

Challenges and Sustainable Transformation in Small-Scale Aquaculture: A Perspective from Taiwan



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Outline

Introduction to aquaculture in Taiwan

Current challenges in Taiwan aquaculture

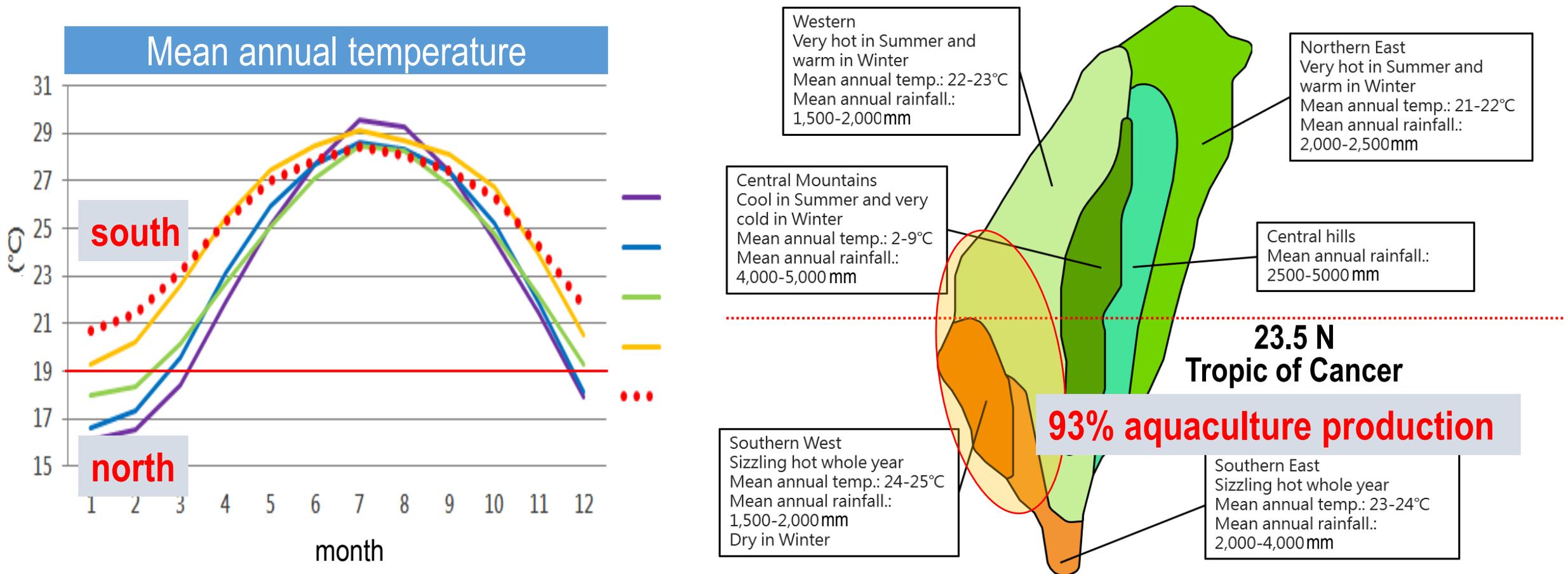
Scientific approaches for sustainable development

Case studies from Taiwan

Aquaculture in Taiwan

Feature

Taiwan is a subtropical island surrounded by ocean, offering favorable conditions for aquaculture.



Aquaculture in Taiwan

Feature

A wide range of species are farmed. More than 70 aquatic species regularly farmed in Taiwan.



Tilapia (57 KT)



Seabass (23 KT)



Threadfin (13 KT)



Japanese eel (3 KT)



Milkfish (46 KT)



Grouper (18 KT)



White shrimp (9 KT)

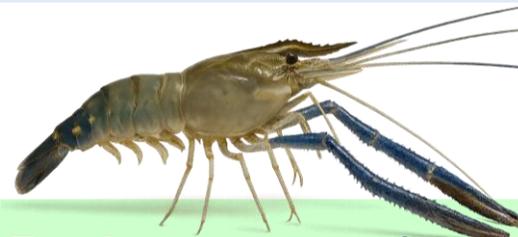
242/267 KT (91%)



Hard clam (54 KT)



Oyster (16 KT)



Freshwater prawn (5 KT)



Asian clam (3 KT)

Aquaculture in Taiwan

Feature

Small-scale, high-density farming is the norm.

Farms are often family-run, incorporating local knowledge and adaptive strategies.

Farming diverse species spreads risk and allows flexible market response.

Ongoing low-cost tech innovation and practical know-how transfer are common.

Current Challenges in Taiwan Aquaculture

Issue

Aquaculture area is limited and poorly planned

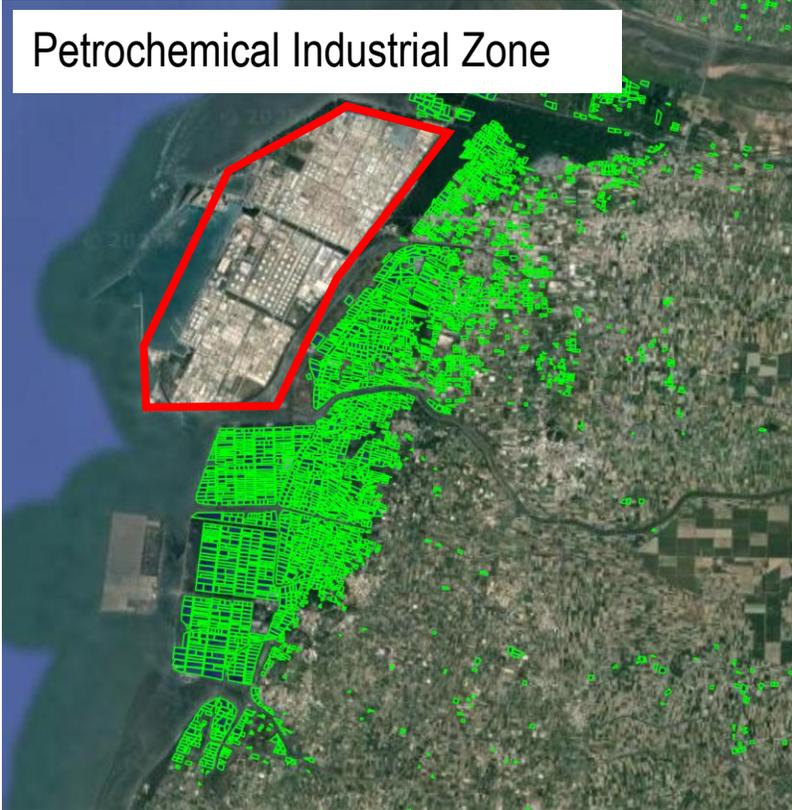
Climate change brings more extreme weather, impacting production stability.

Disease outbreaks and drug resistance are growing concerns.

Aging workforce and lack of young entrants threaten long-term viability.

Current Challenges in Taiwan Aquaculture

Petrochemical Industrial Zone



Livestock farm



Agricultural, and residential areas



Issue

Small-scale, land ownership are complicated, mixed land use

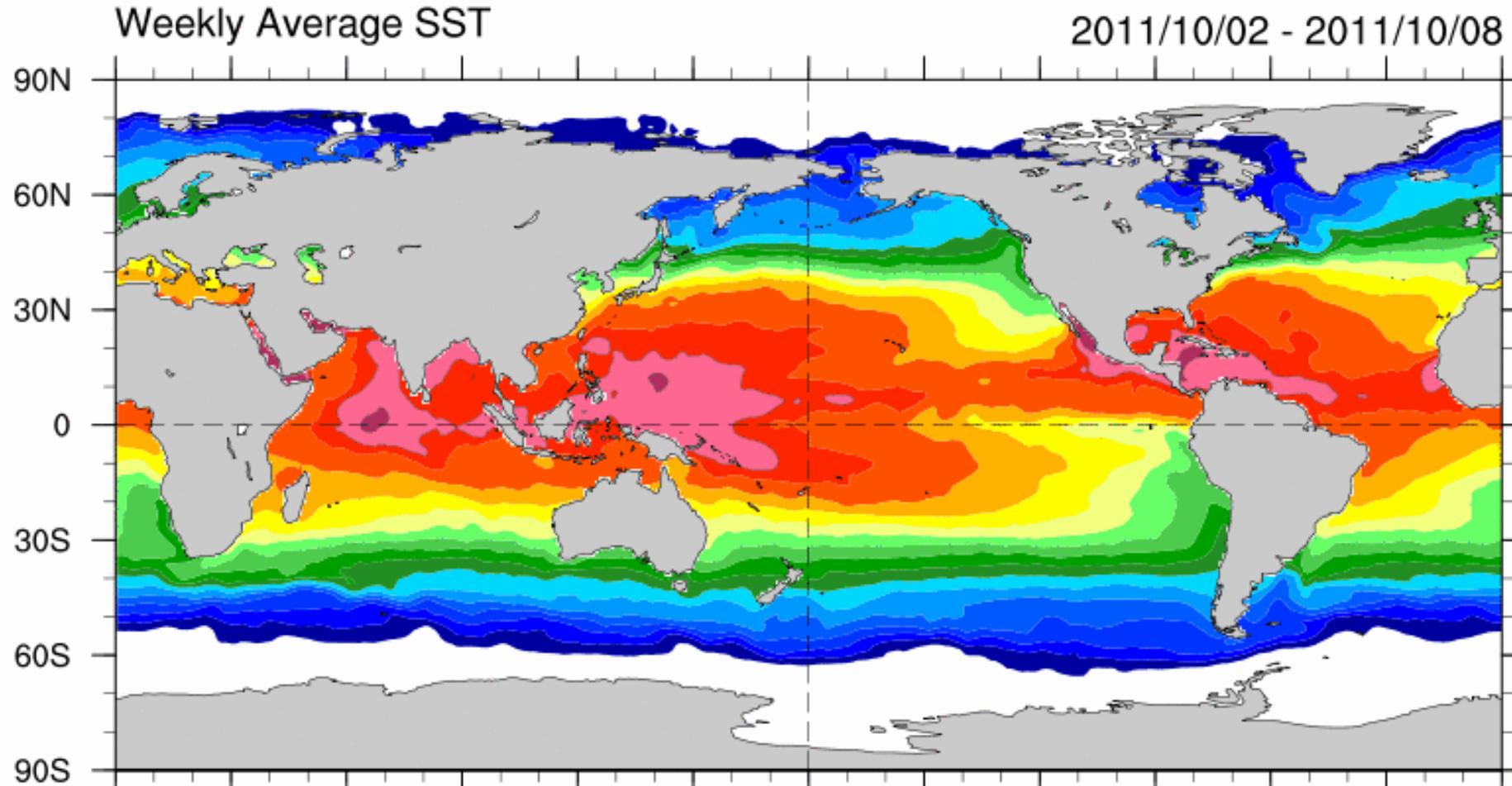
Current Challenges in Taiwan Aquaculture



Issue

Long-developed (over 50 years), leading to poor water intake and drainage systems.

Current Challenges in Taiwan Aquaculture



Issue

Due to monsoons, winters in CT can be quite cold, whereas summers are extremely hot.

Current Challenges in Taiwan Aquaculture

Issue

新竹
花蓮
人工湖湖面飆36度
大量魚群暴斃 飄散惡臭
連日高溫不雨
黃金蜆、台灣鯛死亡
損失破百萬

台視LIVE 即時線上
慘!今夏高溫不雨 新竹花蓮傳"魚.蜆暴斃"
新聞熱點 即時直播 · 請訂閱 TTV LIVE

Heatwaves

澎湖
重創養殖業!成群魚死 蚵棚攪成一團

TVBS NEWS
更多新聞在這裡
掌握新聞脈動 ▶ 訂閱TVBS NEWS頻道

Typhoon

彰化
記者 謝丹慈
而當漁民採收的時候發現文蛤死亡的話

TVBS NEWS
更多新聞在這裡
掌握新聞脈動 ▶ 訂閱TVBS NEWS頻道

Heavy Rain

在地新聞
主編 徐榮寅
損失慘重! 3萬多尾虱目魚凍斃 農業處:加強魚塭保暖

農曆十一月十四
宜 祭祀 沐浴
16:31 88會館案 ▶ 吳子嘉稱曾去88會館 陳家

Cold Damage

最新消息
杜鵑風雨 暴風圈逐漸遠離 本島11:30解除陸警
記者 劉啟茹
焚風? 颱風過後 花蓮台灣鯛暴斃損百萬

高雄市 26~30
15:46 強風助燃 高雄林園民宅火警 一家四口受困屋主危

Heatwaves

屏東
月初卡努毀壞抽水設備 年度大潮導致海水水管遭打斷

台南 29-32

Typhoon

Current Challenges in Taiwan Aquaculture



Tiger shrimp (95 KT)

1987

diseases



White shrimp (9 KT)

2023



Tilapia (85 KT)

2003

export difficulties



Tilapia (57 KT)

2023



Japanese eel (40 KT)

