	RM	-	RM	-	RM	-	RM	-
3	RM	-	RM	-	RM	-	RM	-	RM	-
4	RM	-	RM	-	RM	-	RM	-	RM	-
5	RM	-	RM	1,992.71	RM	-	RM	-	RM	-
6	RM	-	RM	-	RM	-	RM	-	RM	-
7	RM	267.60	RM	1,153.13	RM	-	RM	-	RM	-
8	RM	-	RM	-	RM	-	RM	-	RM	-
9	RM	5,723.96	RM	6,537.50	RM	-	RM	-	RM	-
10	RM	-	RM	8,595.83	RM	-	RM	218.75	RM	-
11	RM	-	RM	-	RM	664.90	RM	270.52	RM	-
12	RM	466.67	RM	2,385.42	RM	-	RM	-	RM	-
13	RM	-	RM	-	RM	562.50	RM	1,594.90	RM	1,999.38
14	RM	-	RM	2,261.46	RM	65.63	RM	2,953.65	RM	112.50
15	RM	-	RM	281.25	RM	-	RM	-	RM	-
16	RM	18.23	RM	2,718.75	RM	10,200.00	RM	24,570.10	RM	30,546.35
17	RM	-	RM	-	RM	1,583.33	RM	2,489.58	RM	2,864.58
18	RM	-	RM	-	RM	2,508.33	RM	2,679.79	RM	4,741.67
19	RM	371.15	RM	1,714.58	RM	-	RM	-	RM	-
20	RM	-	RM	-	RM	1,802.08	RM	7,723.44	RM	7,680.21
21	RM	1,279.69	RM	-	RM	-	RM	-	RM	-
22	RM	-	RM	-	RM	1,056.25	RM	2,781.25	RM	5,067.71
23	RM	-	RM	-	RM	845.83	RM	1,587.60	RM	2,523.65
24	RM	818.13	RM	1,723.96	RM	1,031.25	RM	2,494.79	RM	7,645.83
25	RM	600.10	RM	2,291.67	RM	1,406.25	RM	5,333.33	RM	15,812.50
No. of active lot		9		12		11		12		10
Min return / pax / monthly	RM	18.23	RM	281.25	RM	65.63	RM	218.75	RM	112.50
Ave return / pax / monthly	RM	1,216.09	RM	2,801.13	RM	1,975.12	RM	4,558.14	RM	7,899.44
Highest returned / pax / monthly / lot	RM	5,723.96	RM	8,595.83	RM	10,200.00	RM	24,570.10	RM	30,546.35

Conclusion

These results indicate that, with the developed technologies, Malaysia possesses the capacity for sustainable management of its cockle resources. Thru, sustainable cockle resources, precise farming technology and farm management for high productivity. The results also attract many state governments to do similar project in their state for the benefits of its citizens.

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Presentation 6

From Field Exposure to Aquaculture in FRI, Malaysia: A Personal Reflection

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Abstract: This presentation is given to commemorate the 30th anniversary of the collaboration between the Fisheries Research Institute (FRI), Malaysia, and the Fisheries Division of the Japan International Research Center for Agricultural Sciences (JIRCAS). It reflects the author's personal experiences and insights gained through field visits, research collaboration, and long-term engagement with Malaysian researchers. Although the author's primary research base has been in Thailand, his connection with Malaysia began in 2005 and was later strengthened through a KAKENHI-funded project on shrimp disease epidemiology conducted from 2011 to 2015. Through visits to shrimp farms and interactions with farmers and researchers, the author observed distinctive farming practices, strong biosecurity awareness, and a high level of interest in scientific knowledge among Malaysian farmers. Rather than focusing only on technical results, this presentation highlights the value of field exposure, cross-disciplinary learning, and human relationships in international research. The author also reflects on how these experiences became personal "treasures" and expresses appreciation for the 30-year partnership between FRI and JIRCAS. Although the current collaborative framework will come to a pause, it is viewed as a step toward new forms of cooperation in the future.

