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Integrated Aquaculture in China

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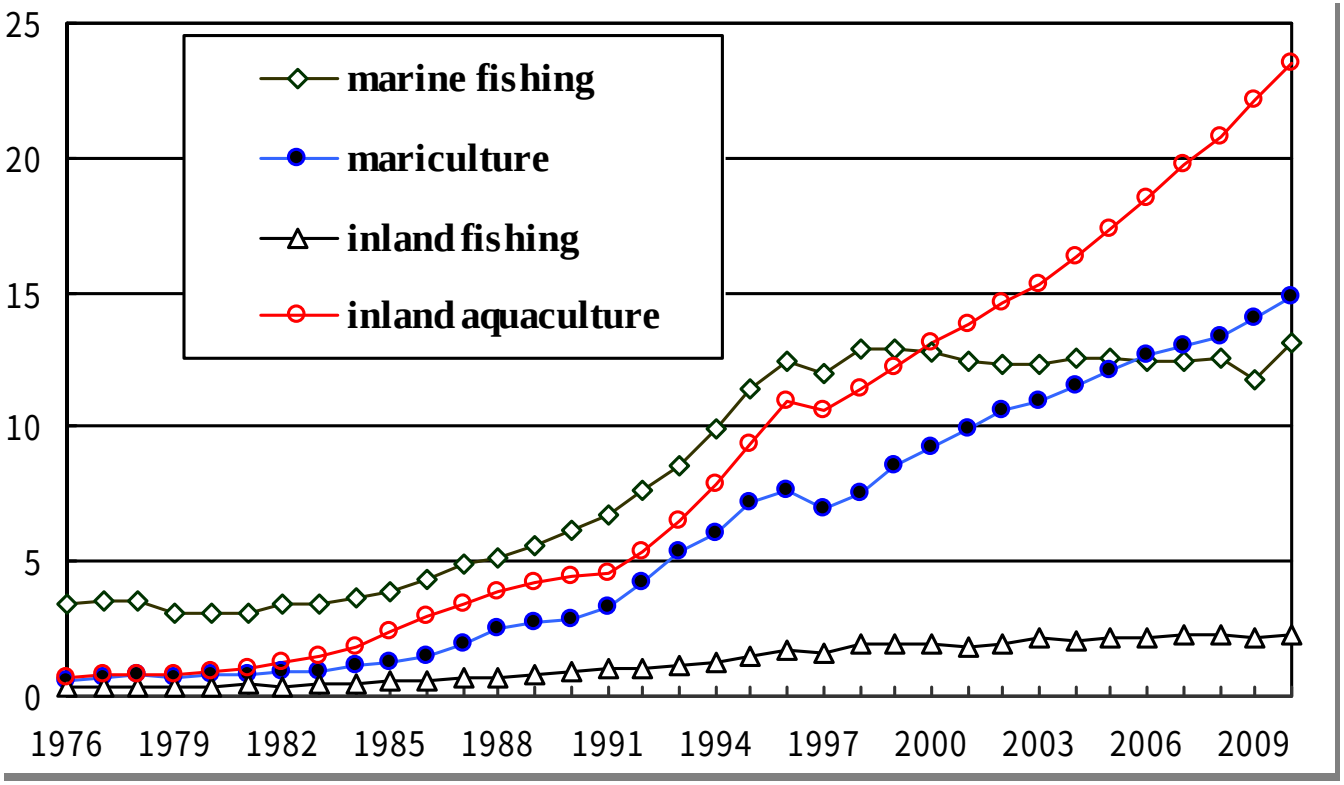
Outline

1. Necessity of Integrated Aquaculture
2. History of INTAQ in China
3. Rationales of INTAQ
4. System classification of INTAQ
5. Current practices of integrated mariculture in China

Aquaculture in China is developing rapidly

In 1988 aquaculture production overrun capture production.

In 2010 71.3% fisheries production (5373 mt) from aquaculture



Fisheries production in China mainland (mt)

Trends of aquaculture development in China

3.49

Intensification of aquaculture systems

Increment of farmed species

0.24

Increment of quantity of high trophic level species

Increment of fishmeal ratio

0.14

kWh/Kg

Increment of energy consumption

(Dong, 2009)

Pollution derived from aquaculture is not negligible

Cui et al. (2005) estimated that N and P discharged from mariculture along coast of Yellow Sea and Bohai Bay was 2.8% and 5.3% of total land-sourced pollutants of these areas in 2002.

Cheng (2009) estimated that in 2008 N discharged from net cage and pond of mariculture is 37,000t and 450 000t, respectively, however, N discharged from city domestic sewage is about 900 000t.

Integrated aquaculture

Integrated aquaculture is defined as the polyculture of multiple aquatic species, or the culture of aquatic species within or together with other productive activities.

(Dong, 2011)

Soto, 2009

- **Additional products**
- **Reduction of waste discharge**
- **Improving culture environment for recirculation**
- **Habitat preservation**
- **Improving growth of target species**
- **Prevention of harmful bacteria**
- **Removal of pest species, or seed from unwanted spawning**

2. History of INTAQ in China

“The Seasonal Food of WEI Wuwang”

(220-265 A.D.)

“A jam was made from the common carp with yellow scales and red caudal fin, which came from paddy field”

“The Curious in Lingbiao Region”

(Xun LIU, 889-904 A.D.)

“In the spring water was stored in ponds, then grass carp was bought and stocked into the ponds. After one or two years the fish had already grown up and wild weeds were grazed by the fish, meanwhile, the paddy fields were also fertile.”

Interpretation of mutually profitable

“Jiatai Notes” (1201-1204 AD)

“Around the south of Huiji and Zhuji regions of Zhejiang Province many people worked as fish farmers. In early spring fingerlings were bought and stocked into ponds…, most of them were bighead carp, silver carp, common carp, grass carp and black carp”

“Complete Book on Agriculture”

(Guangqi XU,1639)

“In early spring about one cun (a unit of length (=1/3 decimeter)) of fingerlings were bought, 600 silver carp and 200 grass carp were stocked into a pond, only the grass carp was fed with grass”

Different trophic fishes

"Complete Book on Agriculture"

(Guangqi XU,1639 AD)

Every morning the faeces of the sheep were swept into the pond as feed or fertilizer.

"The New Story of Canton"

(Dajun QU, about 1700 A.D.)

