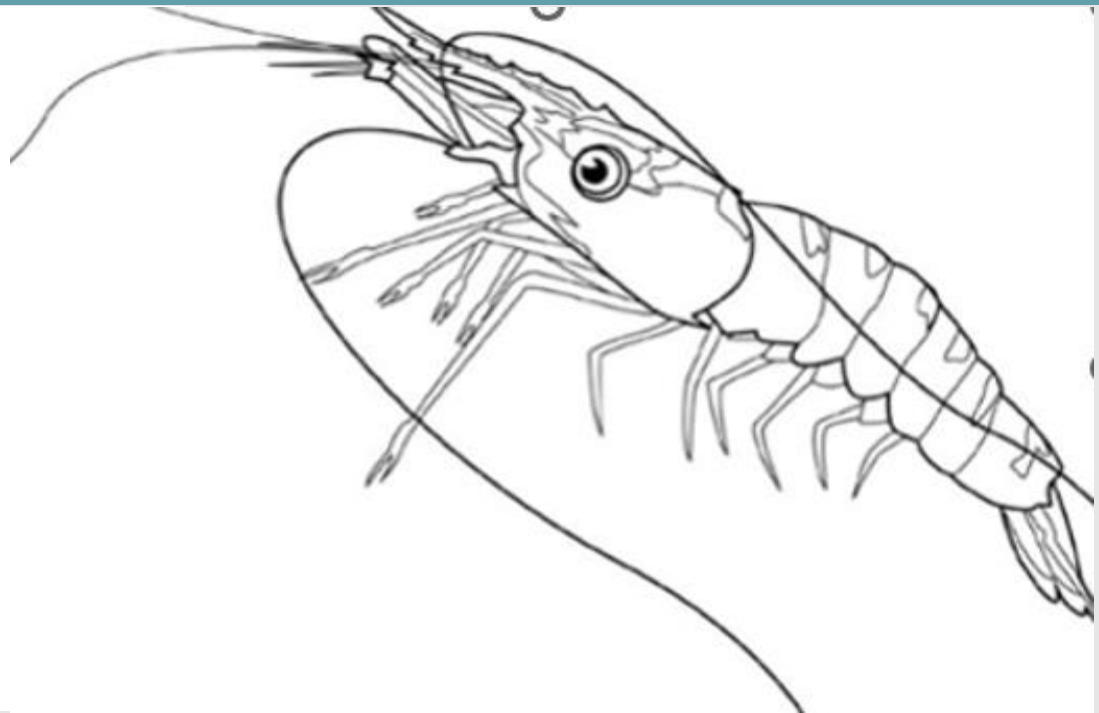
The Current Status and Trends of Recirculating Aquaculture System and Small-scale Greenhouse Shrimp Farming in China

Guozhi LUO

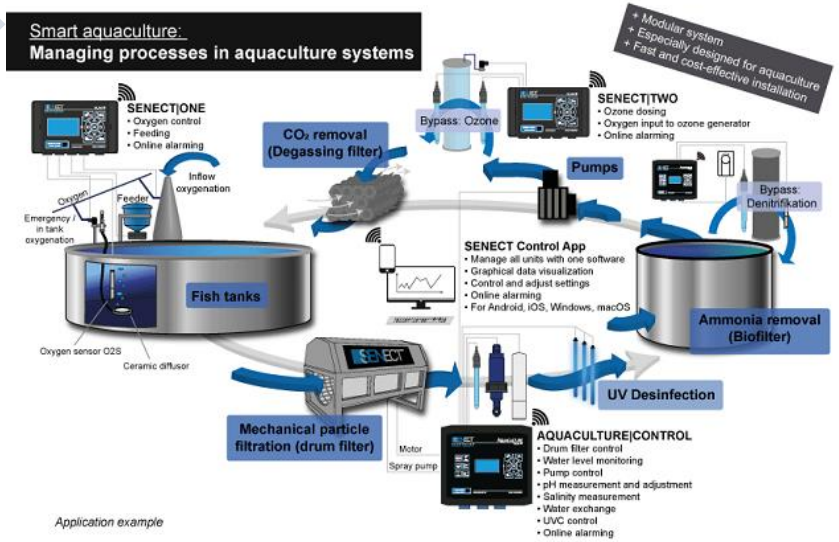
Shanghai Ocean University, Shanghai, China

gzhluo@shou.edu.cn

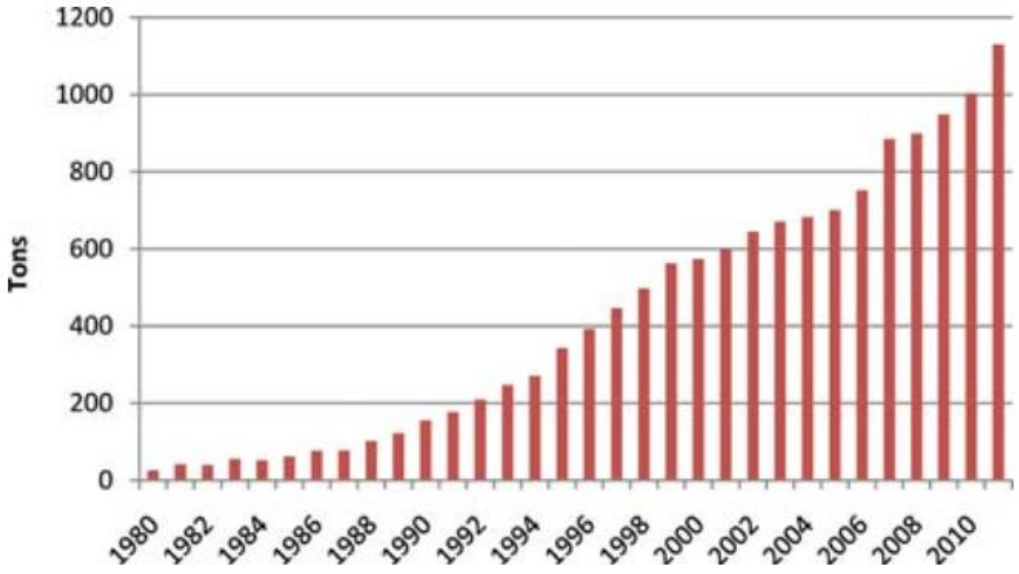


Aquaculture is shifting from resource - dependent horizontal expansion to technology - and equipment - dependent vertical expansion