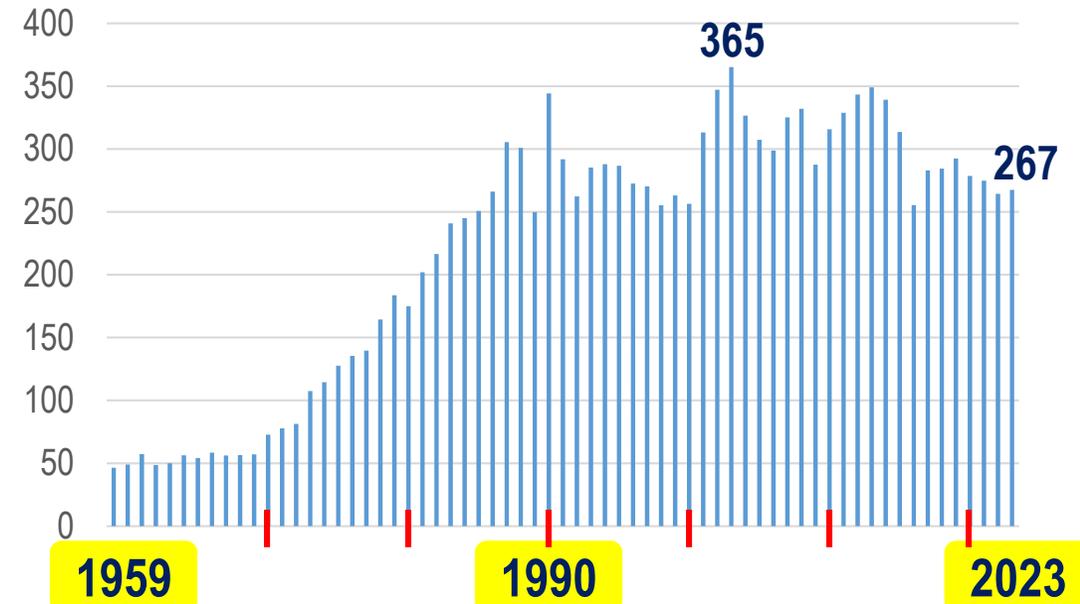
2003

lack of wild fry



Japanese eel (3 KT)

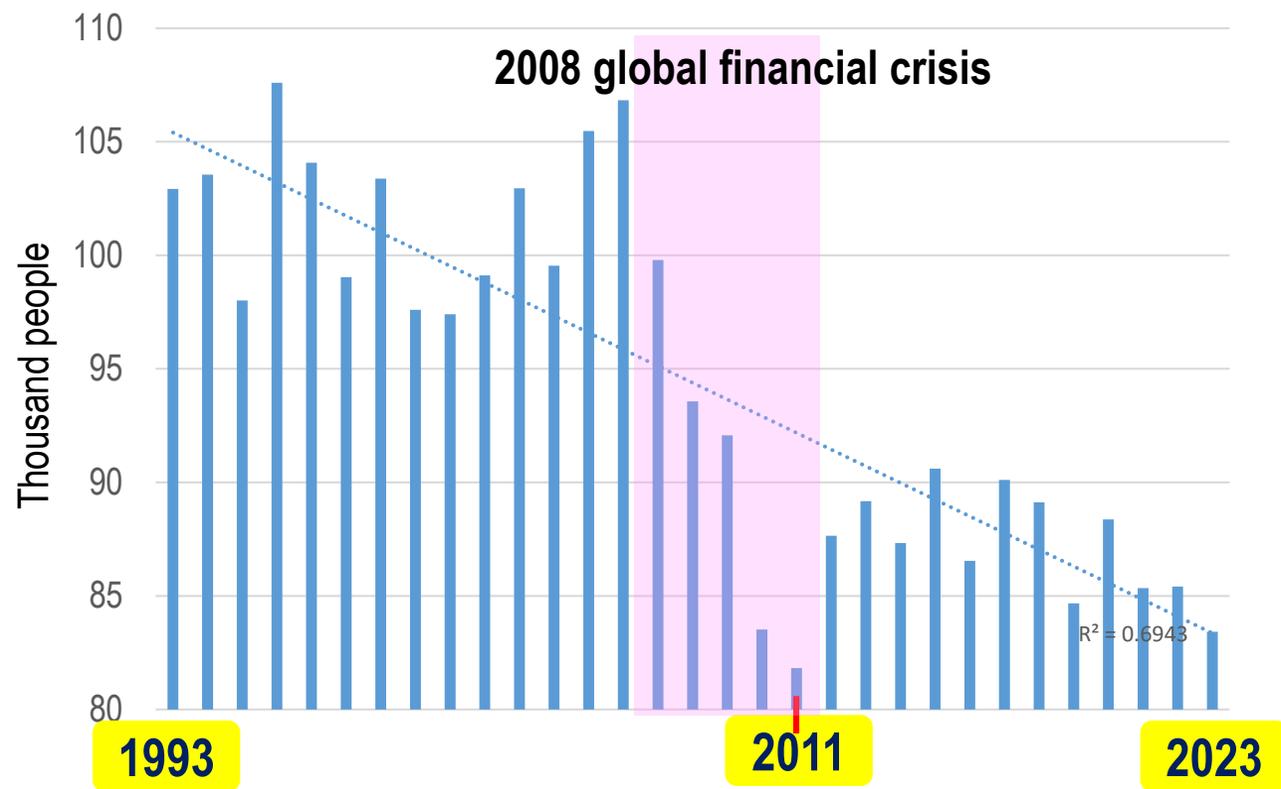
2023



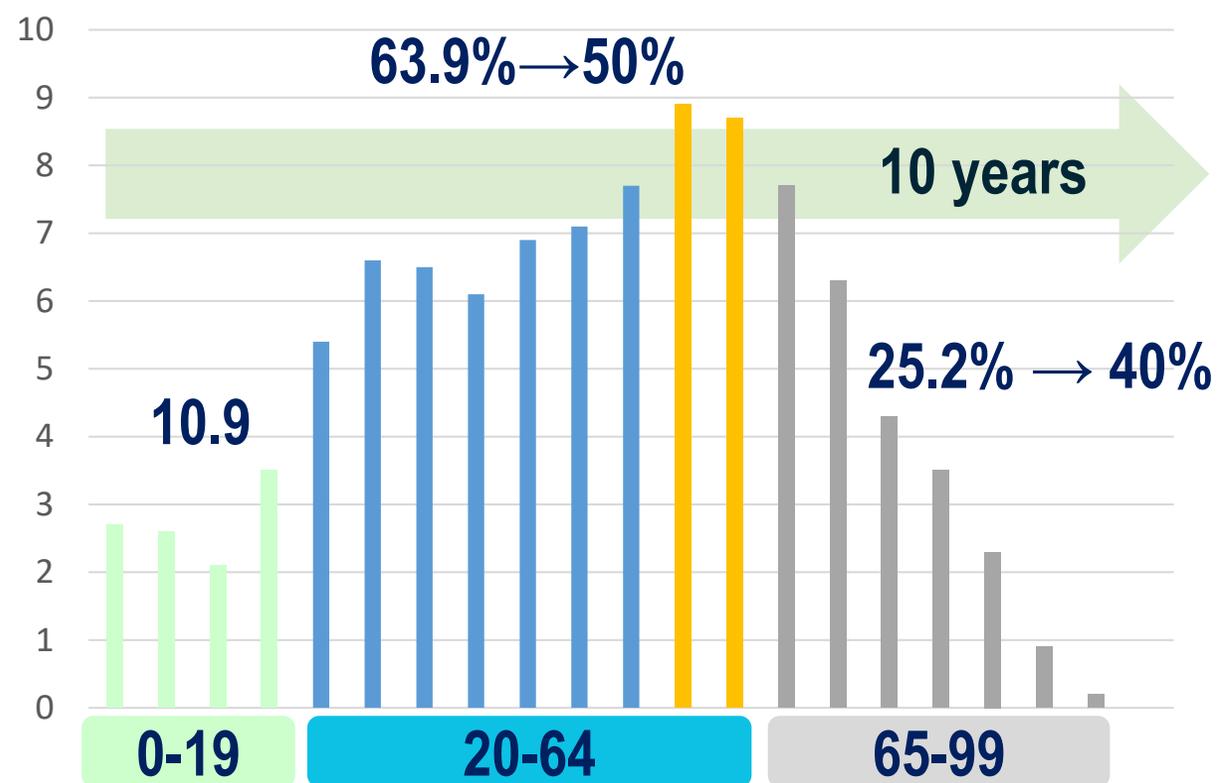
Since the 1990s, annual aquaculture production has remained above 250 KT. However, output of many key species has significantly dropped due to diseases, lack of wild fry, and export difficulties, leading farmers to diversify species and focus on the domestic market.

Current Challenges in Taiwan Aquaculture

Trend of Aquaculture Workforce in Taiwan (1993–2023)



Demographics of an Aquaculture Area: The Jia-dong, Ping-tung



Issue

Declining workforce and an aging population. Aquaculture production is bound to decrease.

This reality highlights the urgent need to support generational renewal in the aquaculture.

Science for Sustainability



Infrastructure Improvement

Equipment Upgrading



Action

The government supports aquaculture modernization by upgrading infrastructure and equipment.

Science for Sustainability

Since 2020, at least 16 local associations and more than 1000 young farmers join.

Strategy for Engaging Young Fishers



Top 100 Young Farmers



Fisheries Youth Associations



Action

Establishing local associations and building a support network to encourage generational renewal.

Science for Sustainability

Practical solutions have emerged to address these sustainability challenges

photosynthetic bacteria, PSB



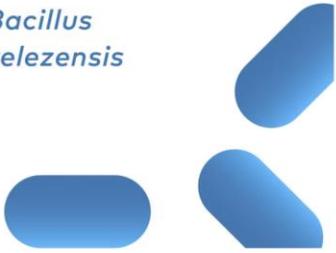
Action

Researchers have promoted PSB with fish farmers to establish on-site scalable production systems

Science for Sustainability

Bacillus spp.

Bacillus velezensis



貝萊斯芽孢桿菌

不提供線上銷售

短小芽孢桿菌
Bacillus pumilus



短小芽孢桿菌

液化澱粉芽孢桿菌

Bacillus amyloliquefaciens



液化澱粉芽孢桿菌

不提供線上銷售

枯草桿菌納豆亞種

Bacillus subtilis var. natto



納豆菌

地衣芽孢桿菌

Bacillus licheniformis



地衣芽孢桿菌

不提供線上銷售

凝結芽孢桿菌

Bacillus coagulans



凝結芽孢桿菌



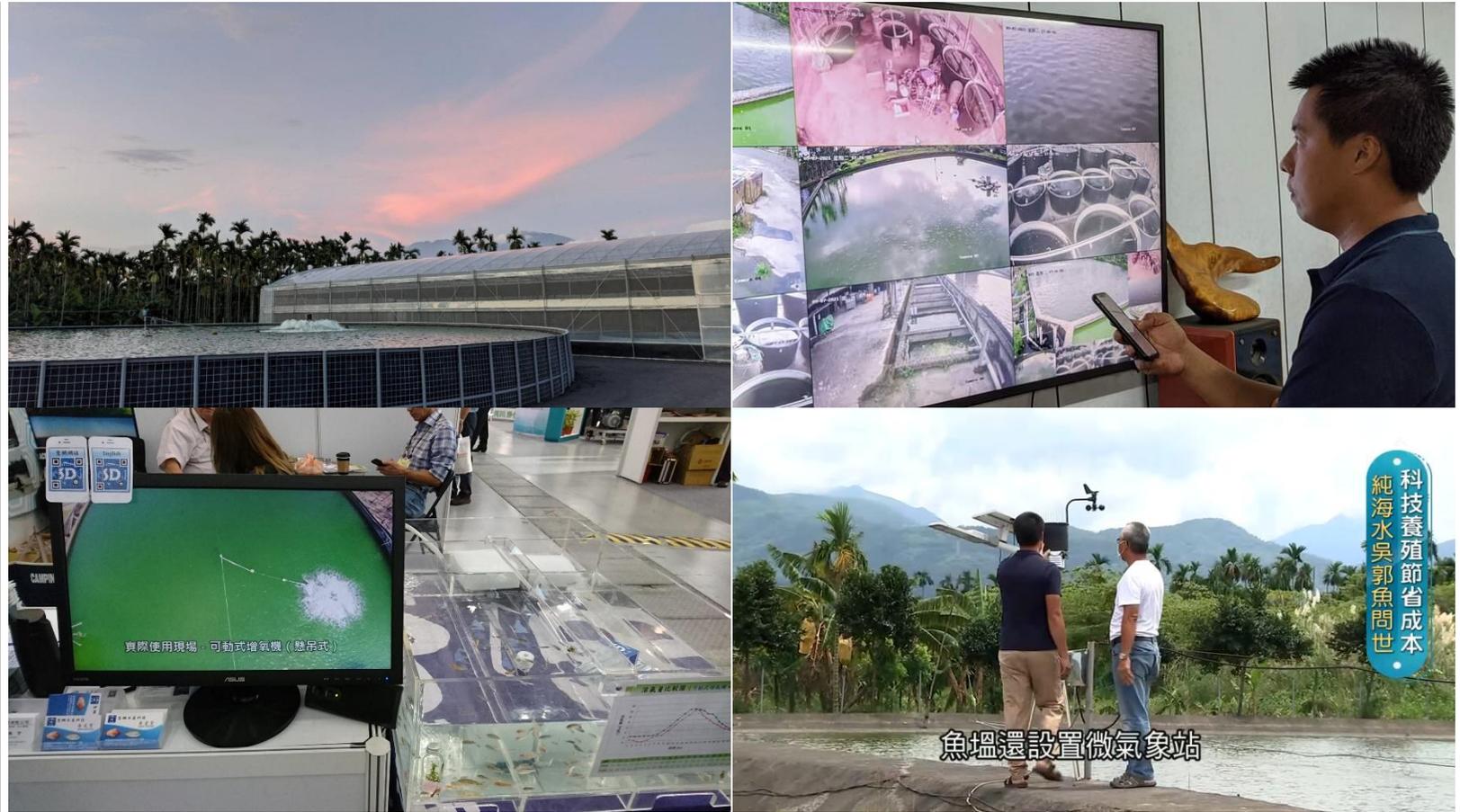
Action

Biotech companies have commercialized *Bacillus*-based probiotics for aquaculture applications.