Integration of dike-pond was very popular in Pear River Delta.

Large scale integrated mariculture of kelp and mussel was done in Penglai, Shandong Province in 1975 (Xie, 1981)

3. Rationale of Integrated Aquaculture

Currently there are several dozen types of INTAQ in China, which are basically based on:

① **Waste reclamation through trophic relationship**

② **Making full use of the resources of aquaculture waters**

time

space or/and natural food

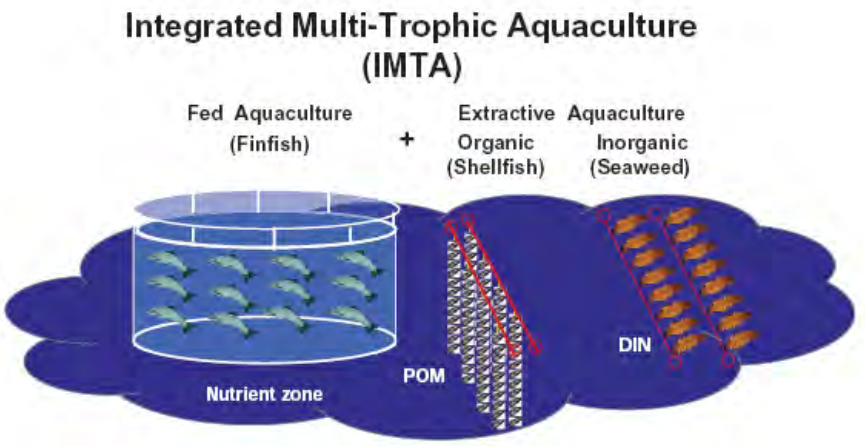
③ **Ecological balance maintenance by complement or commensalism**

of technical measures

of farmed species or production systems

(Dong, 2011)

① Waste reclamation through trophic relationship

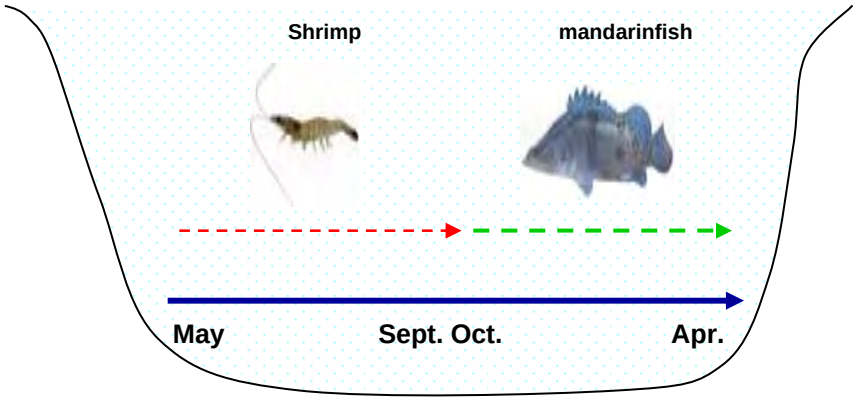


XU (1639) recorded that 600 silver carp and 200 grass carp fingerlings in pond, only the grass carp was fed with grass.

Li (1986) suggested that common carp cultured in cages with silver carp stocked outside in a waters. Common carp fed pellet, its faeces and residual feed can be filtered by silver carp or can promote the growth of plankton. The phytoplankton in turn can be filtered by silver carp as food.

"An output from one subsystem in an integrated farming system, which otherwise may have been wasted, becomes an input to another subsystem …" (Edwards et al., 1988)

② -1 Making full use of the resources of aquaculture waters --- Time

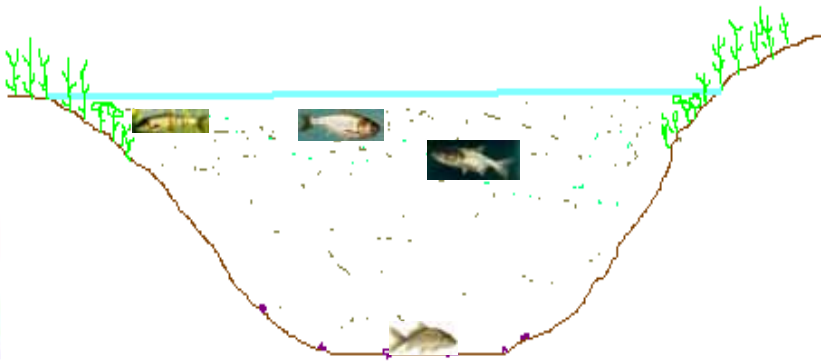


Integration of shrimp and mandarinfish in pond

Integration of sea cucumber, jellyfish, shrimp and scallop

②-2 Making full use of the resources of aquaculture waters --- Space or/and natural food

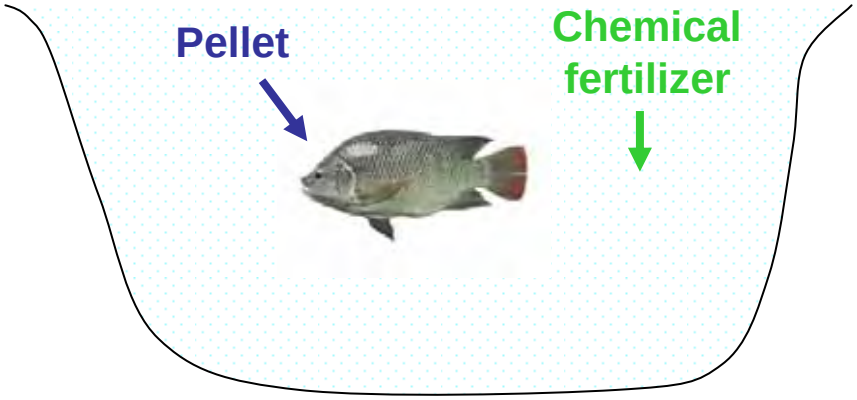
Integration of sea cucumber, jellyfish, shrimp and scallop