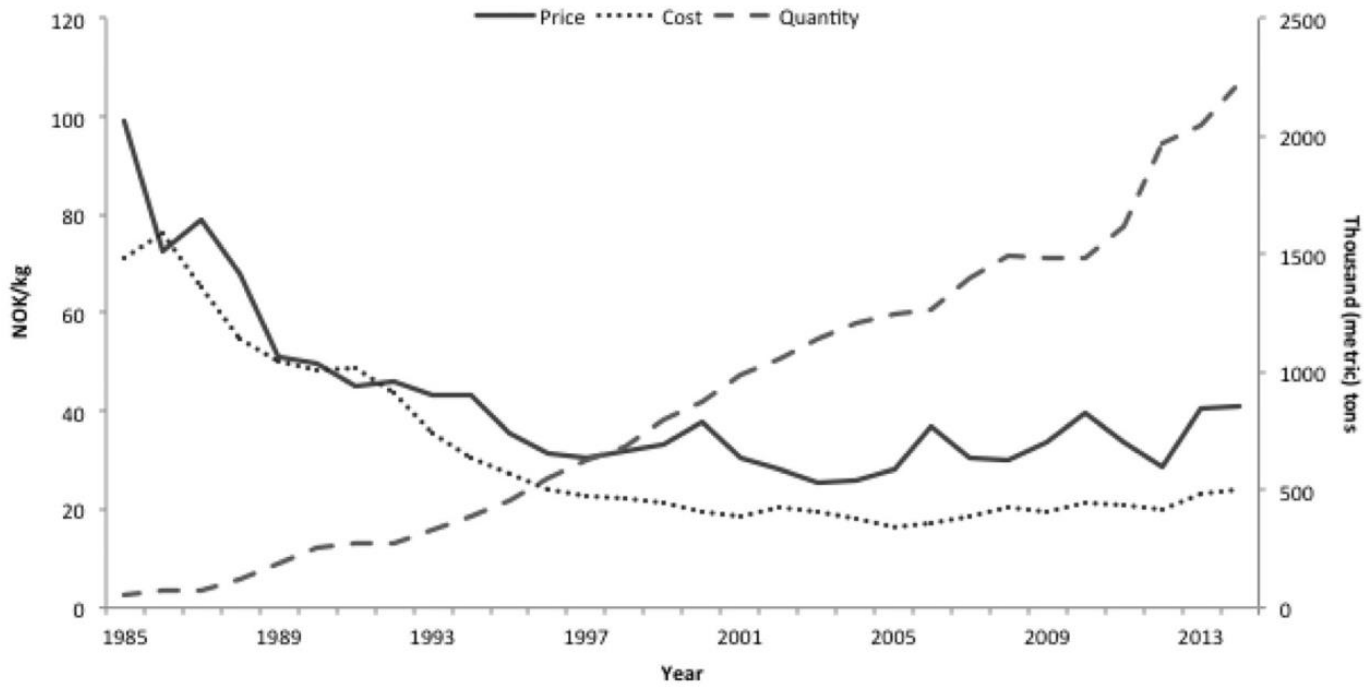
More facility-based and scale



Economies of scale can reduce costs and improve efficiency, for example, Norwegian salmon and trout farming



Average production per license in Norway. Sources: Norwegian Directorate of Fisheries (2007) and Statistics Norway (2013) (color figure available online).



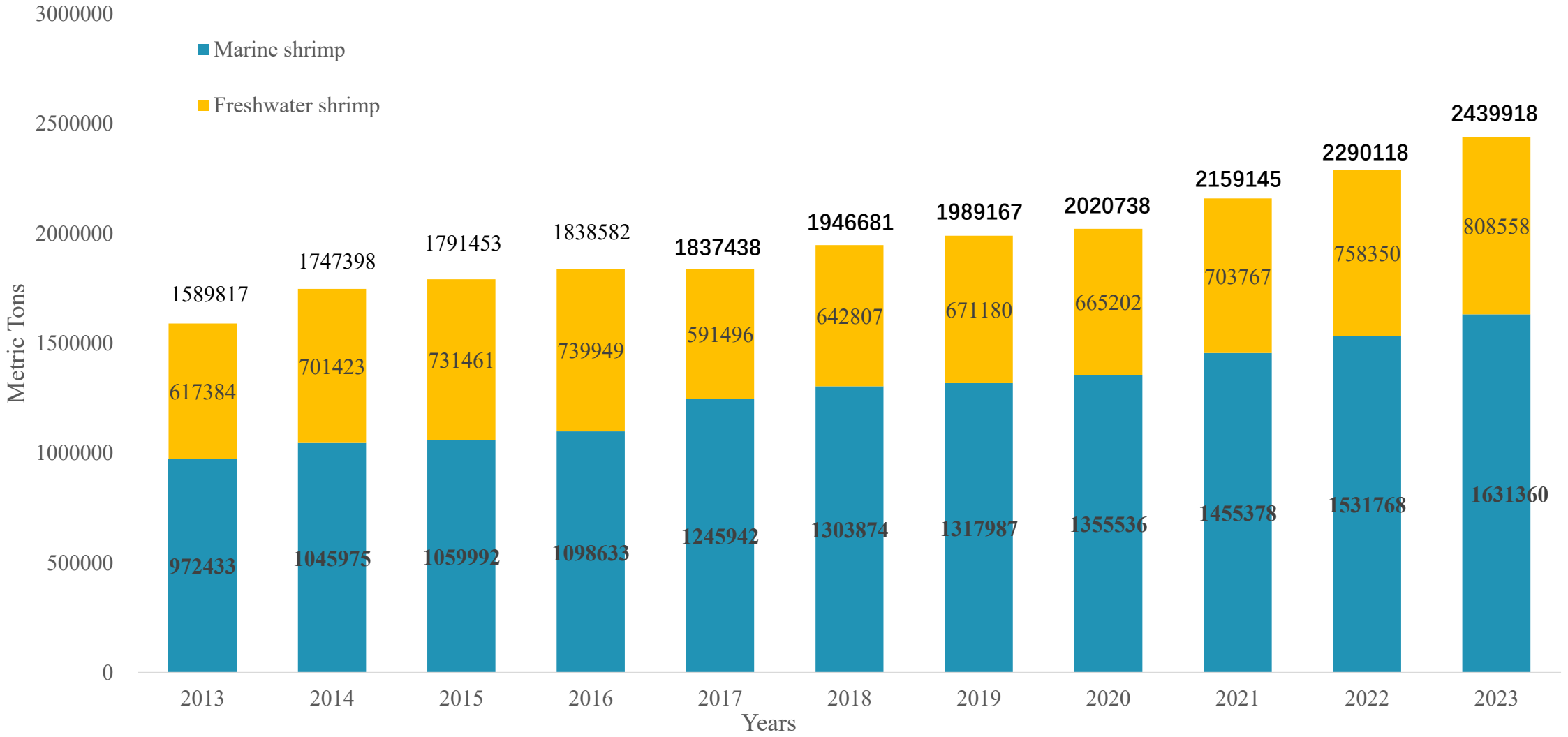
Real Norwegian salmon price and production cost, and global production. Source: FAO and Directorate of Fisheries.

Asche et al., 2013; Andre et al., 2018; Pandy et al., 2023

As the second-largest traded aquatic product after salmonids, can shrimp farming follow it?