Science for Sustainability

Top Ten Outstanding Farmers

養魚世界 5
May 2017

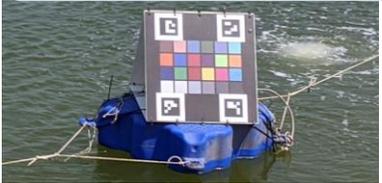


Action

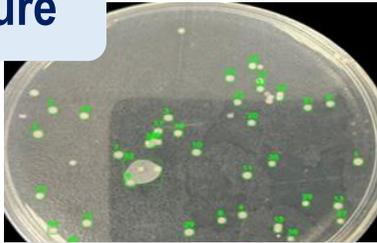
Top farmer led tilapia breeding and smart aquaculture development

Science for Sustainability

Smart Aquaculture



Water color



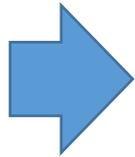
Bacteria colonies



NH₄⁺ · NO₂



DO. pH. Temp Salinity



Action

eKnowFlow
養殖決策系統

Back to list

Homepage

Diary

Consult

Setting

version: 1.1.4

Artificial Intelligence Manufacturing Decision System

謝大明 Farm ownership

Today's aquaculture report:

Water quality Latest record:13:53

pH	DO (mg/L)	Water Temperature (°C)	Salinity (psu)	ORP	Ammonium-Nitrogen(NH ₄ +N) (ppm) (mg/L)	Nitrite-Nitrogen(NO ₂ -N) (ppm) (mg/L)
7.7	6.2	28.1	31.3	99	0.5	1

Pond water color record Latest record:14:41

Water coloration description	Water transparency (cm)
綠色	30

Feeding record Latest record:13:53

1.Start time 13:53 · 東立飼料 3 kg · fed 45 min · condition: common ;

Growth Latest record: 14:48

Length (cm)	Specification (Quantity/Weight)
14	30

Bacterial counts Latest record:14:43

Colony (CFU/mL)	Processing...
7	TCBS

Environmental modifier record Not yet recorded



Dr. Fan-Hua Nan

NTOU developed a Smart Aquaculture System, which incorporates sensors, AI vision, and data analytics

Science for Sustainability

Genetics & Breeding



High Yield



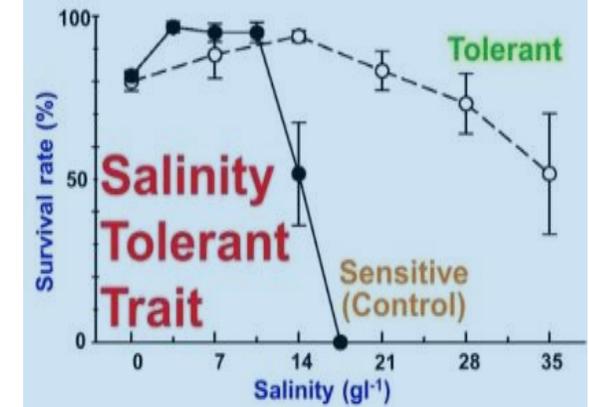
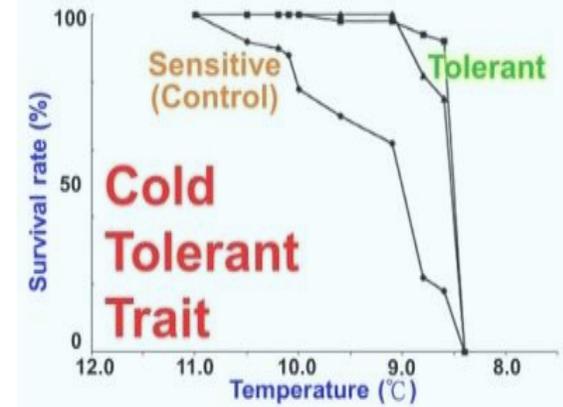
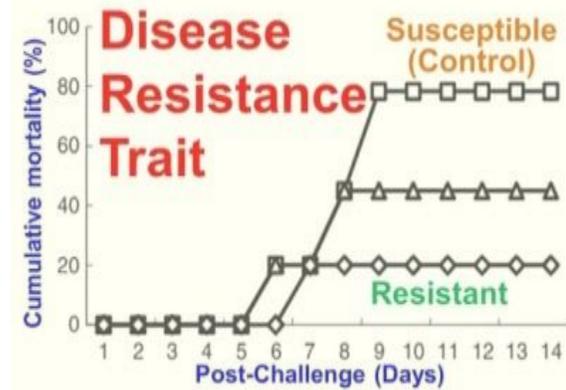
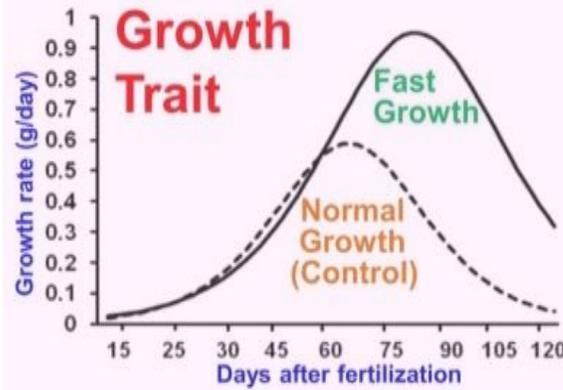
Disease Resistant



Cold Tolerant



Salinity Tolerant

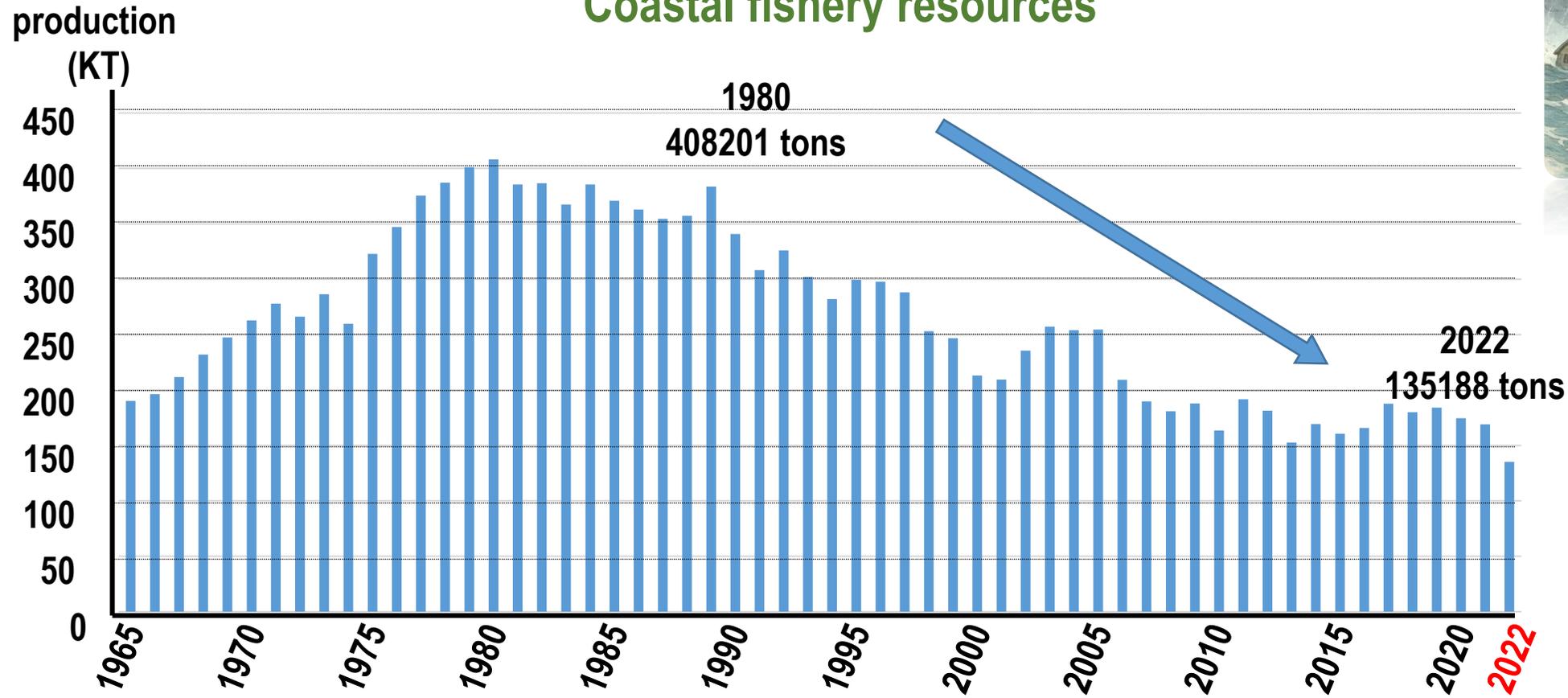


Action

Selective breeding enhances disease resistance, cold, salinity tolerant and improved growth efficiency.

Case 1 - Stock enhancement

Coastal fishery resources



Climate change



Environment destruction



Overfishing

Issue

Coastal fishery resources are significant decline in Taiwan.

Case 1 - Stock enhancement

Action Stationed and collaborated with the local community for nine years since 2014.



Dr. Te-Hua Hsu

Case 1 - Stock enhancement

Action Stationed and collaborated with the local community for nine years since 2014.



Charybdis feriatus



Eriocheir japonica



Heliocidaris crassispina



Magallana angulata



Laevistrombus canarium



Babylonia areolata



Haliotis diversicolor



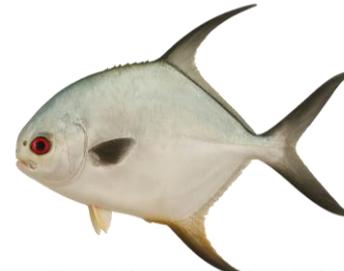
Oplegnathus fasciatus



Oplegnathus punctatus



Platax teira



Trachinotus blochii



Sepia pharaonis



Tectus sp.



Meretrix lamarckii



Lutjanus sebae



Pagrus major



Lutjanus erythropterus



Lutjanus stellatus



Rhabdosargus sarba



Acanthopagrus schlegelii



Girella punctata

Case 1 - Stock enhancement

Action Since 2015, at least 10,000 cuttlefish/year have been released for eight consecutive years.



hatch

select

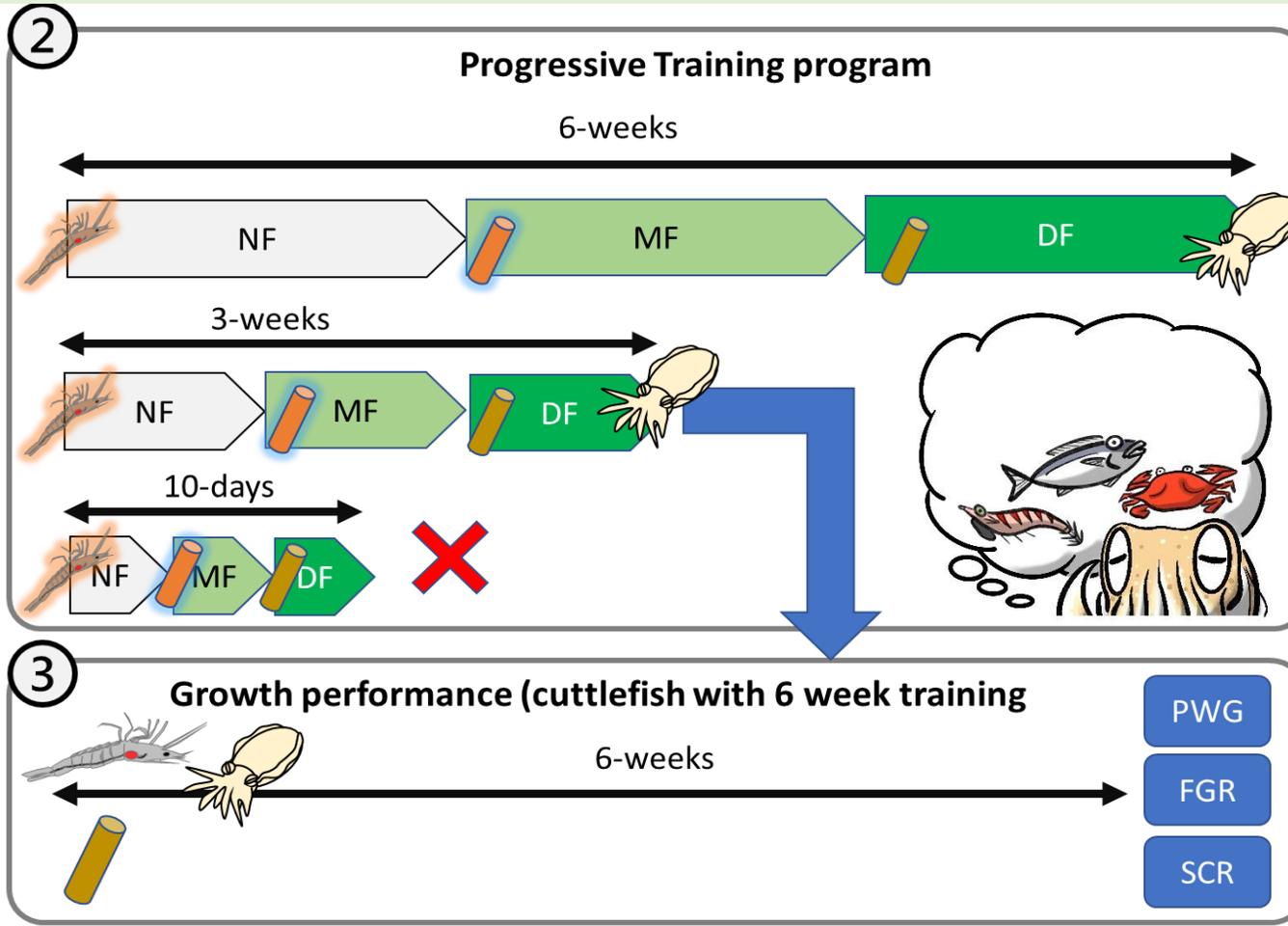
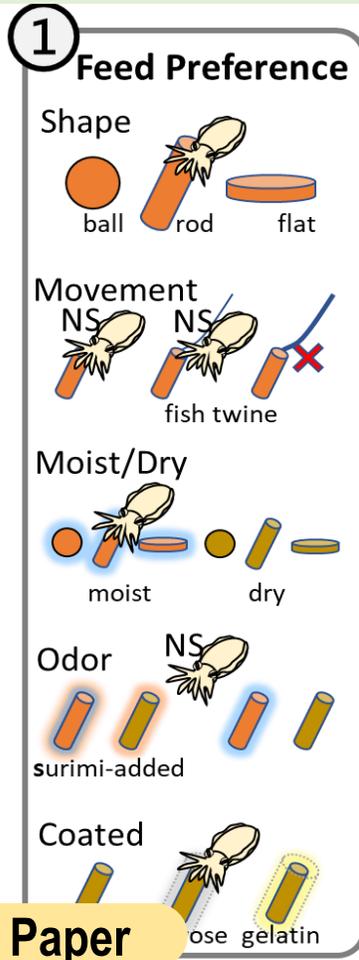
collect