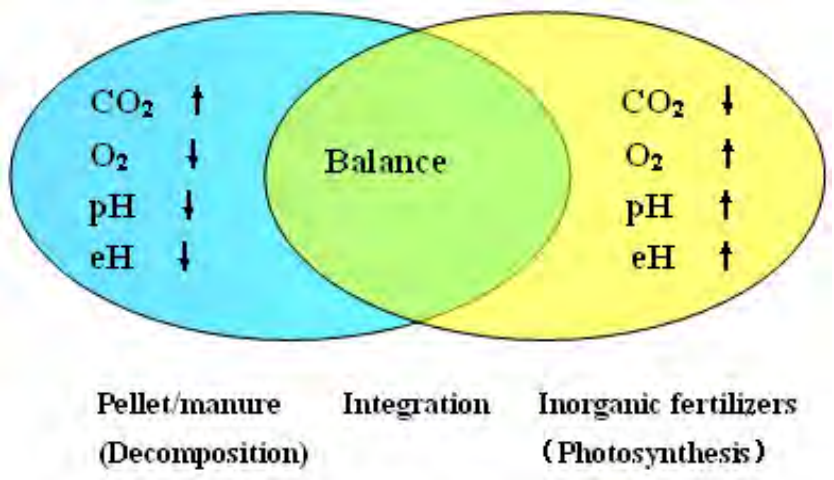


Stocking carps in farming waters

Sea cucumber – deposit feeder, bottom
Jellyfish - zooplankton feeder, upper water, summer
Scallop – phytoplankton filter, upper water, autumn-spring
Shrimp - benthos feeder, summer

③-1 Ecological balance maintenance by complement or commensalism -- technical measures





Tilapia in pond with pellet and chemical fertilizer

In the process of decomposition of residual feed (organic manure) DO, pH and redox potential will go down and CO_2 concentration will go up. However, After applying chemical fertilizer the phenomenon are just opposite, likes photosynthesis.

Good use of complementary function of pellet and chemical fertilizer

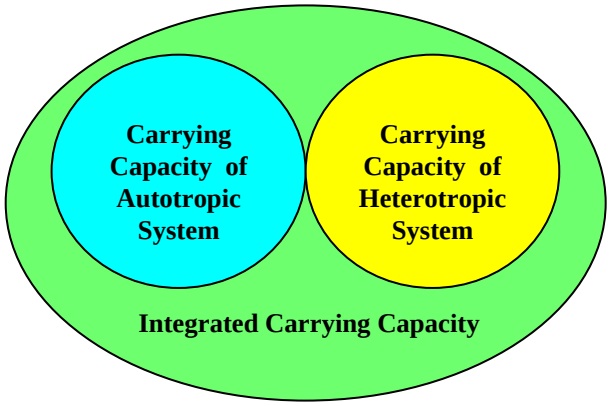
③ -2 Ecological balance maintenance by complement or commensalism -- farmed species or systems

Aquaculture organisms can be categorized into fed species and extractive species (Chopin et al., 2001).

Aquaculture systems can be categorized into autotrophic and heterotrophic systems (Dong et al., 1998).

Characteristics of autotrophic and heterotrophic cultural systems

	Autotrophic	Heterotrophic
Example	Kelp culture	Cage culture of fed fish
Energy	Solar radiation	Pellet feeds
O_2	Produce	Consume
CO_2	Uptake	Exhale
Inorganic nutrients	Absorb	Excrete
Eutrophication	Delay	Accelerate



Ecological effect of two complementary systems

Lao Zi (about 600-500 BC)
philosopher
"Reversal is the movement of Tao "

Confucius (551- 479 BC)
educationalist
"golden mean"

Maxim: "Never too much"
Unity of opposites in integrated aquaculture

Affected by this thinking mode ancient Chinese invented the fish-rice integration (889-904 AD) and integration of grass carp and silver carp in pond (1639 AD), in which the relationships of the both opposite or complement exhibit thoroughly.