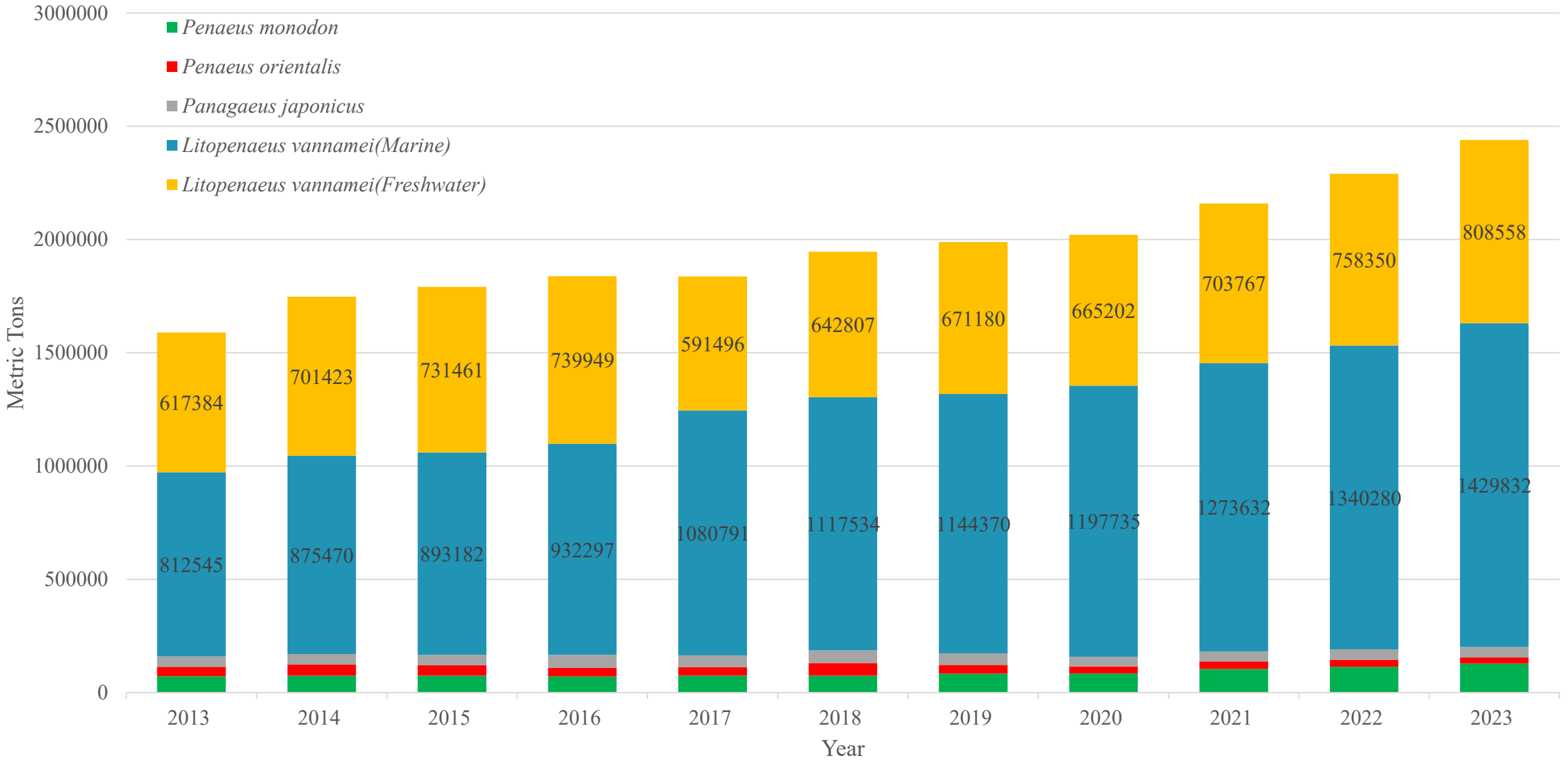
Share of main groups of species in exports of aquatic animal products by value, 2022 （FAO 2024）

In recent decades, shrimp ((not including crayfish and prawn)) production in China have increased continuously, the growth in freshwater shrimp output has been more significant than marine shrimp



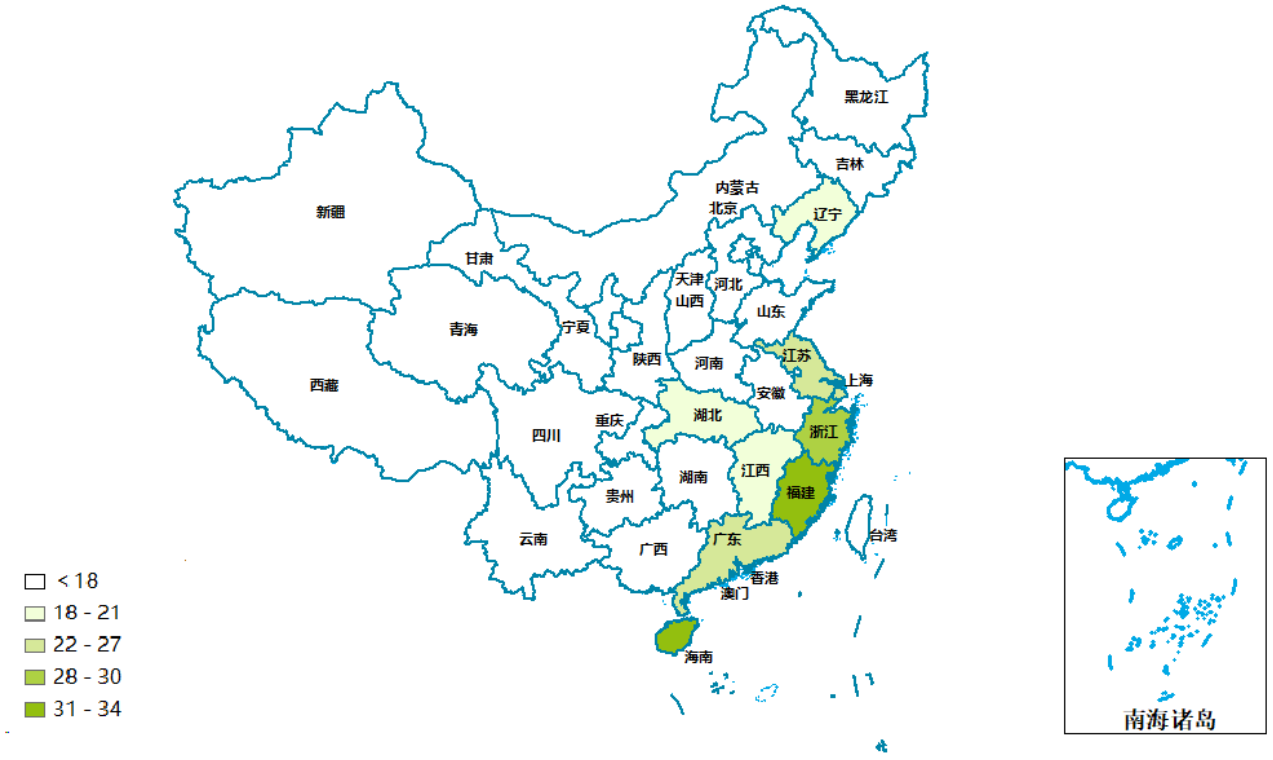
China’s total shrimp production from 2013 to 2023