culture

release

Case 1 - Stock enhancement

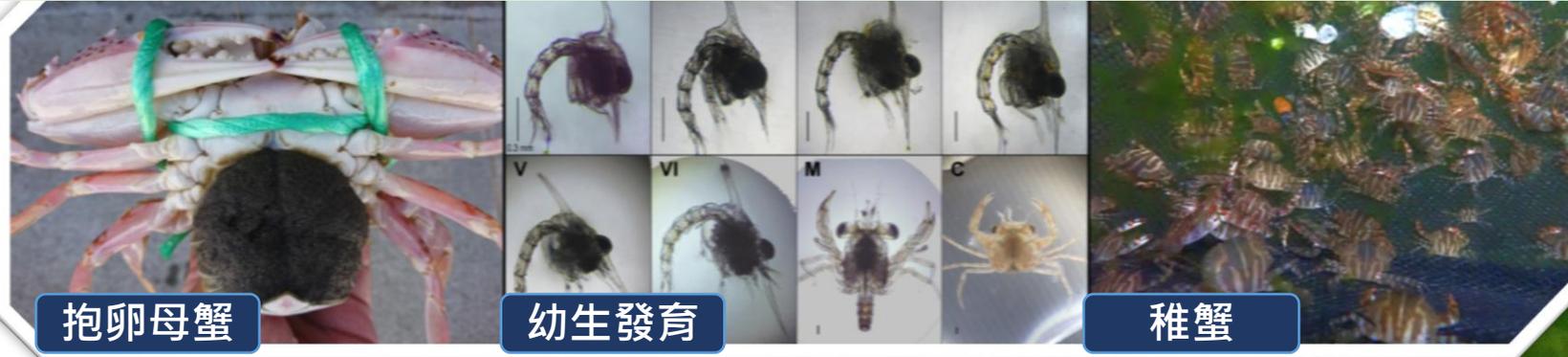
Action Developing training program for cuttlefish to save cost and move toward mass production.



Ma, C.-H., Lin, C.-H., Chang, Y.-C., Lee, H.-T., Liou, C.-H. and **Hsu, T.-H.*** 2022. Progressive training programs reveals the potential plasticity of artificial feed preference in juvenile pharaoh cuttlefish (*Sepia pharaonis*). *Frontiers in Marine Science* 9: 765272. (IF 2.8, Marine & Freshwater Biology: 88.7%, 14/119, Q1) (corresponding author)

Case 1 - Stock enhancement

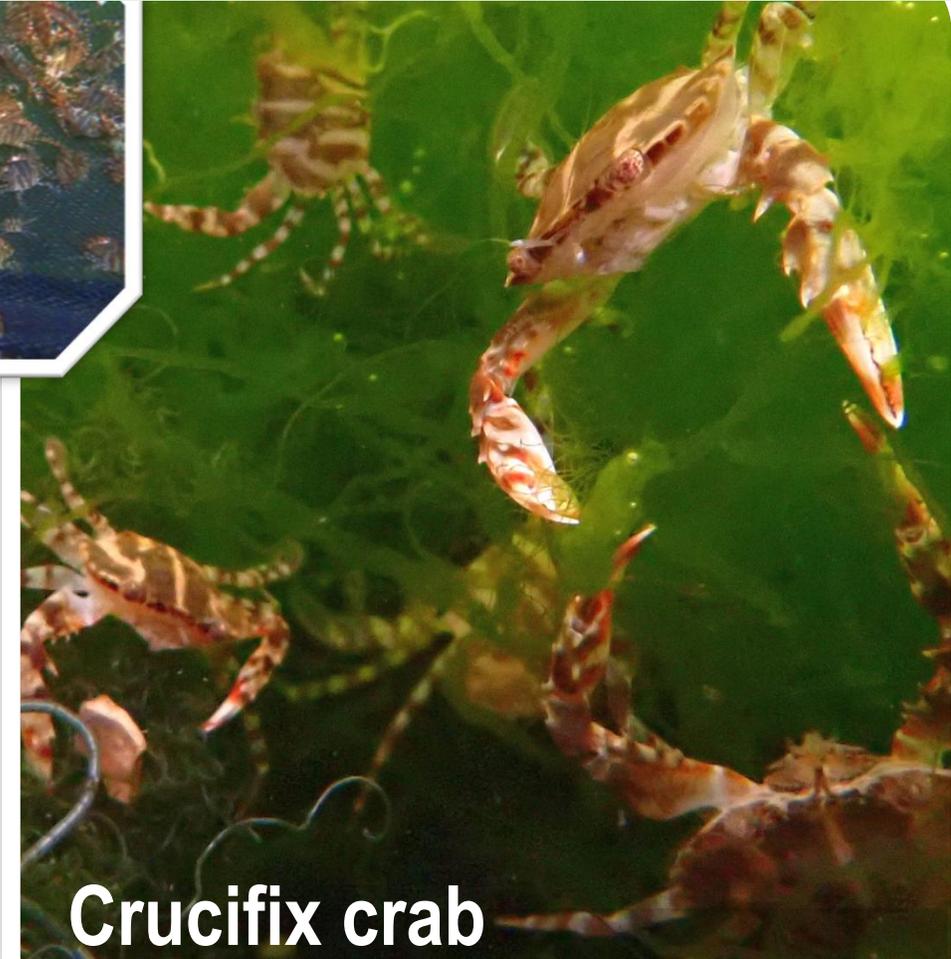
Action Developing breeding technology for crucifix crab.



- With Three-spot Crab and Rock Crab as "Wan-li Crab".
- Habitat in warm waters of the Indo-West Pacific.
- High price and big body size.
- Inhabits sandy mud and captured using crab traps.

Paper

Ma, C.-H., Huang, P.-Y., Chang, Y.-C., Pan, Y.-J., Azra, M.N., Chen, L.-L., and **Hsu, T.-H.*** 2021. Improving survival of juvenile scalloped spiny lobster (*Panulirus homarus*) and crucifix crab (*Charybdis feriatus*) using shelter and live prey. *Animals* 11: 370. (IF 2.7, Veterinary Sciences: 90.7%, 16/167, Q1) (corresponding author)



Case 1 - Stock enhancement

Action Cultivate microalgae and macroalgae for larvae rearing or water treatment.



Case 1 – Stock enhancement

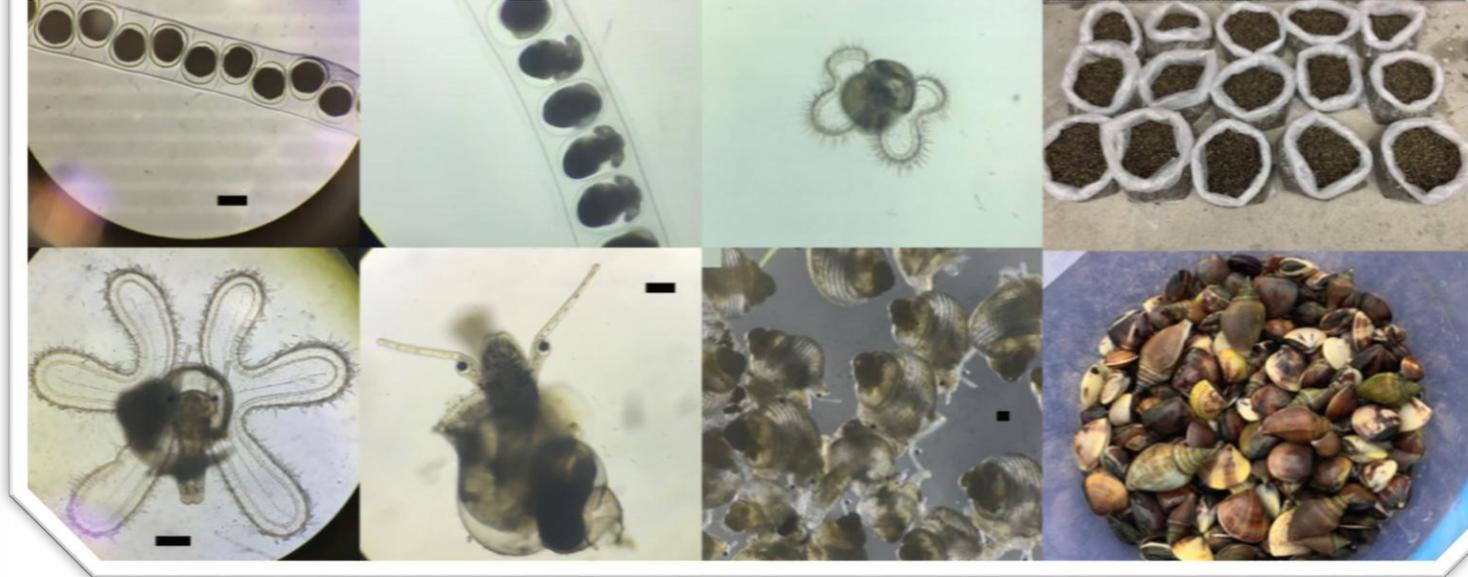
Action Developing IMTA breeding and rearing techniques, mass production for aquaculture



Dog conch

Laevistrombus canarium

Paper



- Indo-Pacific region, subtidal zone, seawater
- Muddy-sandy and coral sand bottoms
- Gathers in sandy seagrass beds

Chang, Y.-C., Ma, C.-H., Lee, H.-T. and **Hsu, T.-H.*** 2021. Polyculture of juvenile dog conch *Laevistrombus canarium* reveals high potentiality in integrated multitrophic aquaculture (IMTA). *Biology* 10: 812. (IF 3.6, Biology: 81.2%, 21/109, Q1) (corresponding author)

Case 1 - Stock enhancement

Action Developing IMTA breeding and rearing techniques, collecting stocks

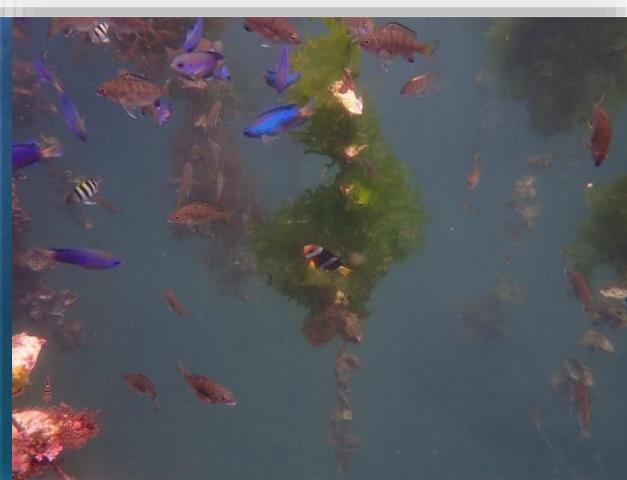
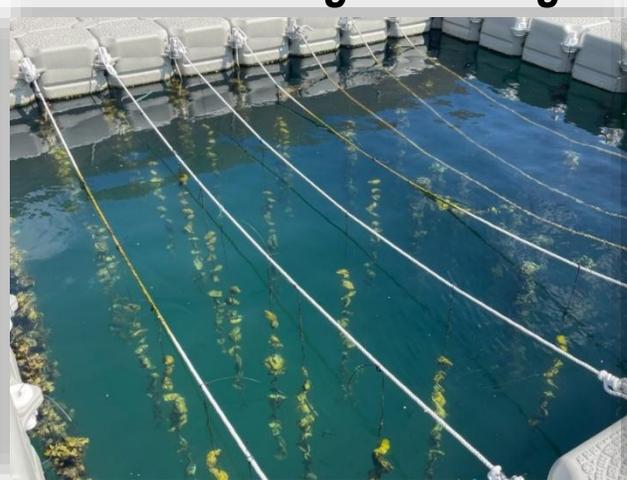
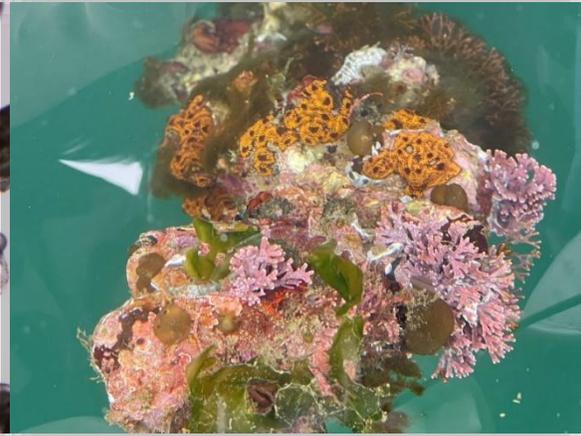
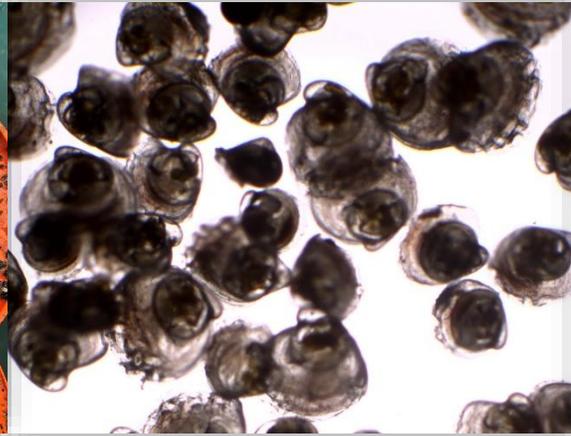


Case 1 - Stock enhancement

Action Oysters are used for habitat restoration and IMTA system.