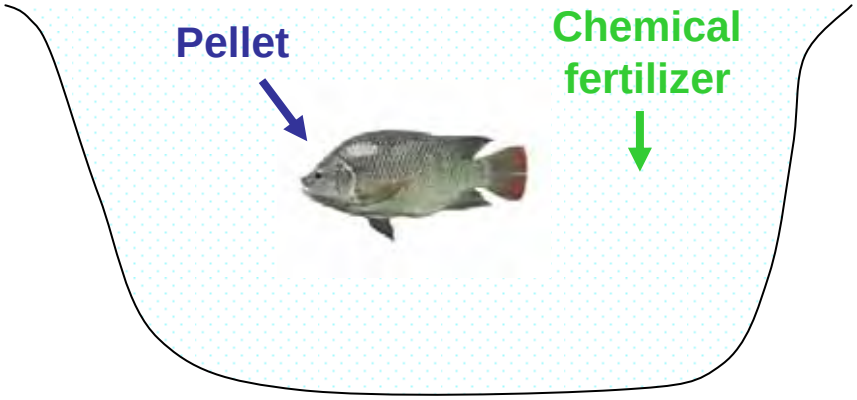
4. System Classification of INTAQ

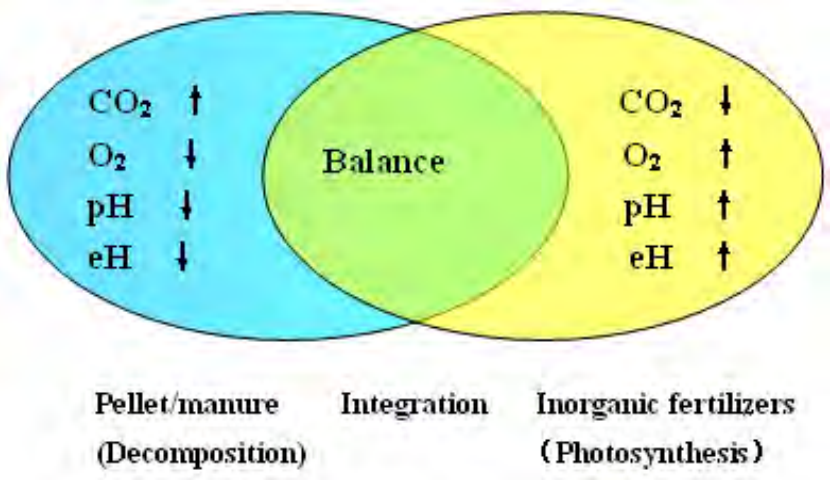
System classification of INTAQ

Groups		Types	Examples
Ⅰ Technique integration			Feeds-chemical fertilizers
Ⅱ Species integration		Ⅱ-1 Trophic integration or	Grass carp and silver carp; prawn and razor fish
		Ⅱ-2 Spatial integration	Fishes in pond
		Ⅱ-3 Rotary stock and harvest	Prawn and crab
		Ⅱ-4 Temporal integration	Prawn and fish
		Ⅱ-5 Multi-function integration	Integration of sea cucumber and so on
		Ⅱ-6 Other integration	Puffer fish and prawn for disease prevention; mandarin fish and bait fish
Ⅲ Systems integration	Ⅲ-1 Integration of aquatic systems	Ⅲ-1-1 Partitioned aquaculture systems	Tilapia + prawn + oyster + Gracilaria
		Ⅲ-1-2 Aquaculture and agriculture integration	Fish-rice
		Ⅲ-1-3 Aquaponics	Aquaponics
		Ⅲ-1-4 Aquaculture and waterfowl integration	Fish and duck
		Ⅲ-1-5 Fish and amphibian integration	Fish and turtle or frog
		Ⅲ-1-6 Aquasilviculture	
		Ⅲ-1-7 Others	Net-isolated polyculture of tilapia and prawn;, cage culture in pond
	Ⅲ-2 Integration of aquatic and land systems	Ⅲ-2-1 Integration of pond and livestock or poultry breeding	Pond-sheep; pond-pig; pond-chicken
		Ⅲ-2-2 Integration of pond and planting	Pond-grain; pond-grass; pond-fruit tree
		Ⅲ-2-3 Other integration	Prawn culture with Cooling water from power plant

(Dong, 2011)

Technique Integration in a waters





Integration of pellet (manure) and chemical fertilizers to culture tilapia (Yang et al., 1998).

Integration of artificial pellet and chemical fertilizers was used to culture common carp in cages and the silver carp outside the cages (Li, 1986; Sun et al., 1990).

Ⅱ Species integration in a waters

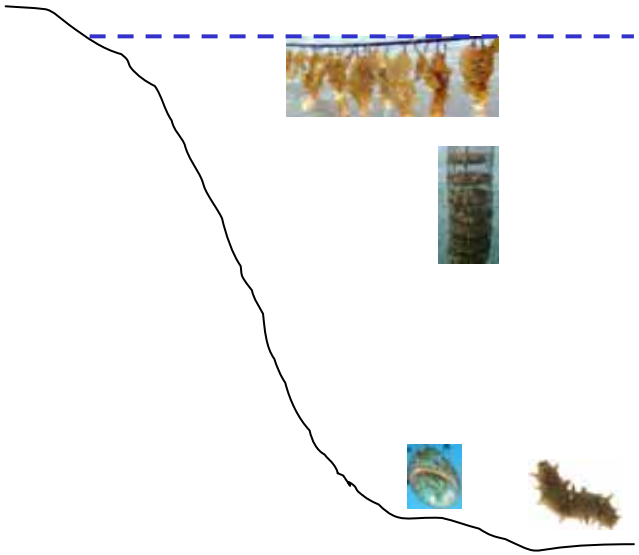
Ⅱ-1 Trophic integration or Integrated multi-tropic aquaculture (IMTA)

Shrimp + jellyfish + razor fish
(Wang and Cui, 2009)

Fish + oyster + seaweeds
(Luo & Wang, 1984)

seaweeds + abalone + sea cucumber
(Lin, 2005)

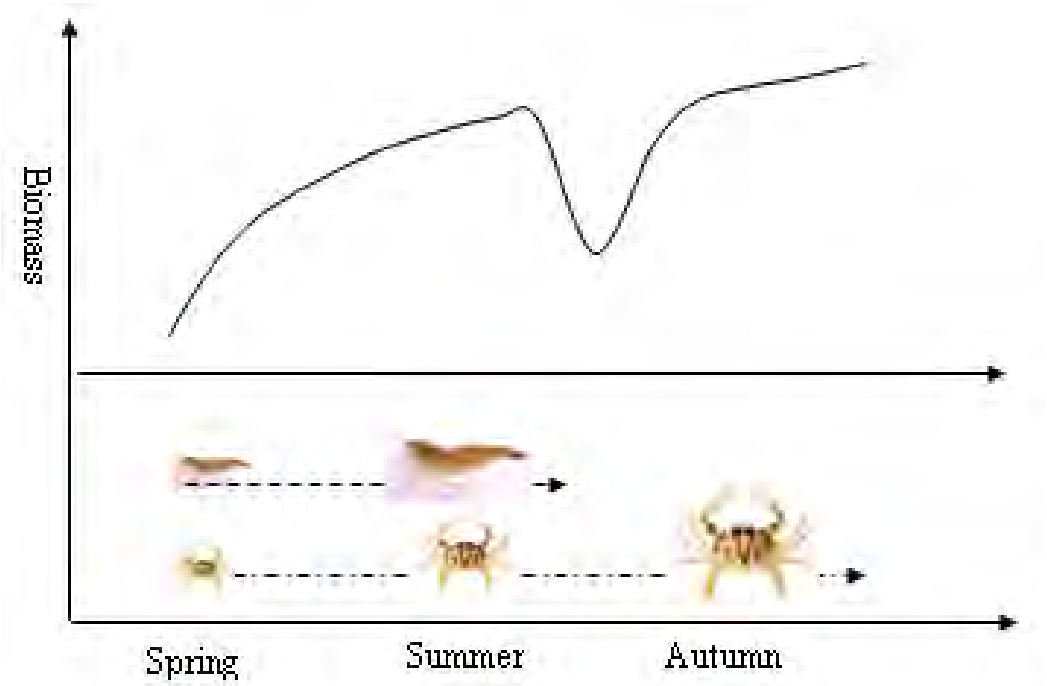
Ⅱ-2 Spatial integration



Integration of kelp, scallop, sea cucumber and abalone
(Luo & Wang, 1984).