Whiteleg shrimp is the dominant species in both marine and freshwater in China, accounting for over 90% of the total farmed shrimp production

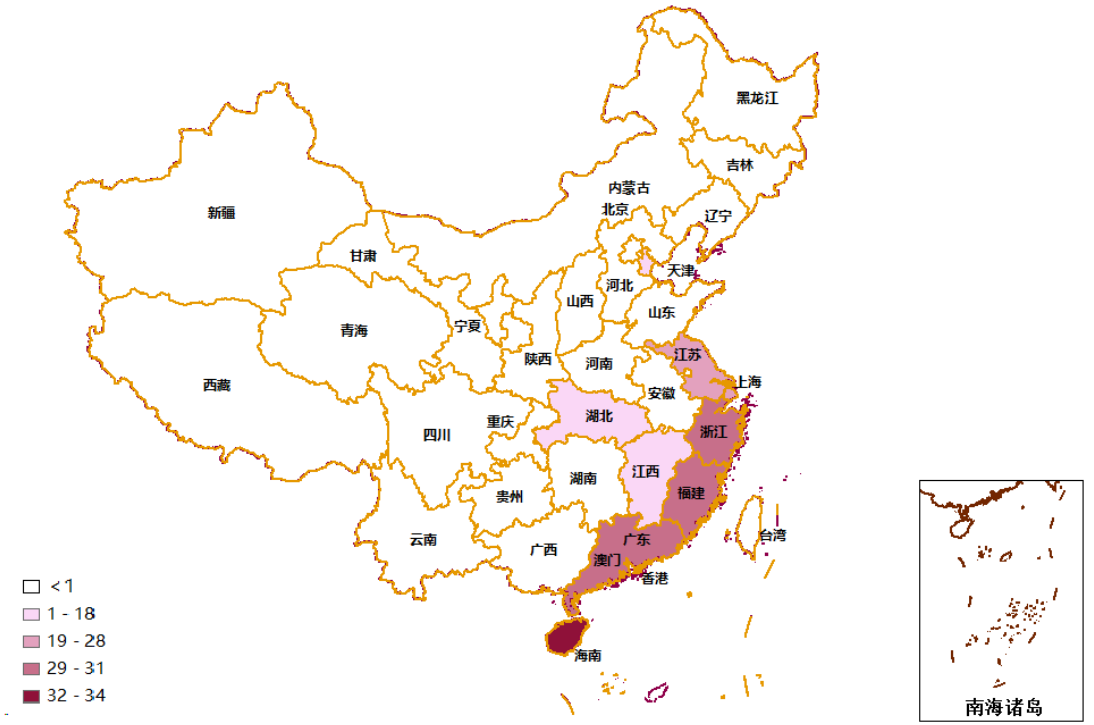


China's Production of Major Shrimp Species From 2013 to 2023

The regional distribution of per capita consumption of aquatic products in 2023



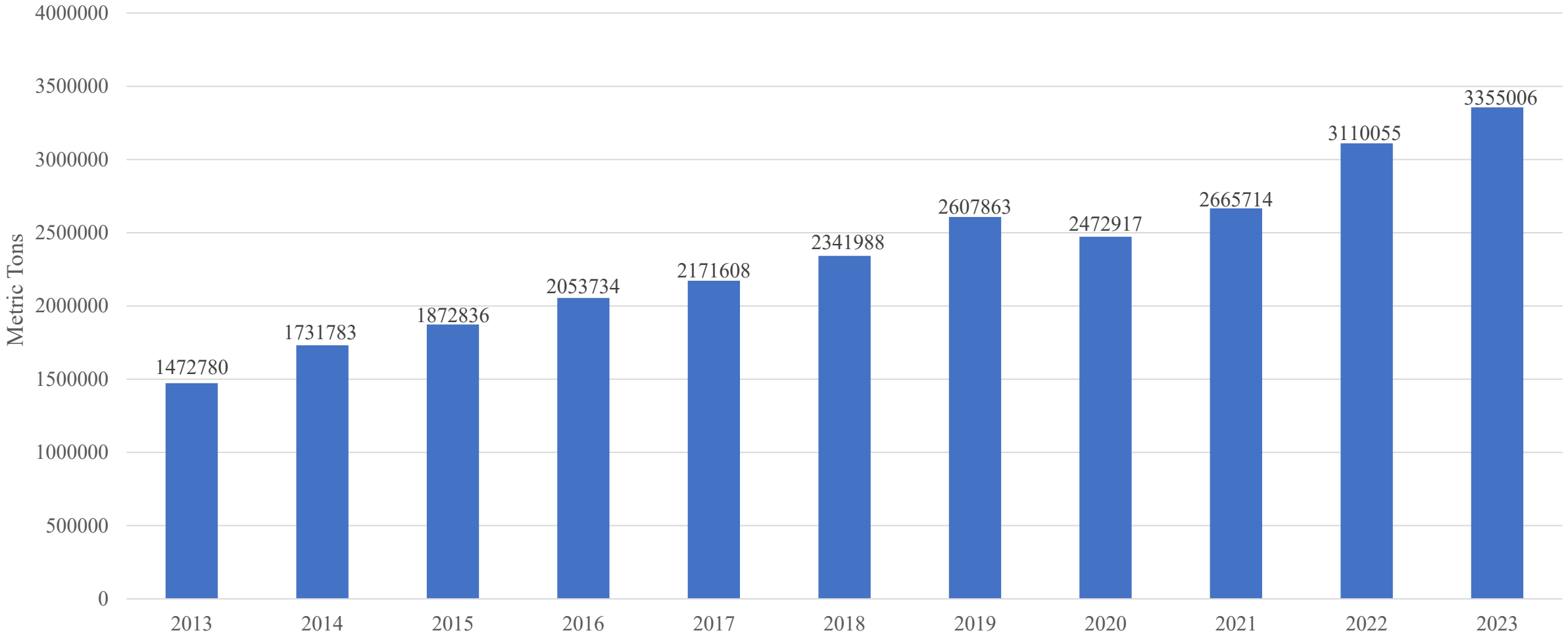
City- average 17.13 kg/capita



Rural - average 12.19 kg/capita

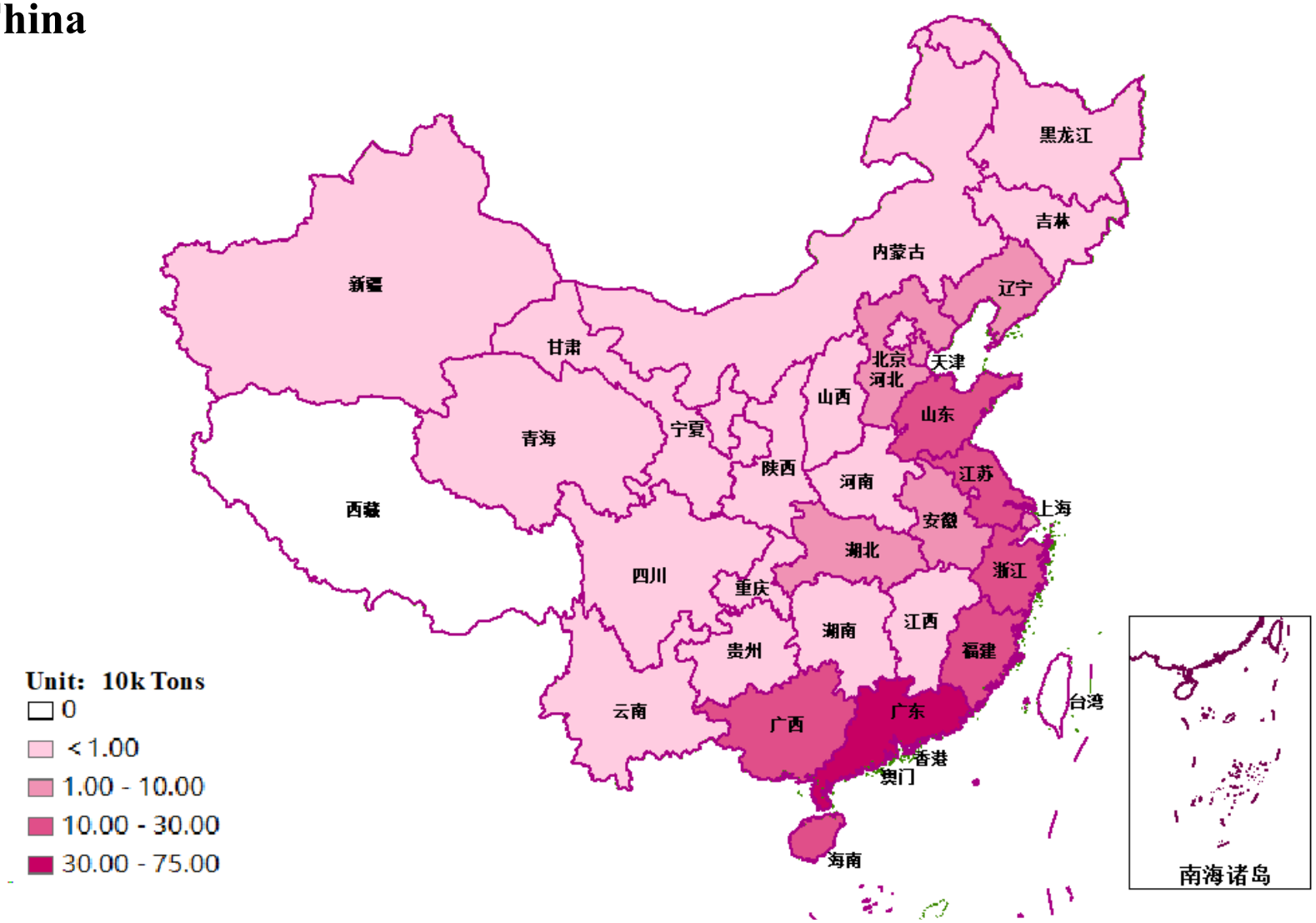
Based on estimates from The Ministry of Agriculture and Rural Affairs of the People's Republic of China.

The per capita consumption of shrimp (not including crayfish and prawn) was about 2.35 kg in 2023, 2.4 kg/per capita in 2024



China’s total consumption of shrimp from 2013 o 2023

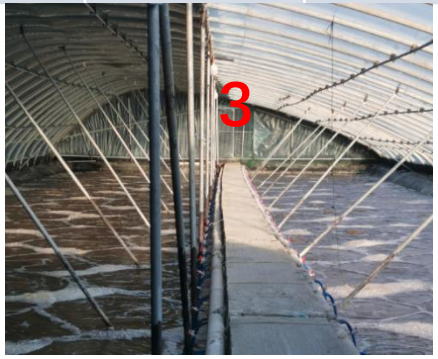
Shrimp farming (and consumption) is mainly concentrated in coastal cities in the southeast. Inland regions have much lower production, shrimp farming activities are present in almost all areas in China



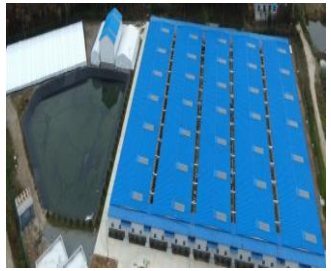
Annual average shrimp production distribution in China from 2013 to 2023

The main shrimp farming skills in China

Model	Unit Area	Stocking density (PL/m²)	Production (kg/m²)	Survival rate (%)	Cost evaluated (RMB/kg)	Prons and Cons