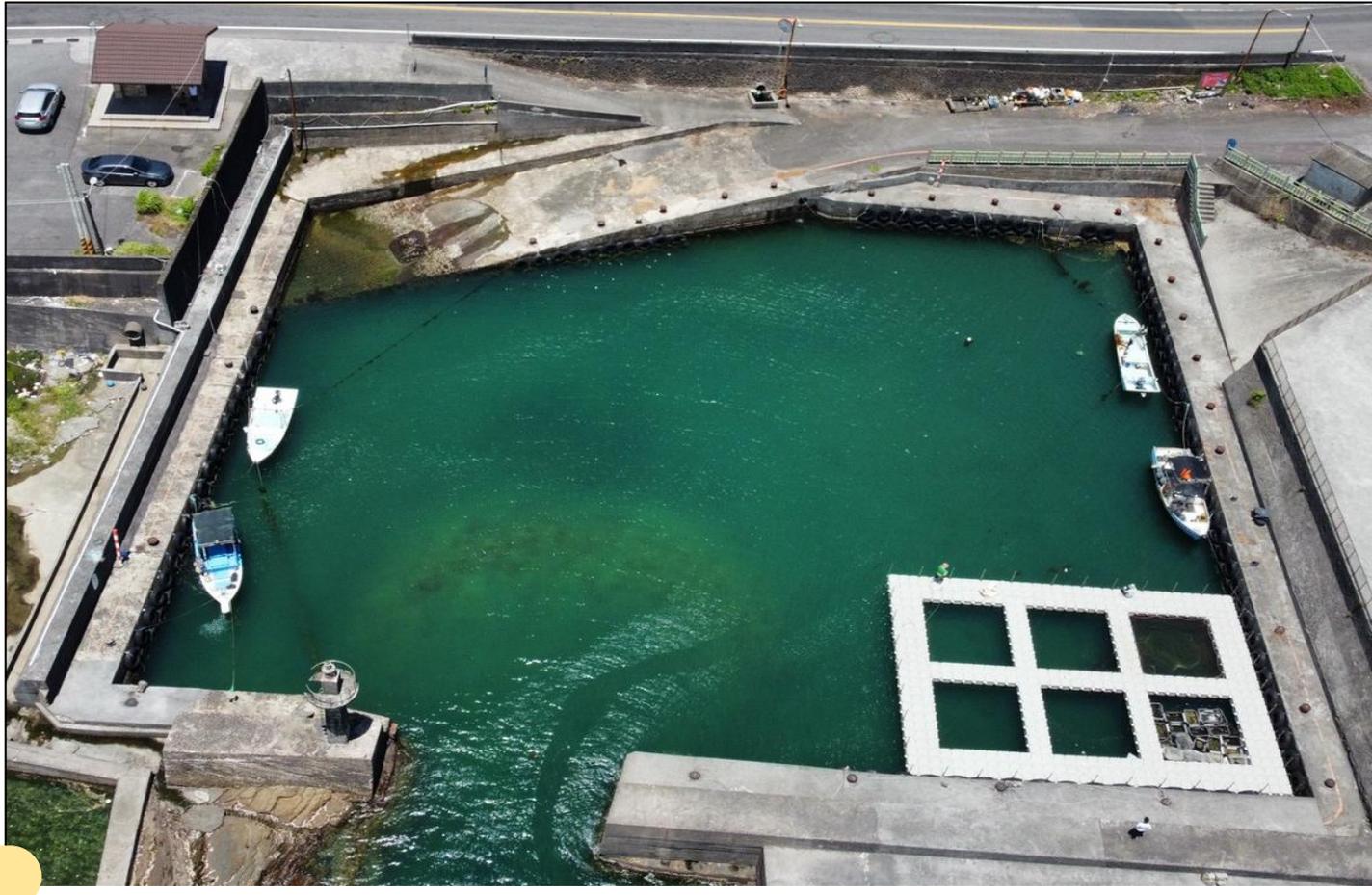


Portuguese oyster
Magallana angulata



Case 1 - Stock enhancement

Action The first IMTA cage-rearing system for stock enhancement in an underutilized fishing port.



Paper

Lee, H.-T., Chang, Y.-C., Liao, C.-H. and Hsu, T.-H.* 2022. Development of integrated multitrophic aquaculture-based cage rearing system in an underutilized fishing port and its application in marine stock enhancement. *Frontiers in Marine Science* 9: 998198. (IF 2.8, Marine & Freshwater Biology: 88.7%, 14/119, Q1) (corresponding author)

Case 1 - Stock enhancement

Action Habitat construction and releasing experiments were continued for two years.



Case 1 - Stock enhancement

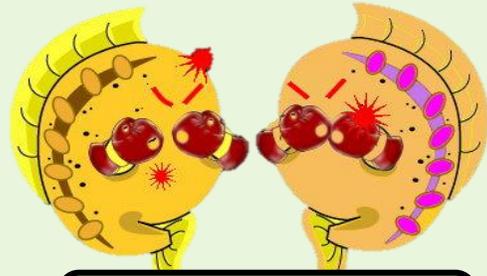
Action Habitat construction and releasing experiments were continued for two years.



Case 1 - Stock enhancement



Pathogens



Competition



Inbreeding



Hybridization

Stock enhancement

Genetic management

Fitness ↓

Genetic effect

Survival rate

Egg size, body size

Reproductive success

Genetic introgression

Outbreeding decrease

Genetic diversity ↓

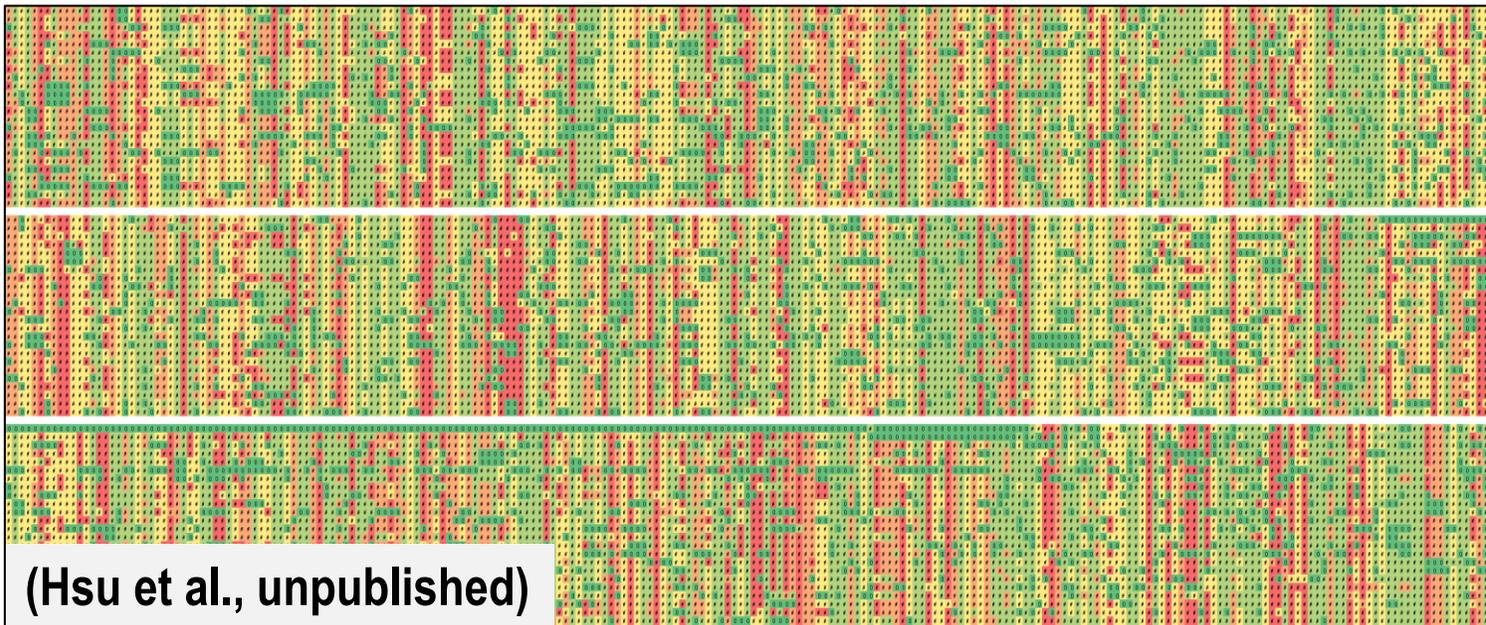
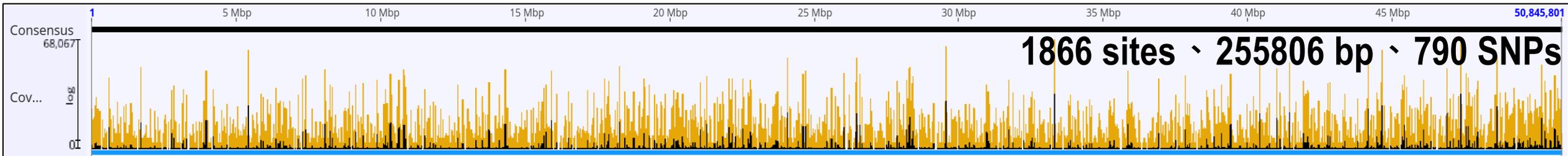
Case 1 - Stock enhancement

Action Application of eDNA, metabarcoding, and microbiota for released species.

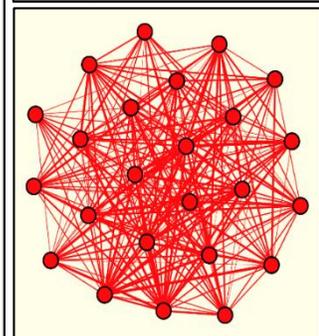
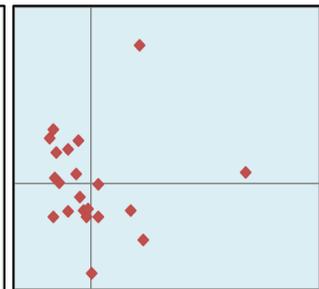
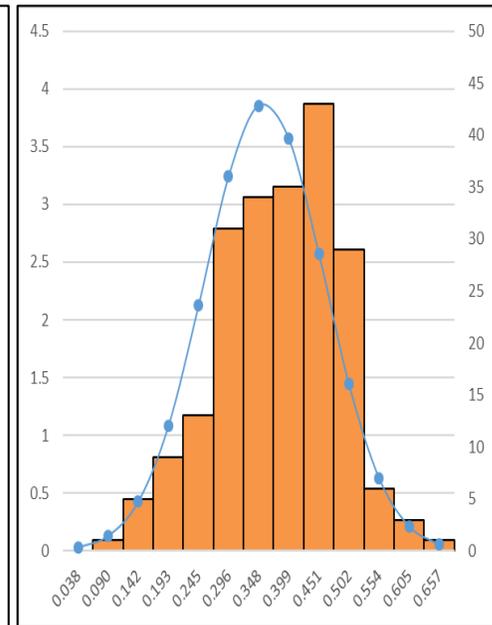
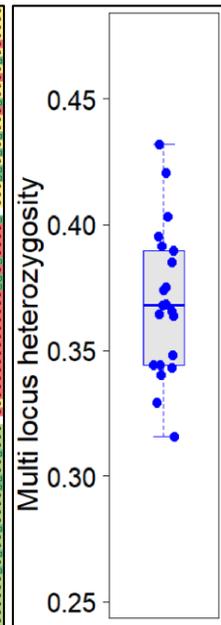


Oplegnathus fasciatus
Rock porgy

<i>N</i>	<i>Na</i>	<i>Ne</i>	<i>I</i>	<i>Ho</i>	<i>He</i>	<i>uHe</i>	<i>F_{IS}</i>
21	2	1.462	0.412	0.369	0.269	0.277	-0.222



(Hsu et al., unpublished)