Keywords: FRI and JIRCAS, shrimp aquaculture, daily life in Malaysia

***Abstrak*:** Pembentangan ini disediakan bagi memperingati ulang tahun ke-30 kerjasama antara Institut Penyelidikan Perikanan (IPP), Malaysia dan Bahagian Perikanan, Japan International Research Center for Agricultural Sciences (JIRCAS). Penulisan ini mencerminkan pengalaman peribadi dan pemerhatian penulis yang diperoleh melalui lawatan lapangan, kerjasama penyelidikan, serta penglibatan jangka panjang bersama para penyelidik di Malaysia. Walaupun pangkalan penyelidikan utama penulis adalah di Thailand, hubungan beliau dengan Malaysia bermula pada tahun 2005 dan seterusnya diperkukuh melalui projek yang dibiayai oleh KAKENHI berkaitan epidemiologi penyakit udang yang dijalankan dari tahun 2011 hingga 2015. Melalui lawatan ke ladang udang serta interaksi dengan para penternak dan penyelidik, penulis mendapati wujudnya amalan penternakan yang tersendiri, tahap kesedaran biosekuriti yang tinggi, serta minat yang mendalam terhadap pengetahuan saintifik dalam kalangan penternak di Malaysia. Berbanding hanya menumpukan kepada hasil teknikal, pembentangan ini menekankan kepentingan pendedahan lapangan, pembelajaran merentas disiplin, dan hubungan kemanusiaan dalam penyelidikan antarabangsa. Penulis juga mengimbas bagaimana pengalaman ini menjadi "khazanah" peribadi serta merakamkan penghargaan terhadap

kerjasama selama 30 tahun antara FRI dan JIRCAS. Walaupun rangka kerja kerjasama semasa akan berehat seketika, ia dilihat sebagai satu langkah ke arah bentuk kerjasama baharu pada masa hadapan.

Introduction

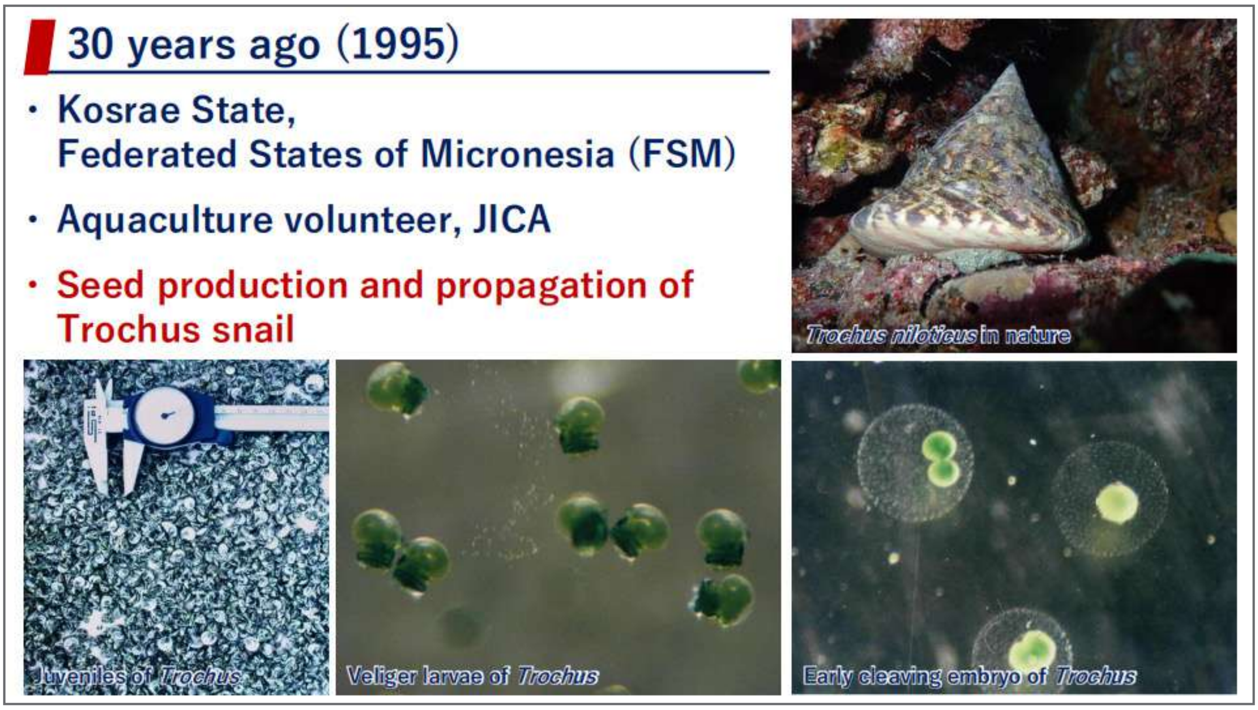
This paper is based on a presentation given at the JIRCAS–FRI Joint 30 Years Anniversary Symposium, "Findings from ecological and aquaculture research mainly focused on mangrove estuary areas in Peninsular Malaysia," held on 20 November 2025 in Penang, Malaysia. The presentation, entitled "From Field Exposure to Aquaculture in FRI, Malaysia: A Personal Reflection," was intended not as a technical research report, but as a reflection on the author's experiences of fieldwork, collaboration, and long-term engagement with Malaysian researchers in aquaculture and aquatic resource management.