1. Indoor, Cement/HDPE Pond, Flow-through	20 - 200 m^2	500 - 800	7.5 - 12.5	80 - 90	30- 35	Pros: controllable, high success rate, stable quality, continuous production. Cons: high investment, high cost, high technical requirements.
2. Intensive Pond (Outdoor, flow-through)	660 - 3300 m^2	150 - 230	1.5 - 4	60 - 90	24 - 28	Pros: low cost, high success rate, average quality. Cons: high external influence, regional limitations, environmental concerns.
3. Greenhouse	400 - 600 m^2	75 - 200	1 - 3.5	65 - 75	20- 30	Pros: low investment, relatively closed system, high success rate. Cons: environmental concerns， disease
4. RAS	500 - 3000 m^2	300 - 600	5 - 15	> 80	> 30	Pros: highly controllable, customizable to orders, eco-friendly. Cons: high input cost, low error tolerance.
5. Large pond (sal 30)	30 - 700 hectare	15 - 22	0.06 - 0.09	20 - 25	20 - 30	Pros: Low cost, simple management, high quality, good transportability. Cons: Low survival rate, uncontrollable process, resource limitations
6. Normal Pond	3 -13 hectare	30 - 45	0.1 - 0.4	40 - 45	20 - 22	Pros: Low cost, high marginal benefits. Cons: Unstable, multiple constraints.



Recirculating aquaculture systems



- External mechanical filter for removing uneaten feed and feces.
- External biofilter with bacteria that convert ammonia to nitrate.
- Higher capital (2,000 RMB/m³) and operational costs, production costs >30 RMB kg.
- Higher stocking density (15 kg/m³).
- Year - round production.
- Not restricted by region or season.