Case 1 - Stock enhancement

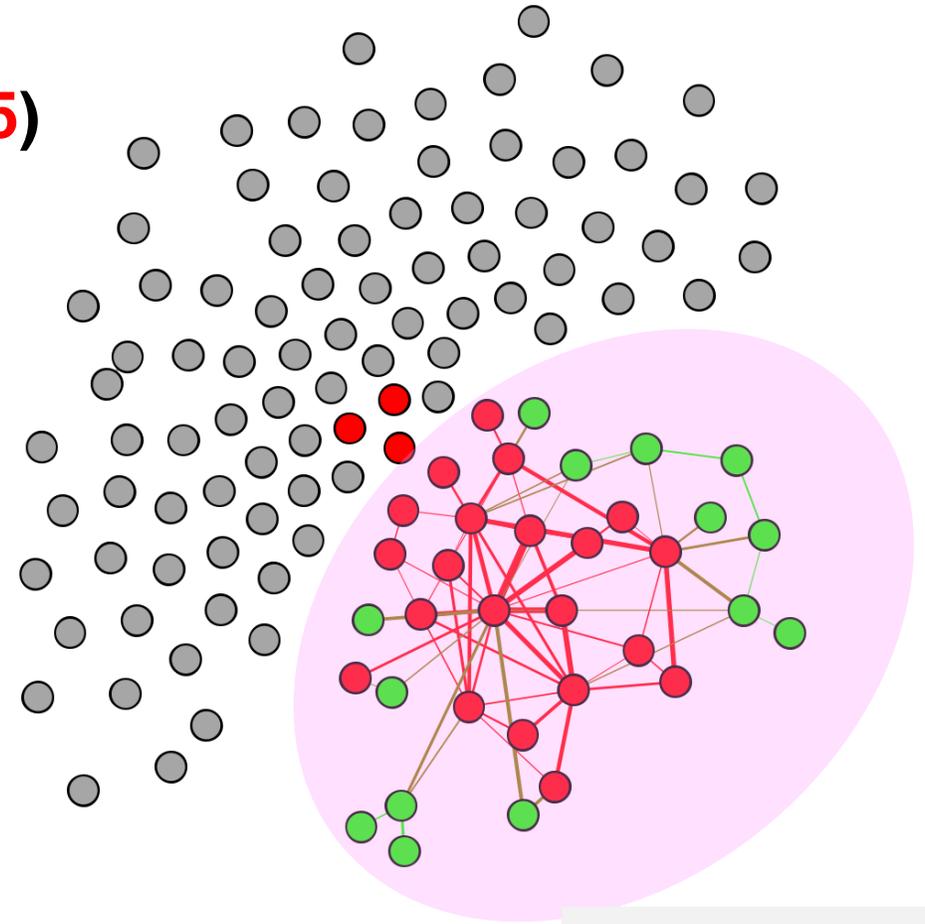
Action Source tracing by using NGS-based molecular markers and kinship network.



Kinship network (> 0.5)

$$14/96 = 14.6\%$$

-  Hatchery sample 24
-  Wild (from hatchery) 14
-  Wild (wild) 82

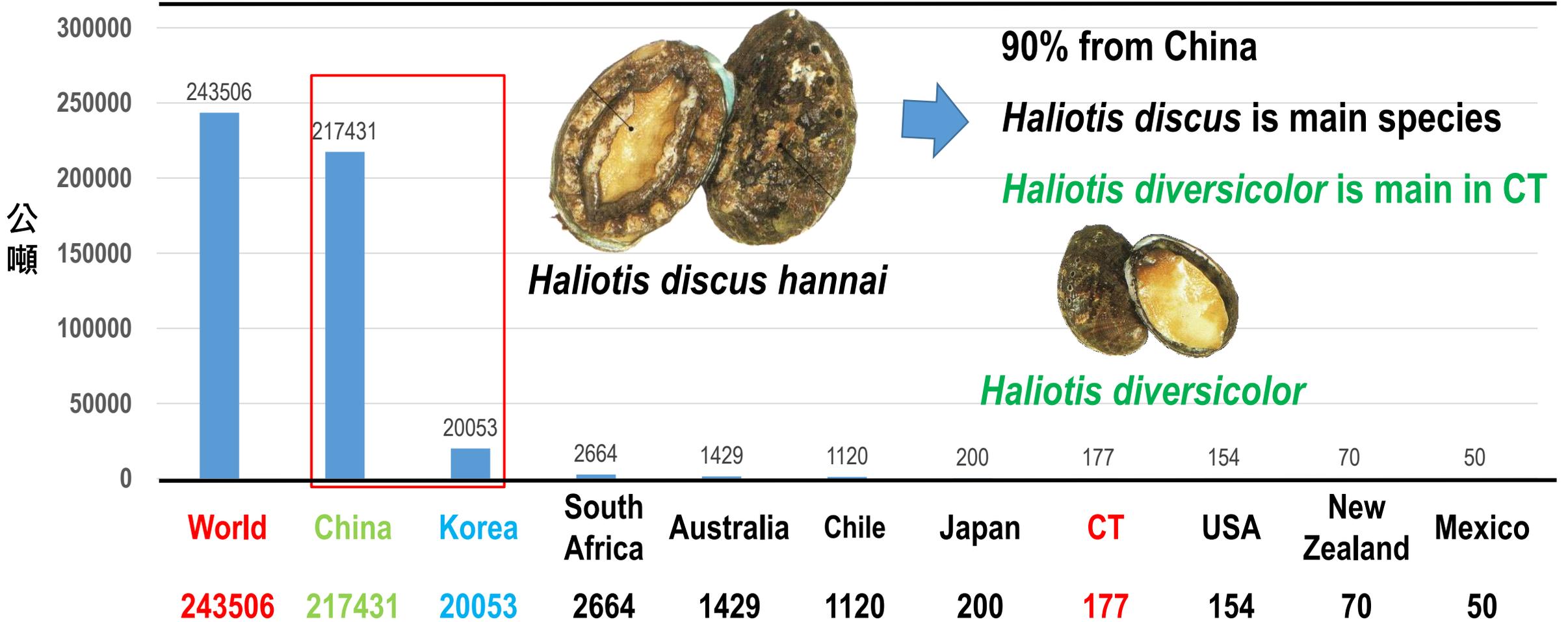


(Hsu et al., unpublished)

Case 2 - Small abalone

2020-2021 Aquaculture production

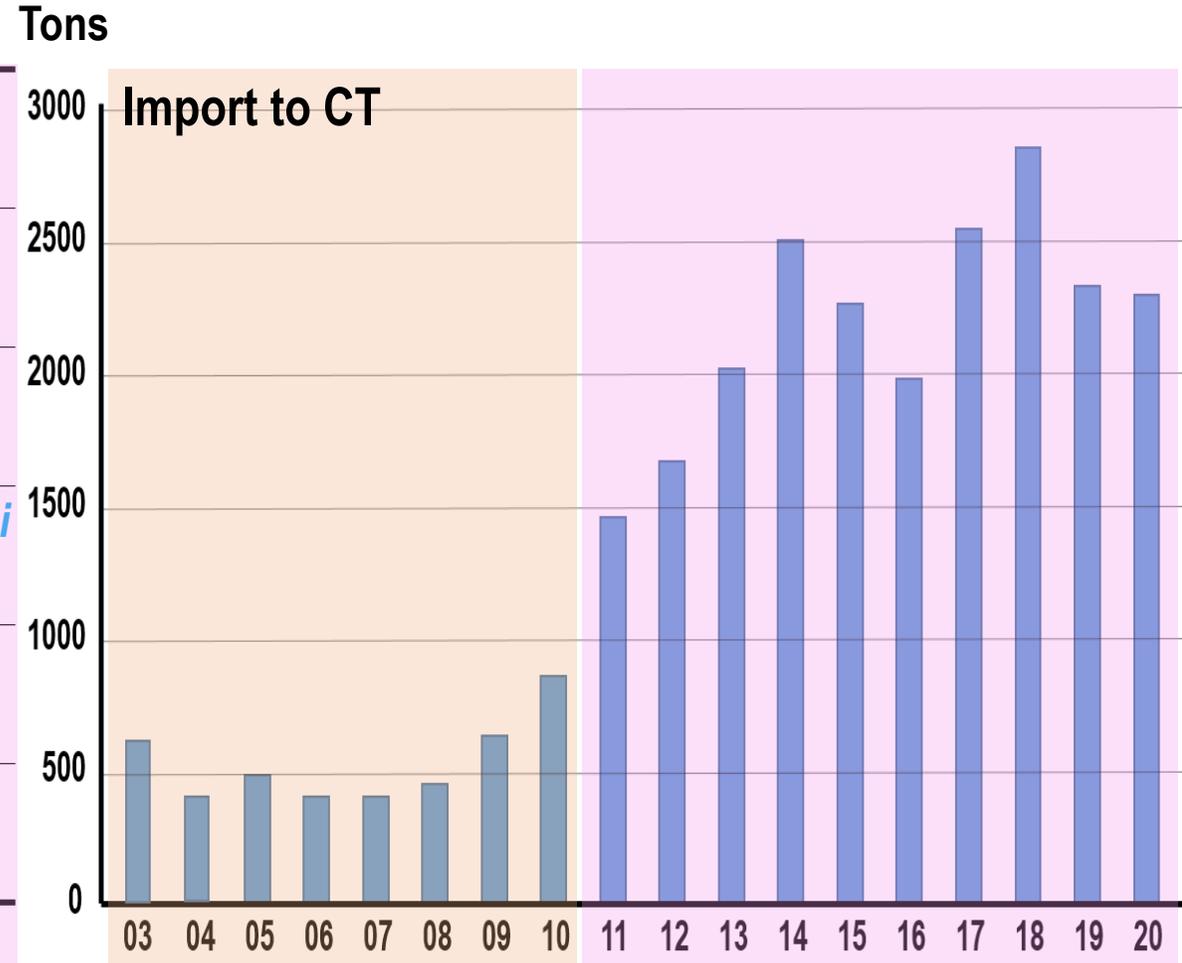
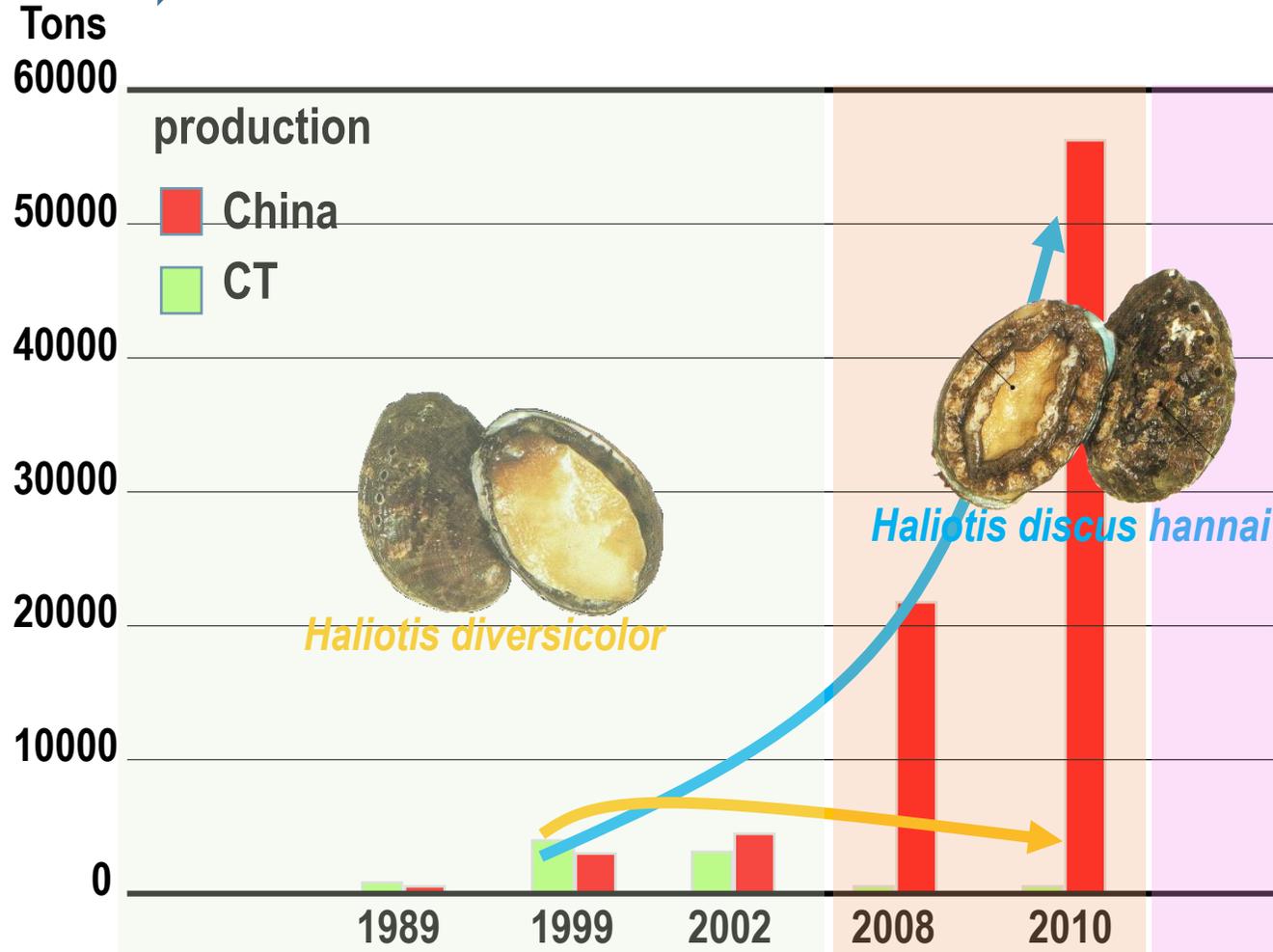
Cook (2023)