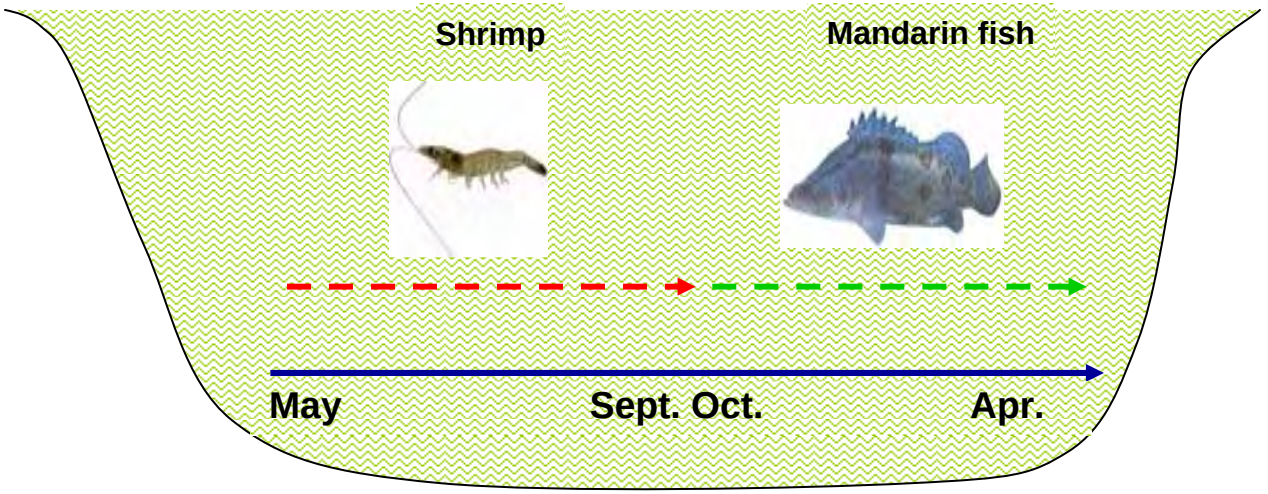
Integration of sea cucumber, jellyfish, shrimp and scallop
(Dong, 2011)

Ⅱ-3 Rotary stock and harvest



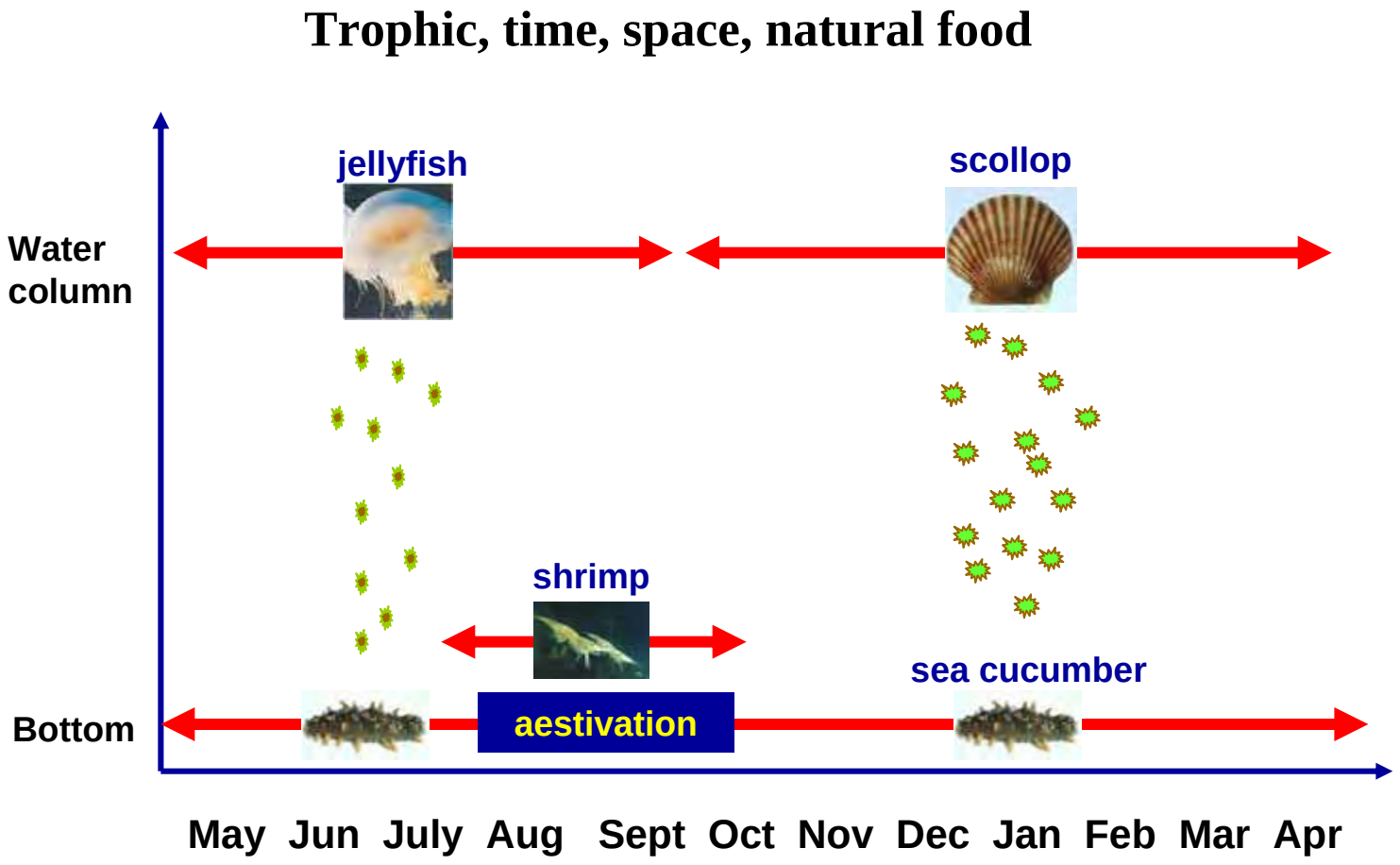
Rotary stocking and harvesting of prawn and crab in pond (Li et al., 2010)

Ⅱ-4 Temporal integration



Integration of shrimp and mandarin fish in pond (Shen and Zhang, 2004)