Companies using the systems:

通威股份 TONGWEI CO., LTD.　正大集团 CP GROUP　恒兴集团　Haid 海大集团 HAID GROUP CO.LTD

Small scale greenhouse

- Leaves more feces and unused feed in the water.
- No external biofilter, relies on algae and bacteria to control ammonia/nitrite.
- Backup mechanical filter.
- Lower capital costs (< 100 RMB/m³), total production cost < 12 RMB/m³.
- Lower stocking density (Average 2.5 kg/m³).
- Two or three crops a year.
- Mainly distributed in the southern coastal areas.

GUO LIAN　Haid 海大集团 HAID GROUP CO.LTD　恒兴集团

China's small-scale greenhouse shrimp farming has experienced a golden decade and is now at a critical point for iteration and upgrading

Initial Exploration:

Began in Rudong, Jiangsu province. Local farmers shifted to this model. There were few diseases, and farming went well, with yields of several hundred kilograms per shed. Many farmers reaped significant rewards

2006–2015

2016–2020

Technological Advancement and Local Expansion:

Drew many investors from other regions (Zhejiang). Financial input increased the number of small-scale greenhouses in Rudong rapidly, boosting the model's growth. Yields rose from 400 – 700 kg per shed in 2018, to 750 kg in 2019, and reached 900 kg in the first half of 2020.

High - speed Development and National Expansion:

The average output of autumn shrimp farming in Rudong's reached > 1000 kg per shed (400 m^2). Since then, there's been a rush to find land for development. The greenhouse farming scale has rapidly expanded in Shandong and South China, and even spread to Xinjiang, Ningxia, and Inner Mongolia region.

2020 - Present

History of small-scale greenhouse shrimp farming in China

Characteristics of greenhouse shrimp farming in China

Consists of small shallow ponds covered with steel frames and plastic film, around 400 m² in area, 80 - 100 cm deep, with a density of 75 - 200 PL/m²

Mainly soil - bottomed, recently some have HDPE lining, costing about 20,000 - 40,000 RBM per shed, lasting around 10 years

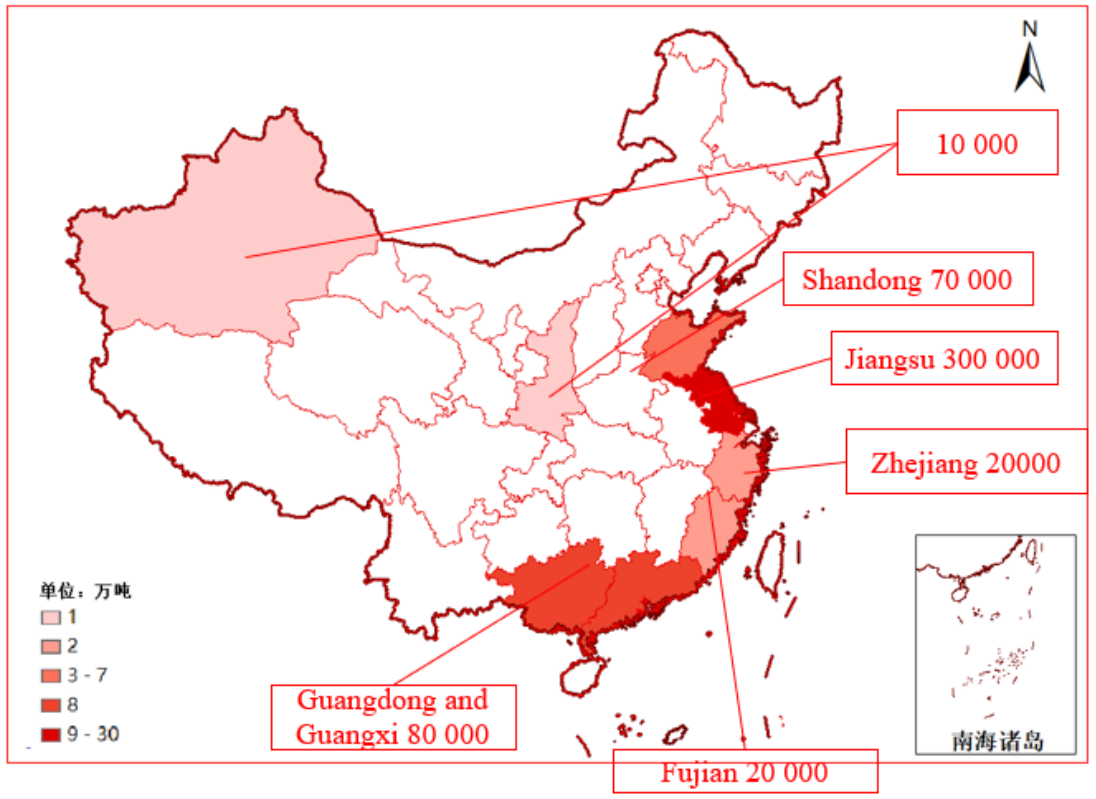
2 - 3 crops a year, yield of 1 – 3.5 kg/m² per crop

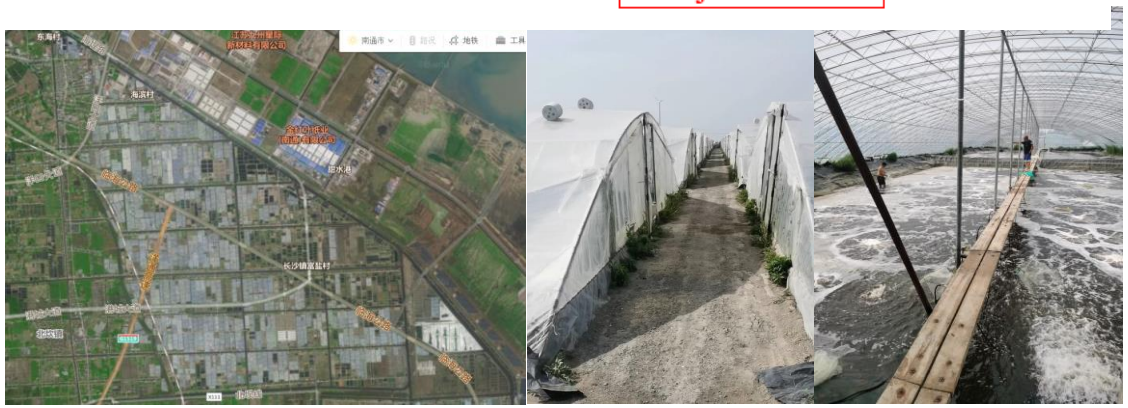
Mostly uses shallow groundwater, low - water - level stocking (around 30 cm) initially, gradually filled to about 100 cm, usually no central drainage or similar devices, minimal or no water change later