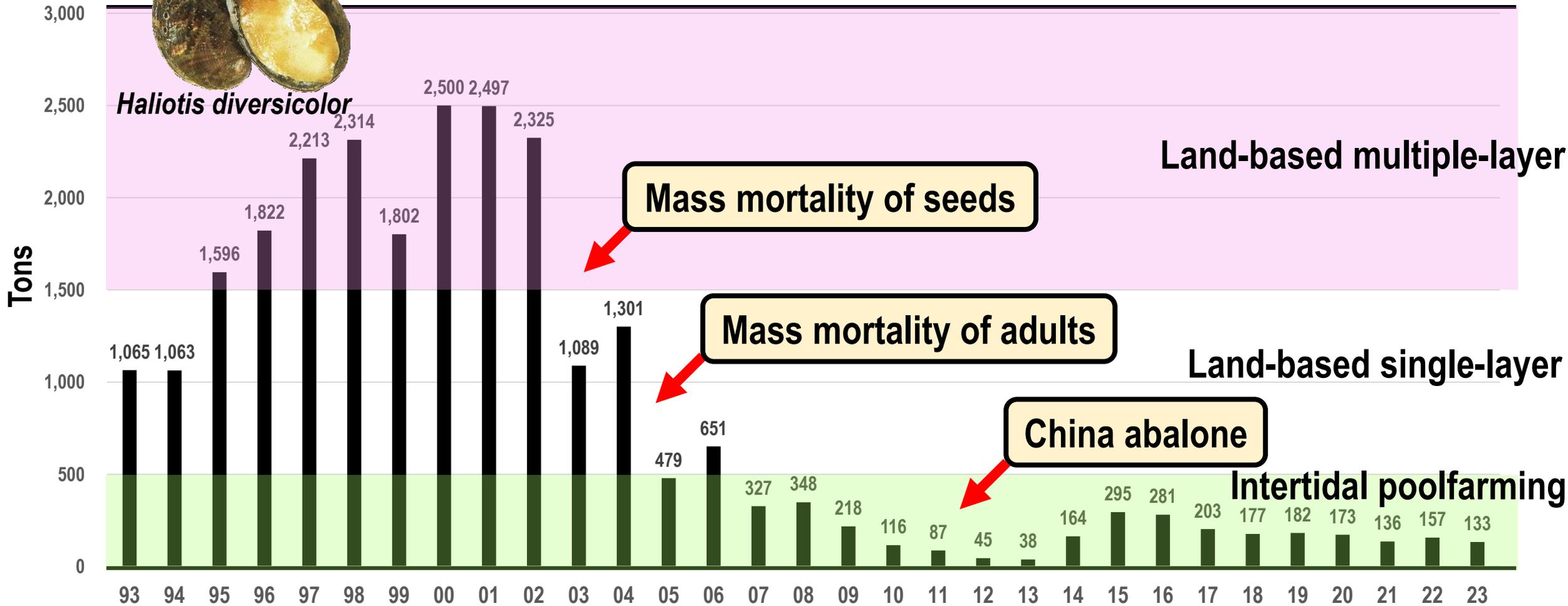
Case 2 - Small abalone

➔ More than 160000T in 2018 of China

➔ About 2800T in 2018



Case 2 - Small abalone

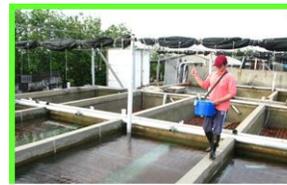


漁業年報(1993~2010)；新北市政府(2011~2023)

Case 2 - Small abalone

Action Genetic management and breeding programs, mass production for releasing

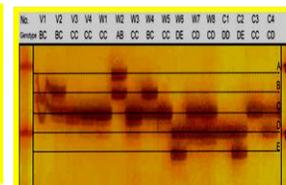
small abalone
Haliotis diversicolor



Management



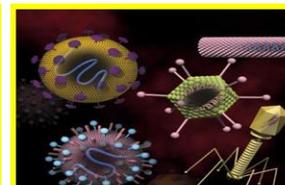
Environment



Genetics



Food



Disease



culture system

- To record "indicators"
- (1) Operating location
 - (2) Operating time
 - (3) Members
 - (4) Operating steps
 - (5) No. of stocks
 - (6) Spawning time (male)
 - (7) Spawning time (female)
 - (8) Fertilization rate
 - (9) Deformity rate
 - (10) Metamorphosis rate
 - (11) 7 days survival rate
 - (12) Seawater Temperature
 - (13) Air Temperature

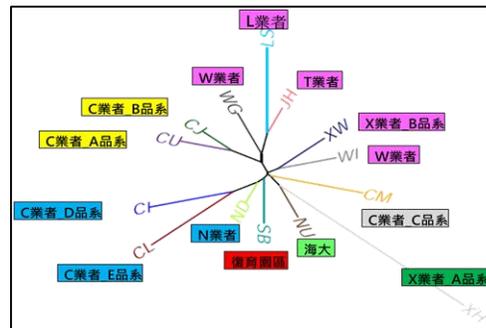
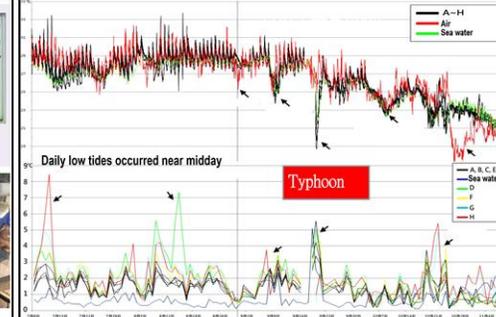


Introducing **WaterLink SpinTouchFX**

Test Parameter Range
 Alkalinity 0-300 ppm
 Ammonia NH₃ 0-40 ppm
 Calcium 200-800 ppm
 Magnesium 500-2000 ppm
 Nitrate NO₃ 0-80 ppm
 Nitrite NO₂ 0-2.0 ppm
 pH 6.5-10.0 pH
 Phosphate PO₄ 0-2.0 ppm

Test Results
 199.5 mVpH
 1.60 pH
 220.6 ORP
 29 %DO
 2.2 ppmO₂
 96 µS/cm
 23 °C

手持式分光光度計 兼具精準及使用方便 手持多功能水質儀 水質物理性質測定



Paper

Hsu, T.-H. and Gwo, J.-C. 2017. Genetic diversity and stock identification of small abalone (*Haliotis diversicolor*) in Taiwan and Japan. PLoS ONE 12:e0179818. (IF 3.752, Multidisciplinary Sciences: 61%, 29/74, Q2)

Case 2 - Small abalone

Action Genetic management by using NGS-based molecular markers and kinship network.

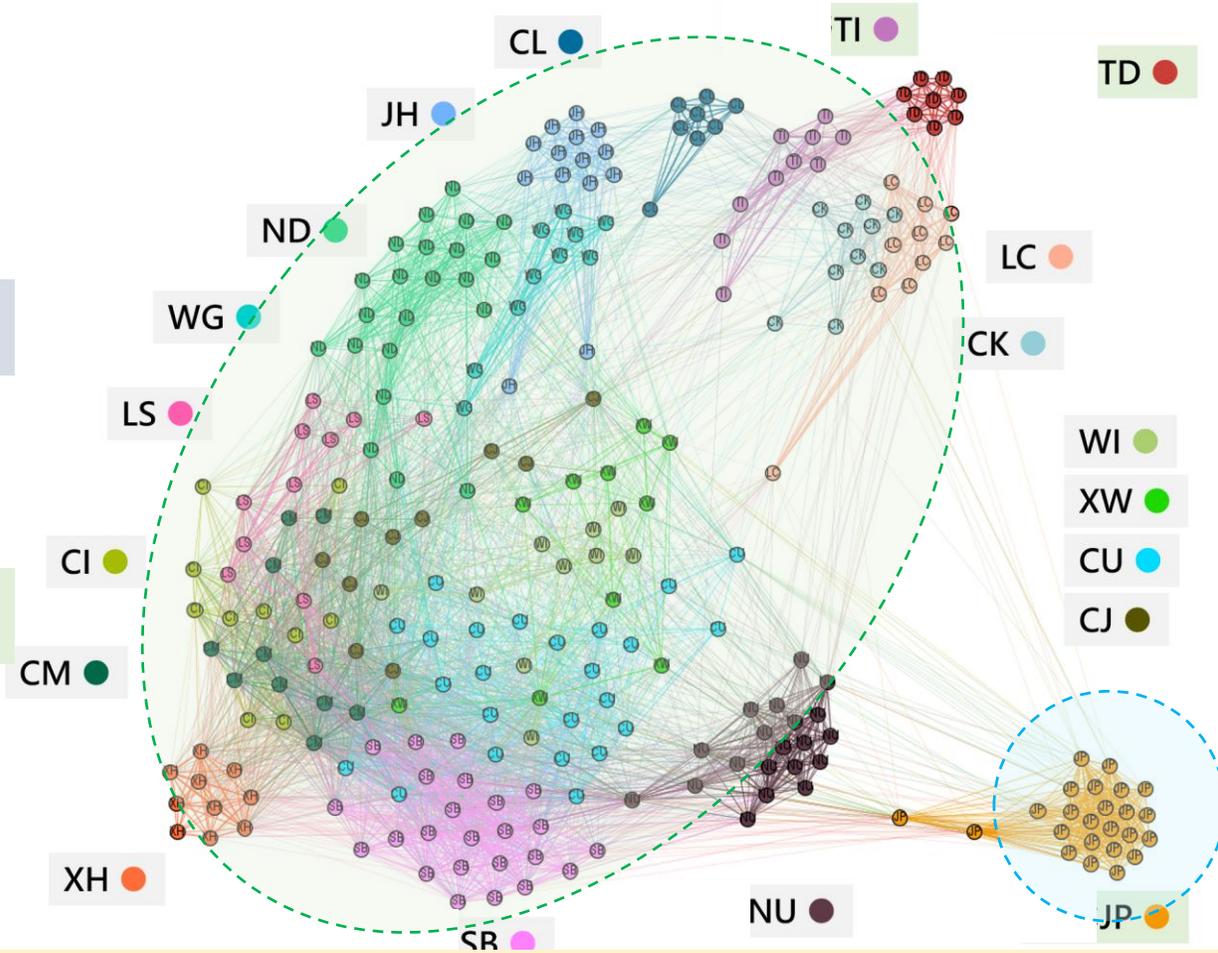


small abalone
Haliotis diversicolor

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High survival rate

High growth rate



Paper

Chang, Y.-C., Nan, F.-H., Hsu, T.-H.* 2024. Genetic management of small abalone (*Haliotis diversicolor*) by using ISSRseq technology. *Aquaculture Reports*. (IF 3.2, Fisheries: 84.7%, 10/62, Q1) (corresponding author)

Case 2 - Small abalone



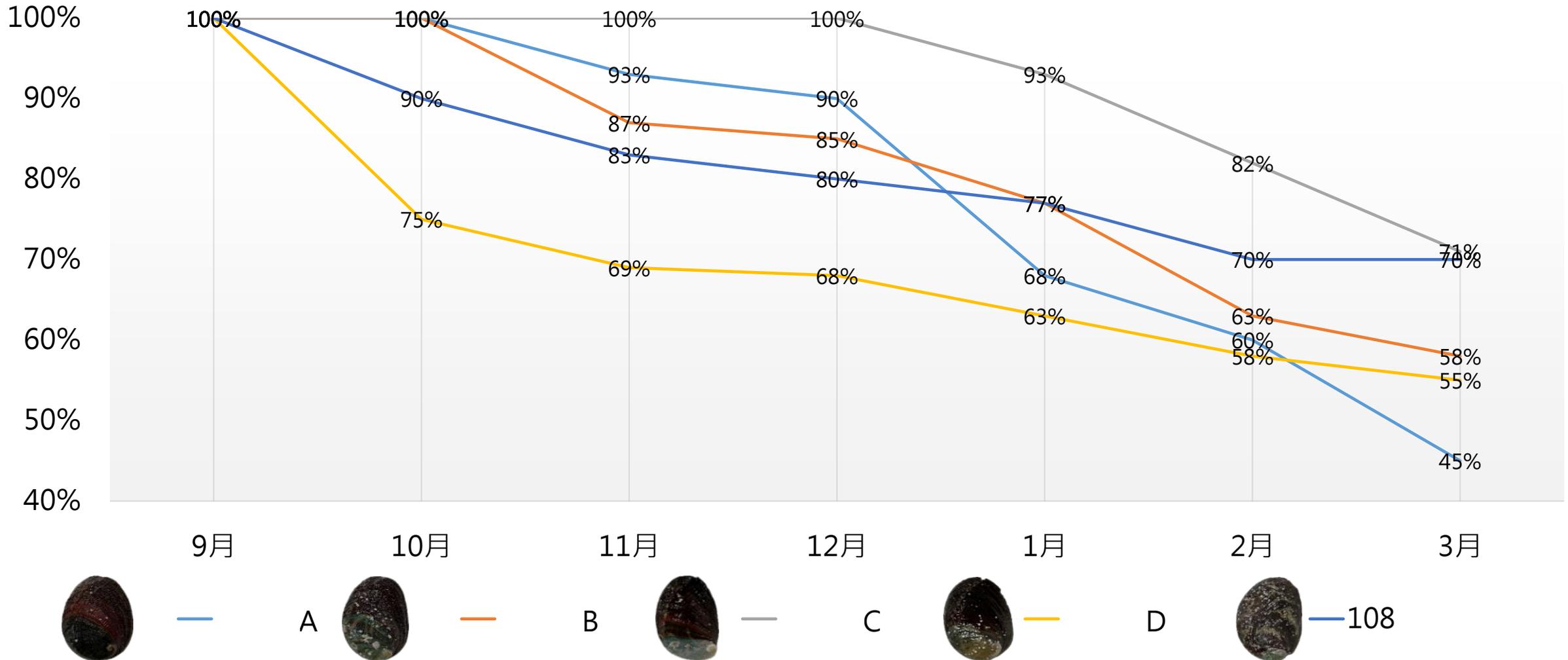
Case 2 - Small abalone

Action Track fast-growing individuals and distinguish them from different sources.