The year 2025 marked the 30th anniversary of the collaboration between the FRI, Malaysia, and the Fisheries Division of the JIRCAS. Over three decades, this partnership has supported scientific progress, human resource development, and mutual understanding between the two institutions. Such long-term collaboration is sustained not only by institutional frameworks, but also by the dedication and trust built among many researchers from both countries.

Although the author did not participate in this collaboration from its very beginning, he has had the opportunity to become part of this long history through his own research activities and field experiences in Malaysia. In the following sections, he reflects on how these personal experiences are connected to the broader 30-year story of cooperation between FRI and JIRCAS.

Thirty Years Ago (1995): The Starting Point

Thirty years ago, in 1995, the author was working in the Federated States of Micronesia (FSM) as an aquaculture volunteer under JICA program. His main responsibility at that time was the seed production and propagation of the trochus snail (*Trochus niloticus*), an important marine resource for local communities. The work involved broodstock collection, larval rearing, juvenile production, and the construction of simple culture facilities under challenging field conditions.



As shown in the photographs, the author was then a young and energetic researcher, directly engaged in physical labor, field sampling, and experimental culture work. These early experiences in small-island aquaculture formed the foundation of his later career in fisheries and aquaculture research. Looking back from the present, this 30-year span represents not only the passage of time in an individual life, but also the remarkable continuity of scientific collaboration between JIRCAS and FRI, which has continued steadily over three decades.

First Connection with Malaysian Researchers (2005)

Although the author's main research base later became Thailand, his first professional connection with Malaysian researchers began in 2005, approximately ten years after the start of the JIRCAS–FRI collaboration. At that time, he participated in a JIRCAS "Brackish Water Project" workshop held in Tsukuba, Ibaraki, which brought together researchers from Malaysia, the Philippines, Thailand, and Japan.

The workshop provided opportunities for intensive scientific discussion on brackish-water fisheries and aquaculture. Researchers from FRI and professors from the University of Malaya joined Japanese colleagues in exchanging ideas and experiences. The group photographs from this meeting reflect the strong sense of collegiality that developed among participants.

Following the workshop, a short excursion to Nikko further strengthened these relationships. Shared meals, natural scenery, and informal conversations created a sense of friendship that went beyond academic exchange. It was during this time that the author first felt a deep personal connection with Malaysian researchers, not only as scientific partners, but also as colleagues and friends. This early experience laid the groundwork for the author's later involvement in Malaysia through the KAKENHI project and subsequent field surveys described in the following sections.

Field Survey on Shrimp Diseases in Malaysia (2011–2015)

Overview of the KAKENHI Project

From 2011 to 2015, the author participated in a KAKENHI-funded research project on the epidemiology of shrimp diseases in Southeast Asia, covering Thailand, Vietnam, Indonesia, the Philippines, and Malaysia. The overall objective of the project was to understand the occurrence, spread, and management of shrimp diseases across different aquaculture systems in the region. In Malaysia, the project was conducted in close collaboration with Dr. Siti and Dr. Beng Chu of the National Fish Health Research Centre (NaFisH), who served as the local counterparts. Their strong commitment and generous support were essential for the successful implementation of the field surveys and data collection.

From the Japanese side, Dr. Hamano served as the project leader, while Dr. Oseko, a specialist in shrimp pathology, played a key role in disease diagnosis and sample analysis. The author's responsibility within the project was to observe, document, and compare shrimp culture systems in each participating country, with the aim of identifying local practices and management characteristics that could influence disease dynamics.