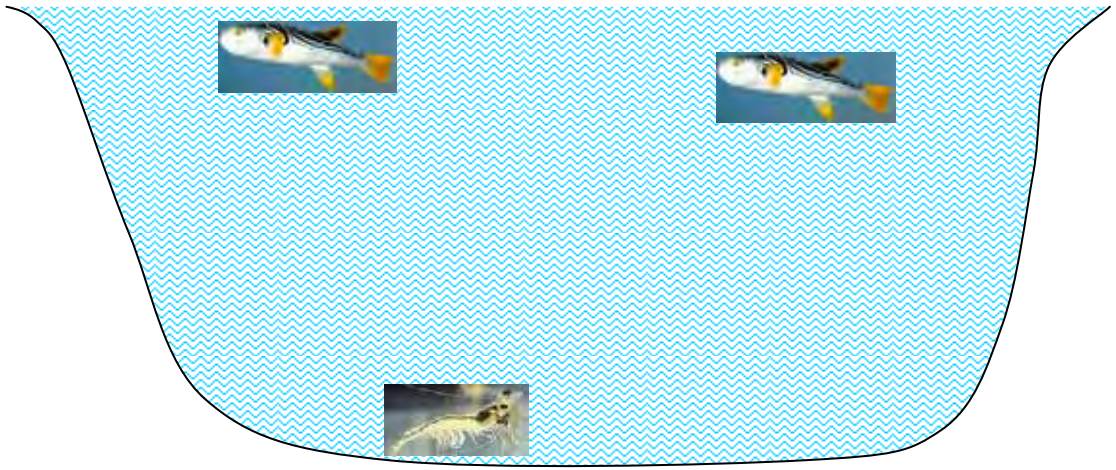
Ⅱ-5 Multiple function integration



(Dong, 2011)

Ⅱ-6 Other integration

e.g. Disease preventive integration

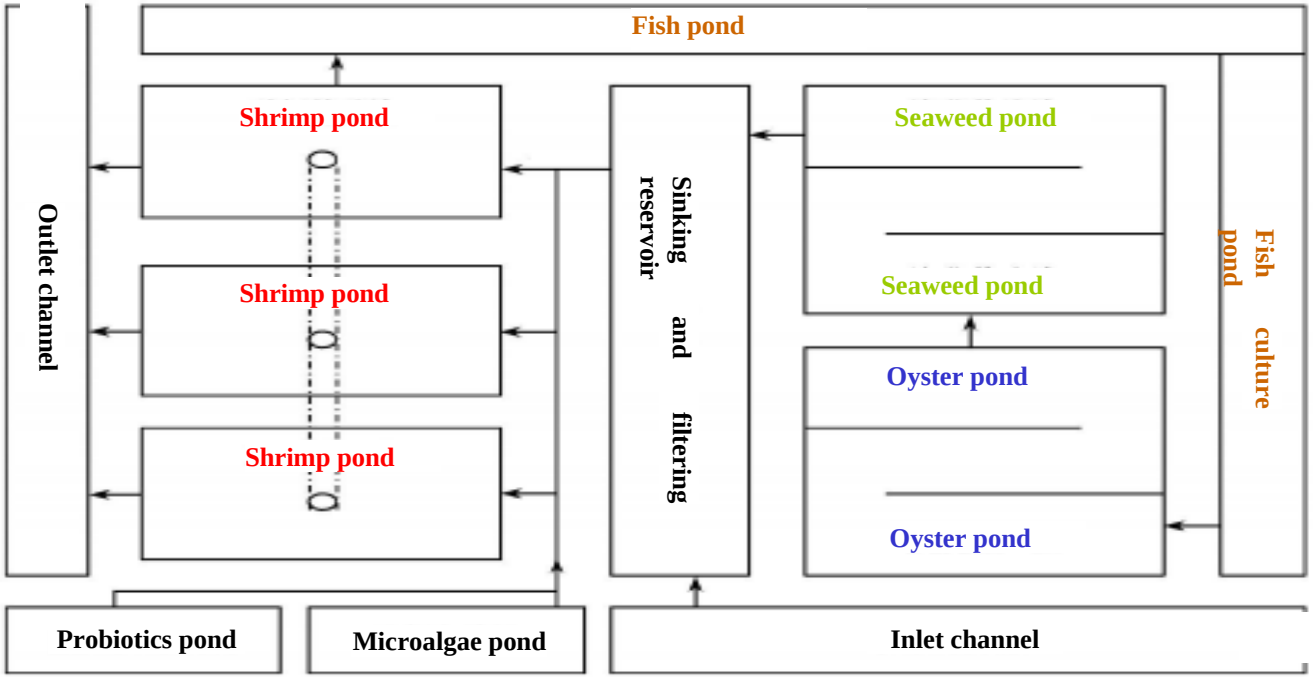


Co-culture of puffer fish (*Fugu rubripes*) and shrimp (Liu et al., 2007)

Ⅲ System Integration

Ⅲ-1 Integration of aquatic systems

Ⅲ-1-1 Partitioned aquaculture systems



Partitioned aquaculture system of shrimp- fish-shellfish-seaweeds
In this system there is a sequential flow of wastes between culture units with different species. (Shen et al., 2007)

Ⅲ-1-2 Aquaculture and rice integration

Fish-rice integration (889-904 AD)

Ⅲ-1-3 Aquaponics

(Yang, 2001; Ding, Lan & Zhang, 2010)

Ⅲ-1-4 Aquaculture and waterfowl integration

(Luo et al., 2002)

Ⅲ-1-5 Fish and amphibian integration

Fish and frog
(Sun, 2004)

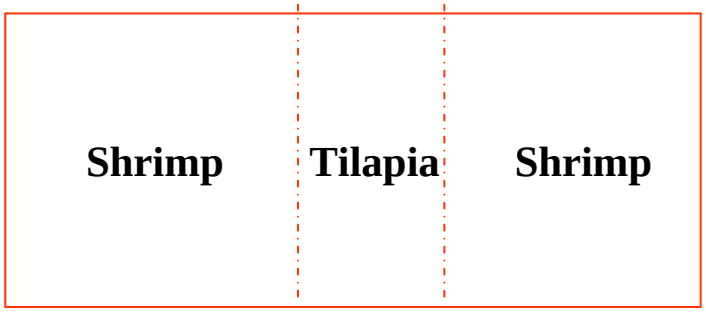
Fish and soft shell turtle
(Sun, 2004)

Ⅲ-1-6 Aquasilviculture

Shrimp or oyster farming within or by mangrove forest (She et al., 2005)

Ⅲ-1-7 Others

Cage culture in pond
(Sun et al., 2010)



Net-isolated polyculture
of tilapia and shrimp
(Jie, 2008)

Ⅲ-2 Integration of pond-land systems

Ⅲ-2-1 Integration of pond and livestock breeding

Pond + sheep (Dai and Yan, 1999)
Pond + pig (Chun et al., 2009),
Pond + chicken (Li and Yu, 2000)

Hygiene issue (Cai et la., 2009)

Ⅲ-2-2 Integration of pond and planting

Ⅲ-2-3 Others

Integrated power plant and aquaculture system (Lin & Ji, 1993)

5. Current Practices of Integrated Mariculture in China

Studies and practices of integrated mariculture in pond

In 2010, 13.3% of mariculture production (1.98 mmt) came from pond farming in China, mainly shrimp, fish, crab etc.