Nanotube aeration throughout, biosolids form naturally, with periodic carbon source and probiotic supplements to maintain water quality; Algae - dominated initially, bacteria - dominated later

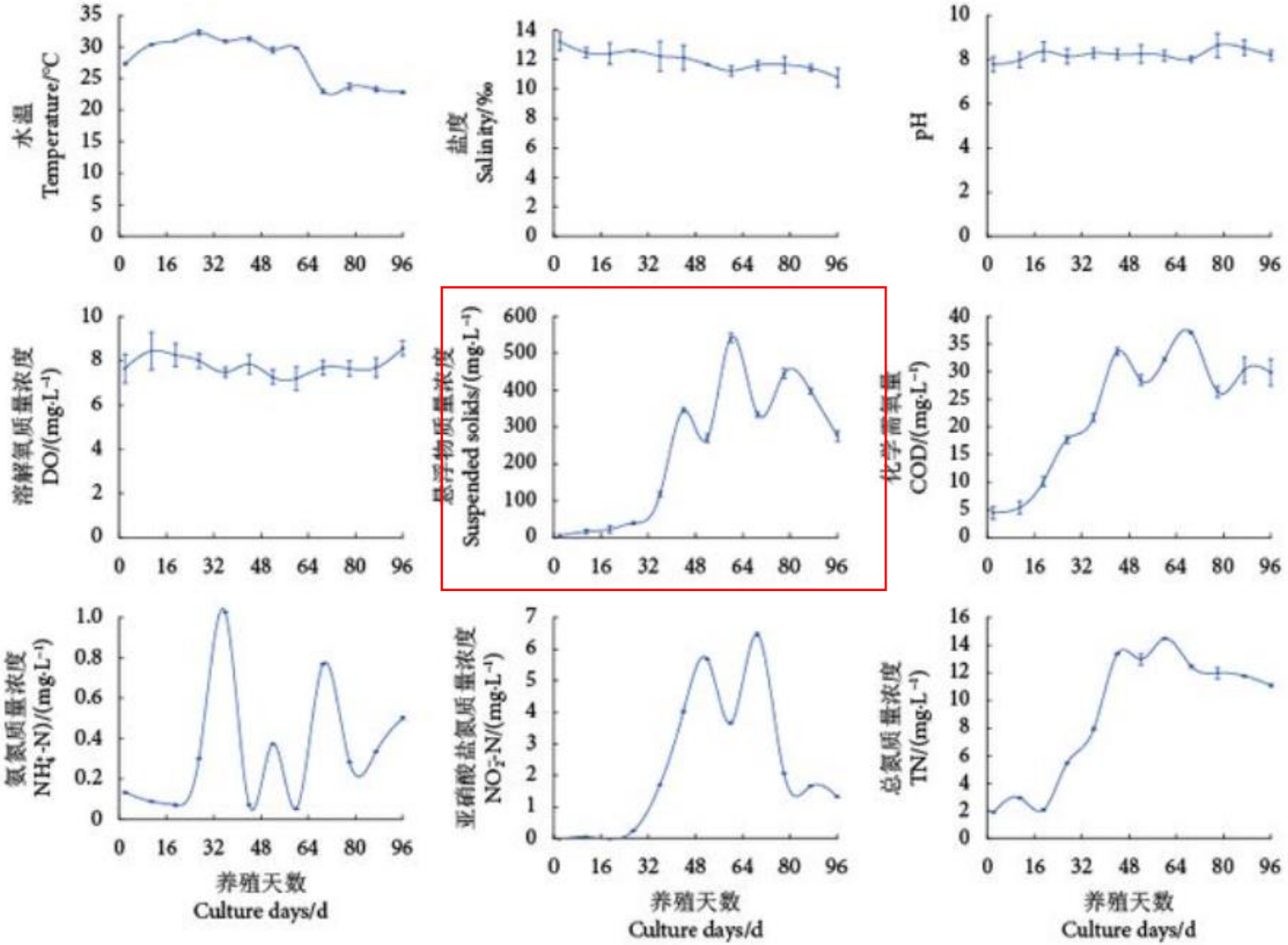
Often equipped with heating for winter/spring harvests

Around 0.5 million sheds nationwide, controlled in Jiangsu, rapidly expanding in Bohai Rim and South China





Judging from TSS, ammonia nitrogen, and nitrite nitrogen, it can be said that small-scale greenhouse shrimp farming mainly relies on biofloc management



Primary water quality parameters in small-scale green-house whiteleg shrimp farming in Rudong, Jiangsu

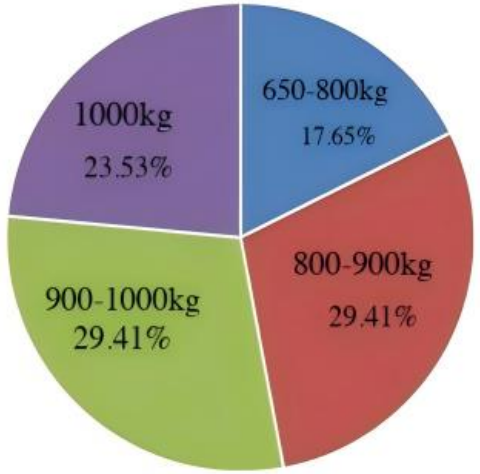
Wan 2023, https://www.163.com/dy/article/I4LEC4BF0556065H.html

Current challenges and ongoing technical improvements for small-scale greenhouse shrimp farming

Success rates are currently unstable, with an overall average of at most 60%. However, if successfully farmed, profits can be made, as high as 30,000 RBM per shed per crop cycle (400 m²).

Diseases such as EMS and EHP persist even with strict seedling control.

Environmental regulation is imprecise, effluent needs to meet the discharge standards (TN< 5 mg/L, TP< 0.5 mg/L).



A farm with 32 small-scale greenhouses, whiteleg shrimp farming in Spring 2024 in Dongtai, Jiangsu province

The use of automatic feeders and improvements in oxygenation methods can significantly enhance efficiency.

Integration with photovoltaic power generation (Install solar panels on the shed's roof.) can provide farmers with additional benefits.

The farming species have been expanded from whiteleg shrimp to *Marsupenaeus japonicus*, *Penaeus monodon, etc*.