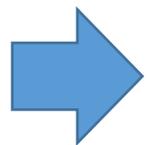
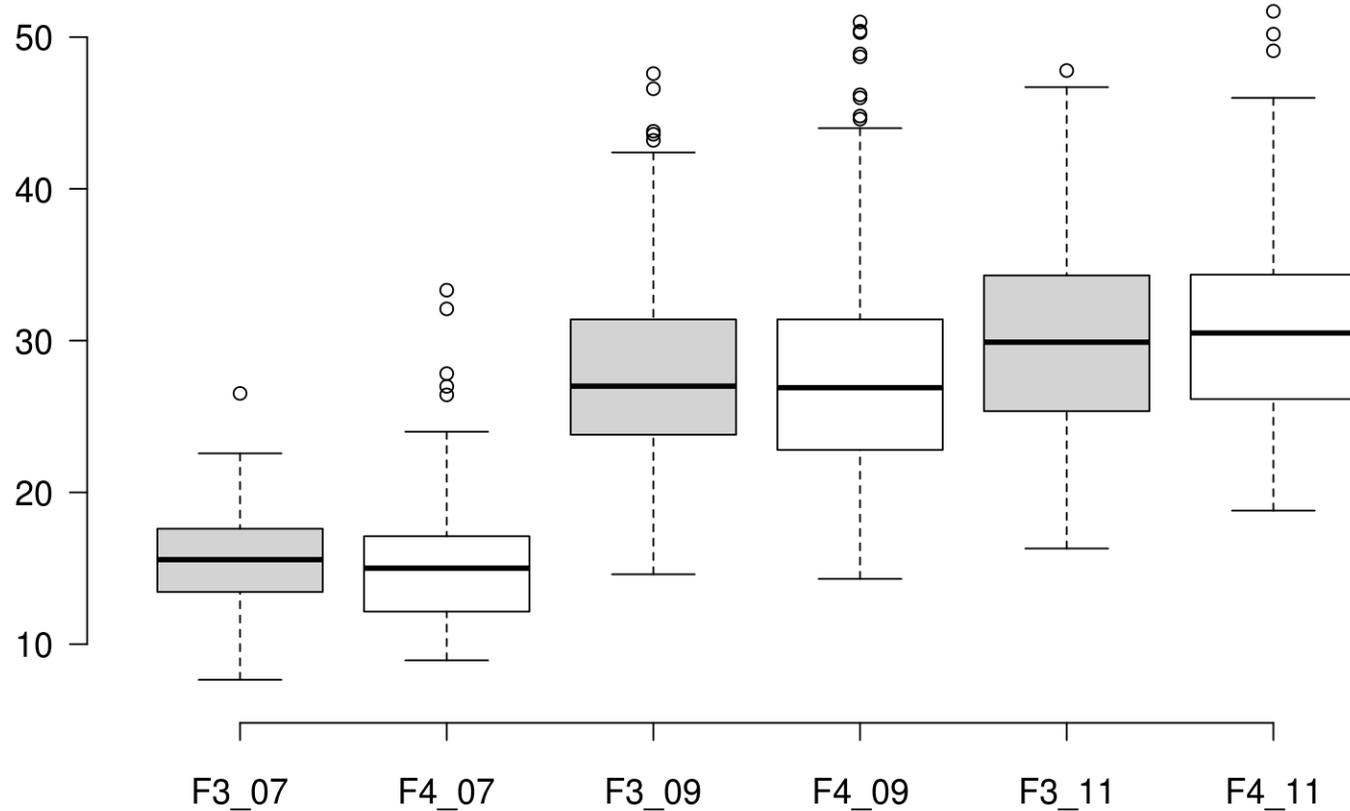
Case 2 - Small abalone

Action High survival rate strains were selected

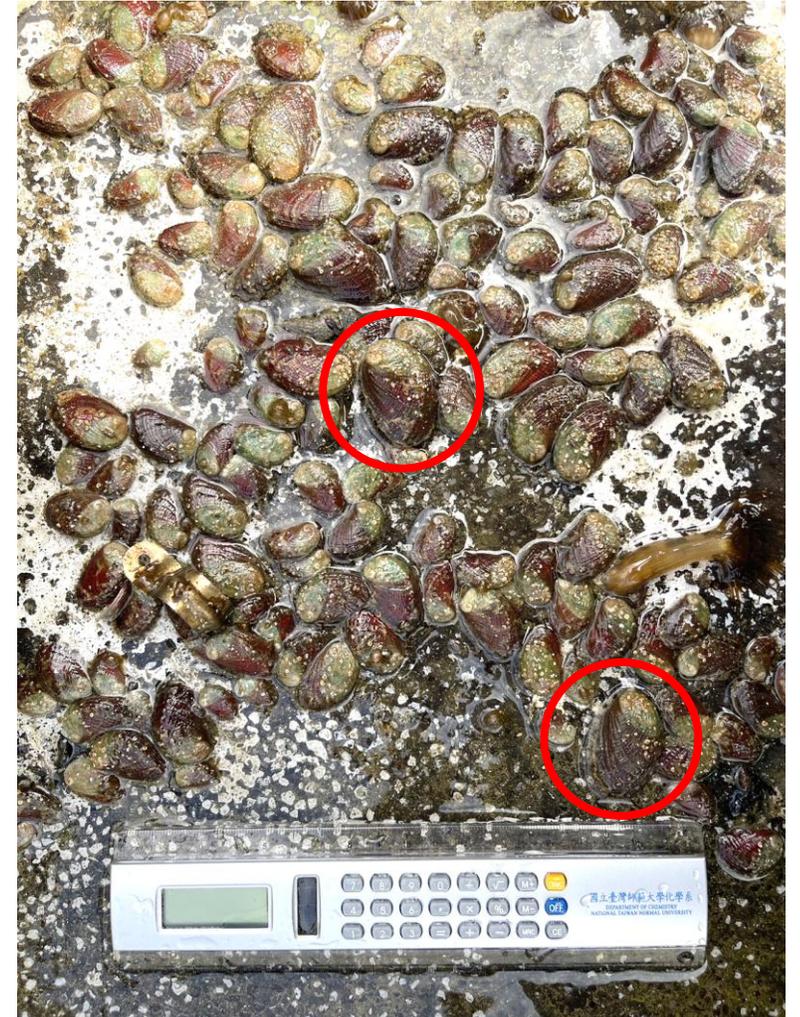


Case 2 - Small abalone

Action High growth rate individuals were selected



1% individuals were selected



Case 3 - Hard clam

Issue In recent years, extreme weather has often caused mass mortality of hard clams.

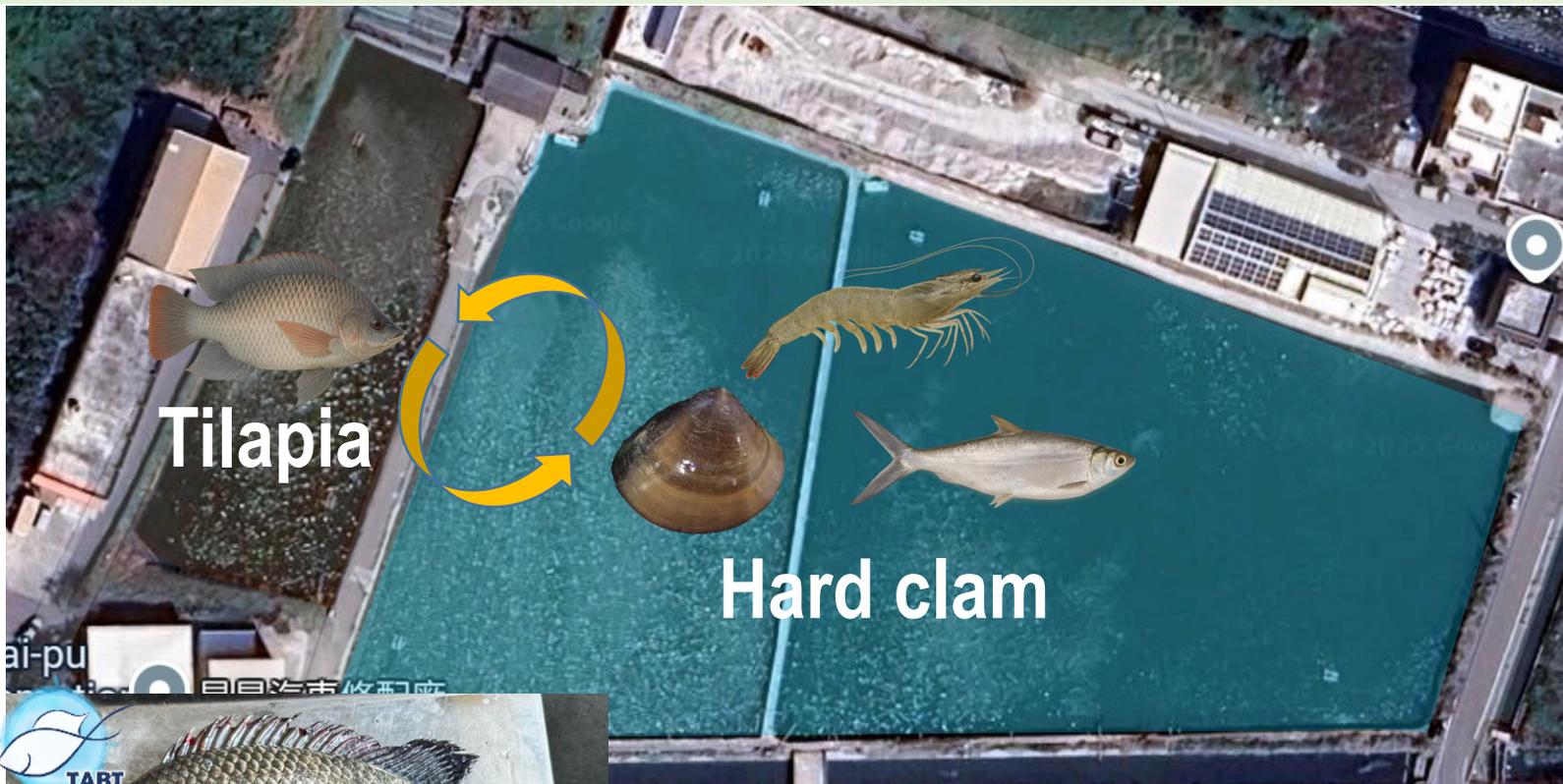
文蛤突暴斃

二月起至五月



Case 3 - Hard clam

Action Developing IMTA mass production system for hard clam aquaculture



海大育種團隊新品系臺灣鯛田間合作交流



Case 3 - Hard clam

Action Developing IMTA breeding and rearing techniques, mass production for aquaculture



Case 3 - Hard clam

Action Developing brackish water IMTA system for pig manure liquid digestate recycling

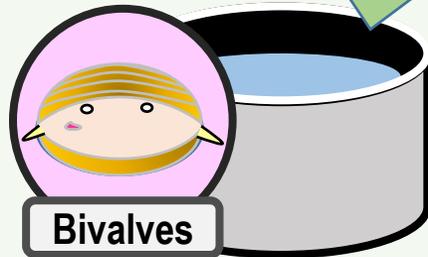


solid-liquid
separation

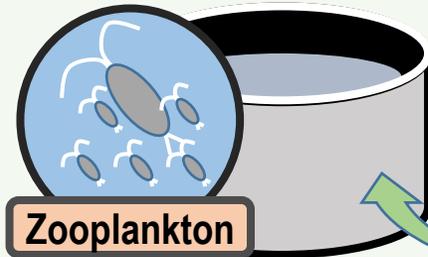
anaerobic
digestion

liquid digestate
High $\text{NH}_4^+/\text{NH}_3/\text{PO}_4^{3-}$
 $\text{NH}_3/\text{NH}_4^+ > 100 \text{ ppm}$

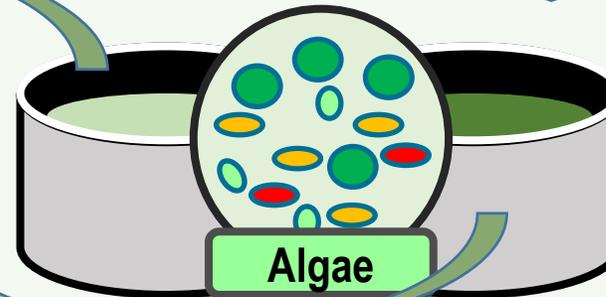
dilute 10-100x



Bivalves



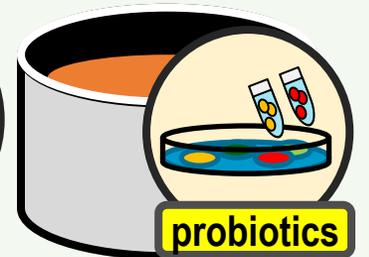
Zooplankton



Algae



macroalgae



probiotics

microalgae $< 1.0 \times 10^4$
 $\text{NH}_3/\text{NH}_4^+ < 0.1$

$< 1.0 \times 10^5$
 $\text{NH}_3/\text{NH}_4^+ < 1$

$< 1.0 \times 10^6$
 $\text{NH}_3/\text{NH}_4^+ < 10 \text{ ppm}$

$\text{NH}_3/\text{NH}_4^+ < 5$

Keep 7 days or dilute $> 10x$

Paper

Chang, Y.-C., Pan, Y.-J., Huang, T.-H., Hsiao, T.-H., Wei, L.-Y. and Hsu, T.-H.* 2023. Cultivation of brackish water microalgae for pig manure liquid digestate recycling. Sustainability 15:16278. (IF 3.9, Multidisciplinary: 62.9%, 48/128, Q2) (corresponding author)

Conclusion

To make small-scale aquaculture more sustainable, we need policy support, scientific tools, and local action. By working together, involving young people, promoting international collaboration, and encouraging overseas exchanges and hands-on learning for students and young fishers, we can create a stronger and more lasting blue economy.