Within this regional framework, Malaysia became one of the most memorable study sites, not only because of the diversity of shrimp farming systems observed, but also because of the warm cooperation and hospitality provided by Malaysian researchers and field staff. The author conducted repeated field visits to shrimp farms in Malaysia, particularly in areas near Penang, which provided valuable opportunities to closely examine farming practices and disease-related issues in real production settings.

Field Visits and Data Collection in Malaysia

During the KAKENHI project period, the research team conducted annual field visits to shrimp farms located in Penang, Selangor, and Kedah. These visits provided opportunities to directly observe farming practices and to collect information on shrimp health and disease occurrence under real production conditions. Interviews were conducted with shrimp farmers to understand the current status of shrimp diseases, management practices, and responses to disease outbreaks. In addition to these interviews, the team carefully observed the structure and operation of the farming systems, including pond management, water use, and biosecurity measures.

The farmers generously shared their time and knowledge, often providing detailed explanations and allowing the researchers to inspect their ponds and facilities. This openness reflected the strong trust and cooperation that had been built between Malaysian researchers and local farmers over many years. After each field visit, biological samples collected from shrimp showing disease symptoms were transported to the laboratory, where pathologists conducted diagnostic analyses to identify possible causative agents. This combination of field observation, farmer interviews, and laboratory analysis formed the core of the epidemiological investigation.

Local Life and Personal Memories in Malaysia

In addition to visiting shrimp farms, the author had many opportunities to experience everyday life in Malaysia through visits to local restaurants and food stalls, often arranged by Dr. Siti. These informal settings provided valuable opportunities to interact with colleagues outside the research environment and to gain a deeper understanding of local culture.

The author particularly appreciated simple, local eateries where ordinary people dine, rather than formal restaurants. Such places offered not only food, but also a sense of the rhythms of daily life in Malaysia. Many memorable experiences were associated with these visits, including dishes such as Nasi Kandar, unusually large desserts, the famous Malaysian durian, and a wide variety of local sweets.

These shared meals and casual conversations strengthened the relationships among team members and added a human dimension to the field surveys. They contributed to creating an atmosphere of trust and friendship that supported the scientific collaboration.

The author would also like to express sincere appreciation to Dr. Yurimoto, who kindly drove the official vehicle and provided continuous logistical support throughout the field surveys. His assistance was essential for the smooth execution of the research activities.

At the end of these field surveys and everyday interactions, the author realized that his experience in Malaysia had provided not only technical data, but also important lessons from the farmers themselves. These lessons became the foundation for his reflections on the value of collaboration and learning in aquaculture.

Learning from malaysian farmers

Farmers as knowledge partners

One of the most impressive observations made by the author in Malaysia was that some shrimp farmers actively read academic papers in English in order to obtain reliable and scientifically based information. This level of engagement with scientific literature was rarely observed in other countries involved in the KAKENHI project.

In Thailand and other Southeast Asian countries, shrimp farmers, including even well-known producers, typically rely primarily on their own experience and informal networks for decision making. In contrast, several Malaysian farmers demonstrated a strong interest in scientific evidence and actively sought information from peer-reviewed publications.

This experience had a significant impact on the author's own perspective as a researcher. It led him to recognize the importance of open-access publication, so that scientific findings can be directly accessed and used not only by academics, but also by farmers in the field. For the author, this realization became one of the most valuable outcomes of his engagement with Malaysian shrimp farmers.

Use of Artificial Pigments in Shrimp Ponds

Another notable practice observed in Malaysia was the use of artificial pigments in shrimp ponds to modify water color. Products designed to produce green-colored water are commercially available in several countries, including Thailand. However, during the regional surveys, the author rarely observed their actual use outside Malaysia. In contrast, some Malaysian shrimp farmers actively applied these pigments to their ponds, as illustrated in the photographs. Although the precise scientific basis for this practice was not always clear, it was commonly associated with the belief that "green water" provides a favorable environment for shrimp culture, possibly by supporting phytoplankton growth or by improving visual and environmental conditions in the pond.

This example highlights how Malaysian farmers combine commercial products, practical experience, and locally shared knowledge to manage their culture systems. It also illustrates the diversity of management approaches found across countries and the importance of understanding local practices when interpreting disease and production outcomes.