Production Area	Success rate	Survival rate
Guangxi	30%	50-60%
Yangjiang (Guangdong province)	65-70%	50-60%
Taishan (Guangdong province)	< 30%	<50%
Nantong (Jiangsu province)	50%	80%
Yancheng (Jiangsu province)	60-65%	75-93%

Situation of whiteleg shrimp greenhouse farming in Some Typical Production Areas in Autumn 2023

Status of RAS shrimp farming in China

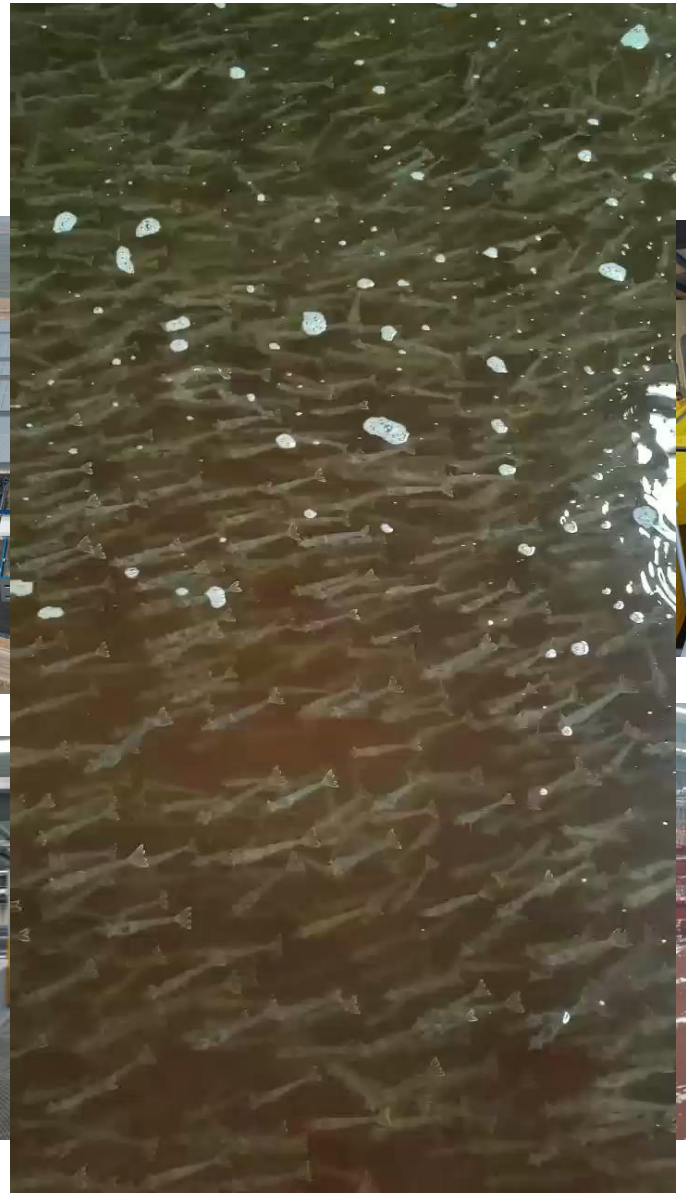
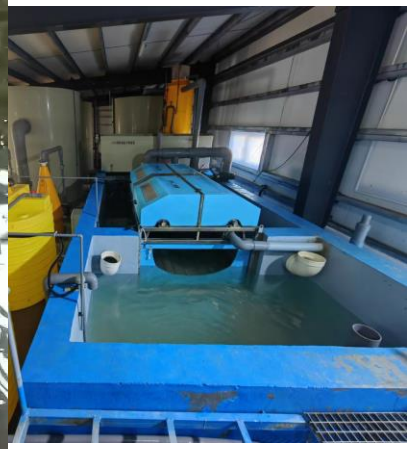
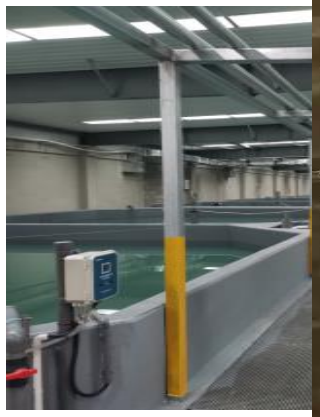
- Still in the stage of exploring commercial application
- Mainly invested in by large enterprises
- Whiteleg shrimp is the main specie, exploring farming technology for *Penaeus (Marsupenaeus) japonicus*
- Actively advocated by the government

RAS whiteleg shrimp farming (Anhui Province) by SHOU

Item	Nursery	Grow-out	Total
Water volume(m³)	960	4000	4960
Survival rate (%)	>80%	> 80%	
Period (d)	35-40	40-45	75-85
Initial size	P5	P40	
Market size	P40	17 g/PL	17 g/PL
FCR	1.0	1.2	
Harvest biomass	---	30000 kg	7.5 kg/m³
Annual Production (Tones)		150 000	5 crops/year
Annual production (kg/m³)		37.5	
Annual value (10 000 RBM)		1200.00	Average price : 80 RBM /kg
Value (RBM/m³)		3000.00	

"Million-Ton Shrimp Project" by Tongwei Group

- Annual production target: Million-ton shrimp (white leg shrimp)
- The object production cost： < 20 RBM/kg
- Area： Inland and coastal
- Phase I has been essentially completed
- Water volume: 60000 m^3
- Continuous production (75 d one crop, 17-20 g/PL)
- Production： 10 kg/m^2 on average; peak 16 kg/m^2


Current challenges and ongoing technical improvements RAS shrimp

High costs and low shrimp prices.

How to achieve ionic balance in water with high reuse rates.

How to address shrimp body color issues in indoor systems at a low cost.

Low salinity and high density can lead to black spot and soft shell in shrimp.

The system's production capacity can't be fully utilized without order - based production, reducing its monetisation ability.

For old systems, how to achieve safe production: all solid surfaces may harbor pathogenic bacteria like vibrio. *Panulirus ornatus* (vibrio) was found to be dominant in the biofilters of shrimp RAS, and lethal *V. harveyi* was isolated.

Responsible Seafood ADVOCATE

Health & Welfare

Bacterial pathogens in biofilms pose health risks in recirculating systems

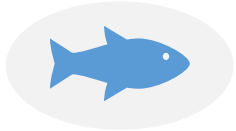
(Bourne et al., 2006).

The development trend outlook of RAS shrimp farming and greenhouse shrimp farming in China

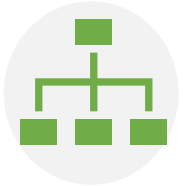
Closed farming effectively addresses current resource and environmental constraints.

At present, small-scale greenhouse shrimp farming suits better than RAS in China. It's relatively closed with lower relatively cost, scalable, and fits individual farmers well.

However, small-scale greenhouse-based shrimp farming remains resource-dependent, leading to the concentration in specific areas and elevated risks of disease spread and water resource shortage. In the long term, RAS offer greater promise due to their enhanced resistance to environmental risks, compliance with industrial standards, and greater potential for achieving intelligent and unmanned production.



Industrialization is the inevitable pathway for aquaculture to meet humanity's growing demand for animal protein. The shrimp farming industry serves as the key driver in advancing aquaculture industrialization at present.



This requires comprehensive transformation across all dimensions (technology, processes, models, management, and marketing, etc) to establish a sophisticated RAS-based shrimp farming system, thereby achieving optimized cost-effectiveness and sustainable development.

Thanks