Last 15 years my laboratory has optimized shrimp polyculture structure with land-based enclosures.

Optimized structures of shrimp polyculture

Structure	Biomass ratio	Data source
Shrimp-tilapia	1: 1	Wang, J. et al., 1998
Shrimp-razor fish	1: 3	Tian et al., 2001
Shrimp-scallop	1: 1	Wang, J. et al., 1999a
Shrimp-razor fish-tilapia	1: 0.3: 2	Tian et al., 2001
Shrimp-Manila clam	1: 1	Wang et al., 1999b
Shrimp-Cyclina	1: 0.8	Wang, D. et al.， 2006
Shrimp-Gracilaria	1: 5	Niu et al.， 2006
Shrimp-Cyclina-Gracilaria	1: 1.3: 8.3	Wang, D. et al., 2006
Shrimp-bloody clam-Gracilaria	1: 1: 5.9	Niu et al., 2006

Efficiencies of shrimp polyculture

Efficiencies	Shrimp	Sh-F	Sh-Rf	Sh-F-Rf
Total production	1	+40%	+104%	+82% (+17%)
N discharge	1	-23%	-63%	-86%
Output/ input	1	-3%	+7%	+10%

Effect of polyculture on water and sediment quality

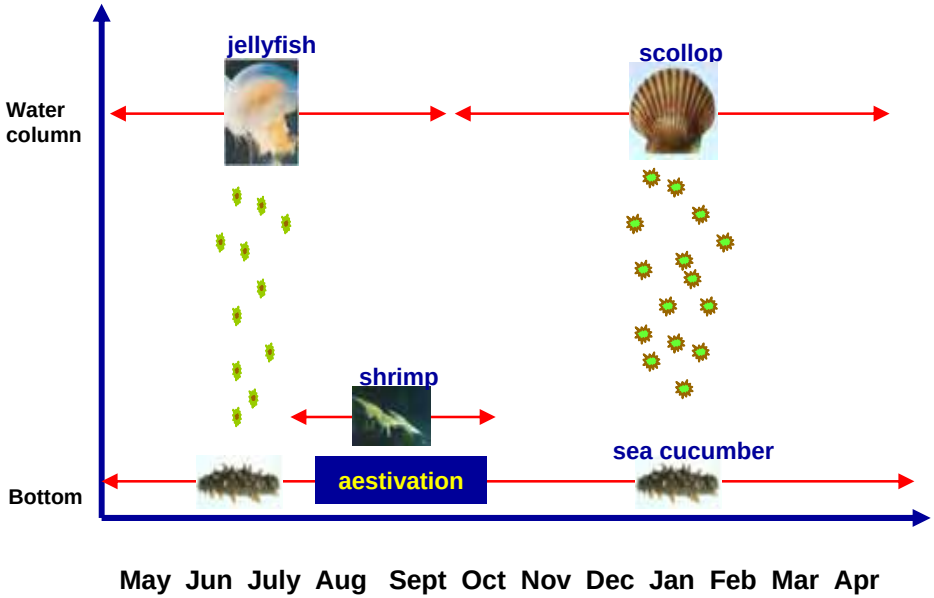
Species composition	Water		Sediment	Discharge rate	
	TN%	TP%	TOC%	N%	P%
Shrimp-Manila clam	-5.2	-18.2	—	—	—
Shrimp-Cyclina	-21.3	-10.5	-32.5	-24.5	-17.8
Shrimp-Gracilaria	-21.0	-30.1	—	—	—
Shrimp-Cyclina -Gracilaria	-42.6	-31.7	-239.8	-109.9	-252.7
shri,mp-bloody clam-Gracilaria	-37.0	-37.5	—	—	—

Manila clam

Gracilaria

Cyclina

Homey Marine Development Co., Ltd



1300 hm^2 mariculture ponds

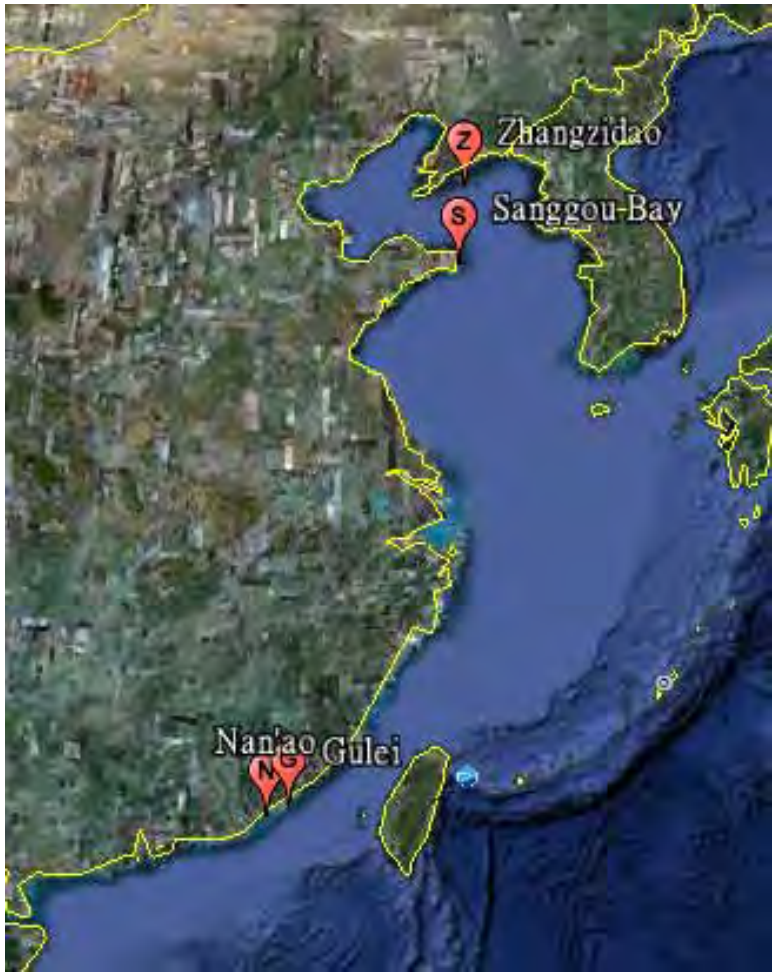
1.3 million kg sea cucumber

4.0 million kg jellyfish

mariculture profit 81 million RMB

An integration of sea cucumber with jellyfish, prawn and scallop is extending in the farm