Biosecurity Practices in Malaysian Shrimp Farming

In addition to their interest in scientific information and pond management practices, Malaysian shrimp farmers demonstrated a strong awareness of disinfection and biosecurity, particularly with regard to preventing the introduction of pathogens from outside the farm. Some farms had established systems to disinfect vehicles and people at the entrance before allowing access to pond areas, as shown in the photographs. However, in contrast to this high level of awareness regarding ground-based contamination, control of birds appeared relatively weak. In several cases, ponds were not protected by bird-prevention nets, and large numbers of birds were frequently observed around ponds, especially after harvesting. These birds were sometimes seen feeding on dead or leftover shrimp, potentially carrying pathogens between ponds.

In Thailand, by contrast, farmers are generally very sensitive to the risk posed by birds, and even small-scale farms commonly install bird-netting around their ponds. This comparison highlights how different countries place emphasis on different components of biosecurity, reflecting local experience, priorities, and perceptions of disease risk.

These observations further emphasized to the author the importance of understanding local practices when evaluating disease control strategies in shrimp aquaculture. They also reinforced the value of learning directly from farmers who operate within their specific environmental and social contexts.

Treasures from My Time in Malaysia

Through his visits and field surveys in Malaysia, the author gained a wide range of valuable experiences. These included not only technical knowledge related to shrimp farming and disease management, but also a deeper understanding of the attitudes, dedication, and openness of both researchers and farmers. The kindness shown by colleagues and the many shared experiences in the field made these years especially meaningful, and they have become precious personal and professional treasures.

The 30th anniversary of the JIRCAS–FRI collaboration represents an important milestone. It reflects three decades of continuous effort, mutual trust, and shared commitment to advancing research in fisheries and aquaculture. The author expresses deep respect for all the researchers, technicians, and collaborators from both institutions who have devoted their time, energy, and passion to building and sustaining this strong partnership over the years.

Not an End, but a Next Step

At the end of the current fiscal year, the ongoing JIRCAS–FRI collaborative research program will formally come to a close. However, the author does not regard this moment as an ending, but rather as a pause and a transition toward the future.

The trust, friendship, and mutual understanding that have been built between JIRCAS and FRI over the past three decades will not disappear. On the contrary, these relationships form a strong foundation for future cooperation. When the right time and conditions emerge, new forms of collaboration will naturally grow from this shared history.

Closing

The author expresses his sincere gratitude to all colleagues in Malaysia who have supported JIRCAS, as well as to all participants who contributed to and attended the 30th Anniversary Symposium. The author hopes that the spirit of cooperation cultivated over the past 30 years will continue to inspire future generations of researchers in both countries.

Acknowledgements

The author would like to express his sincere appreciation to the Fisheries Research Institute (FRI), Malaysia, and the Japan International Research Center for Agricultural Sciences (JIRCAS) for their long-standing collaboration and support. Part of the work presented in this paper was conducted under a KAKENHI-funded research project (Grant Number: 23255013), entitled “Epidemiological study and elucidation on spread routes of

shrimp viral diseases in Southeast Asian countries." The author also acknowledges the valuable cooperation of Malaysian researchers and shrimp farmers who supported the field surveys.

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Visit to the Merbok River Estuary

Day 2 – Friday, 21st November 2025

Venue: Merbok, Kedah

Timetable

Time	Activity
09:00	Meet on FRI and depart
10:30	Arrive at the oyster farm (Tiram Sungai Merbok) in Merbok.
12:15	Visit Sungai Batu Archaeological Site (Kedah Tua)
12:45	Visit Pier Complex, Sungai Merbok
14:30	Depart for hotel in Georgetown
16:00	Disband near the hotel

Oyster Farm (Tiram Sungai Merbok) Visit


The farm owner explains the oyster farming process


Tasting fresh oysters produced at this farm

Sungai Batu Archaeological Site (Kedah Tua) Visit


Visit the remains of charcoal kilns that were once popular along the river.

Pier Complex, Sungai Merbok

Visit a mangrove forest reserve and encounter a water monitor.

MINISTRY OF AGRICULTURE
AND FOOD SECURITY
DEPARTMENT OF FISHERIES MALAYSIA

JIRCAS

Proceedings of the JIRCAS-FRI
30 Years Anniversary Symposium FRI Penang
(20 Nov. 2025)

eISBN 978-967-2946-63-2

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