Practices of integrated mariculture in open waters

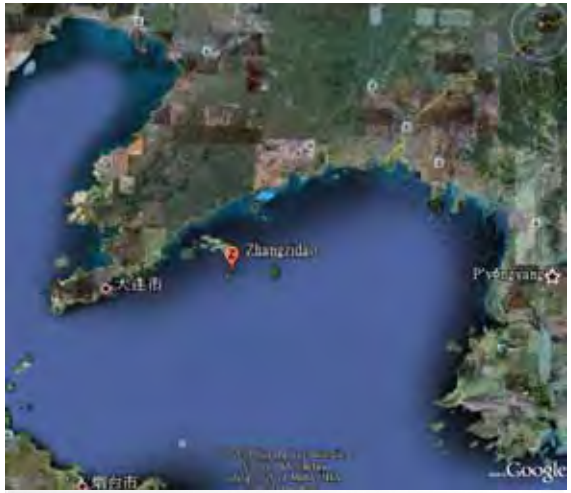


Zhangzidao Island – scallop

Sanggou Bay – scallop, oyster

Gulei – abalone, sea cucumber

Nan’ao – fish,

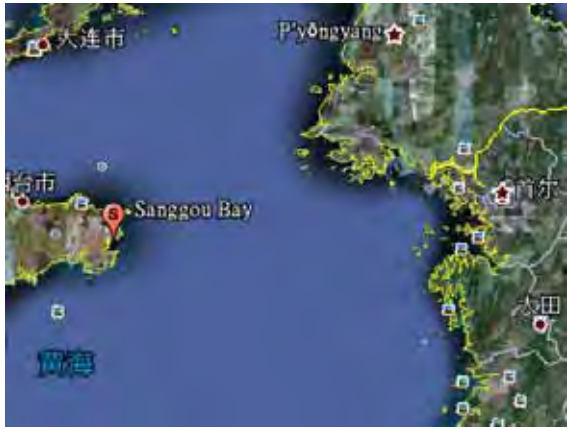


Zhangzidao Fishery Group Co. Ltd

Authorize to a farm area about 1,900 km^2
In 2010, mariculture profit 570 million RMB

scallop (*Patinopecten yessoensis*) 49 890 t
sea cucumber (*Apostichopus japonicus*) 237 t
abalone (*Haliotis discus hannai*) 20 t
conch (*Rapana venosa*) 719 t
sea urchin (*Strongylocentrotus nudus*) 351 t

Sanggou Bay, Shandong Province



Optimal structure

kelp and abalone:

33,600 inds + 10,000 inds

fish and seaweed :

1 kg fish: 353.25 kg *Laminaria*

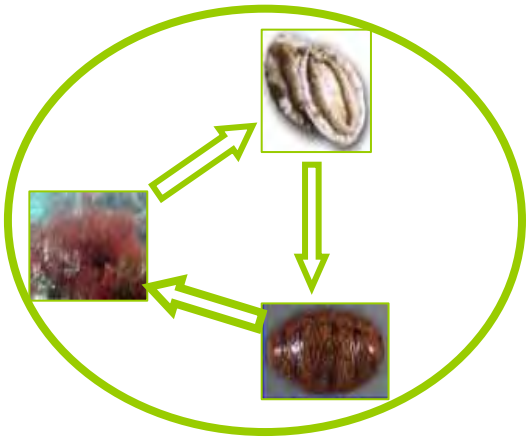
1 kg fish: 457.6 kg *Gracilaria*

sea cucumber and abalone:

4 inds./cage + 250 ind./cage

(Fang, 2011)

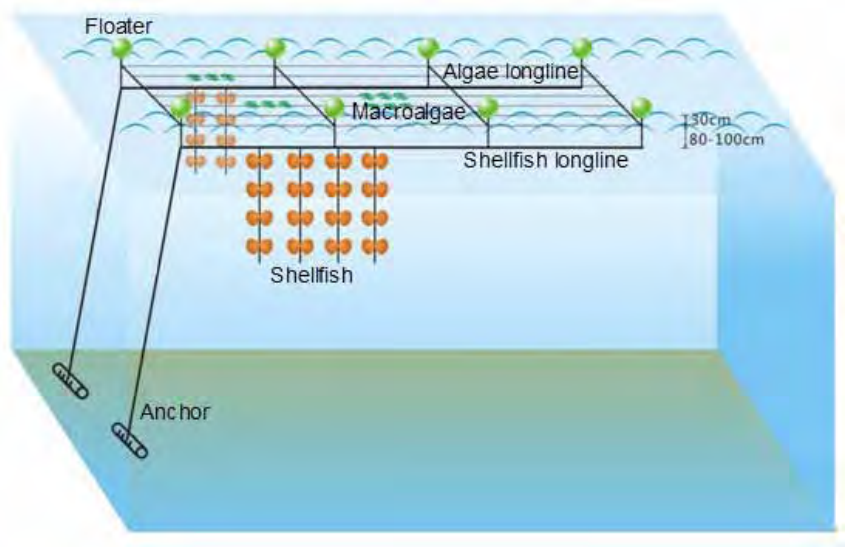
Gulei, Fujian Province



Kelp + abalone

***Gracilaria* + abalone + sea cucumber**

Nan'ao, Guangdong Province



Fish (cages) + oyster + *Gracilaria*

Area: 1894 hm^2 in 2009
Production: 3,644 t (sea bass, Red drum, cobia, croaker)
35,654 t (oyster, clam)
28,246 t (*Gracilaria,* nori and kelp)

Land-based mariculture – Which way to go?

High productive and high C

High efficiency with low C

Low productive and low C

Intensive
High productive
Low carbon
Multi-trophic species
Balance between
hetero- and autotrophic
(Dong, 2011)