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## Review on the development of kelp industry in Shandong province: A comparative perspective

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### Abstract

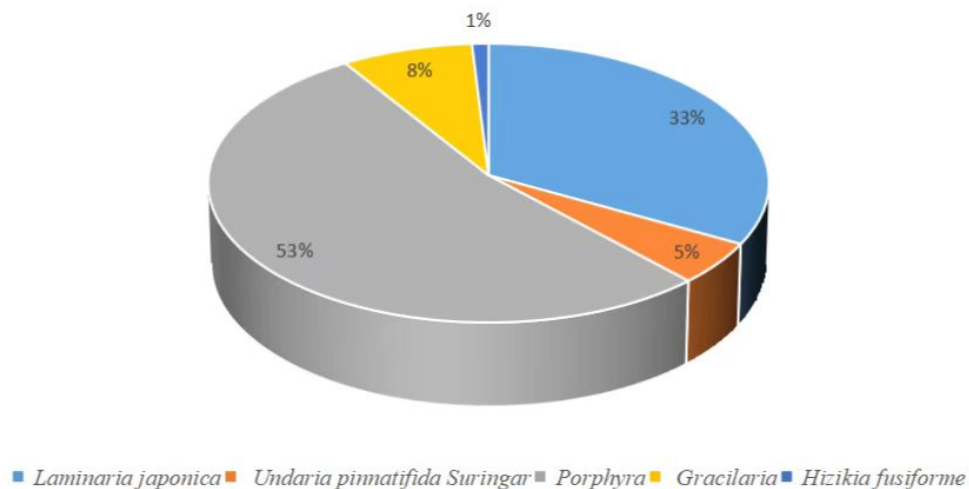
Shandong and Fujian are two important provinces regarding the development of the seaweed industry, which shared three-fourths of the national seaweed yield in the year 2020. The present study has analyzed the overall situation of the seaweed industry in Shandong and Fujian provinces by comparing annual output, farming area, and species structure. The current status of *Laminaria japonica* cultivation in two provinces is also compared to the production process, industrial organization, progress, and innovation. On this foundation, the following development strategies are proposed for the seaweed industry in Shandong Province: (1) change the mindset based on the present industrial basis, (2) retain and transform innovative achievements, (3) enhance the services of associations and organizations and (4) construct brands based on current market share.

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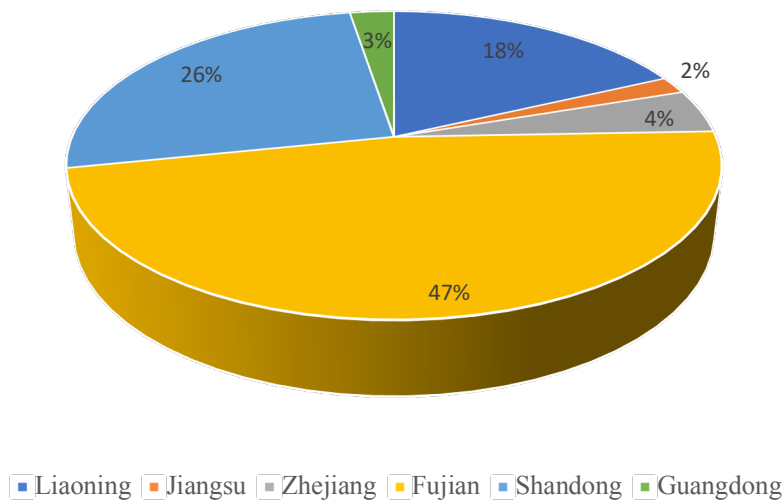
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## Introduction

With more than 60 years of development, the seaweed industry of China has taken an important position in the world seaweed industry (Cong et al., 2009). At present, China is one of the countries with the largest seaweed production globally (Sudarwati et al., 2020). In 2020, the national algae farming area was 142,000 hm<sup>2</sup> with a total output of 2,165,000 tons. The main cultivated seaweed species are *Laminaria japonica* and *Porphyra*, with a farming area of 46,000 and 72,000 hm<sup>2</sup> and production of 1,652,000 and 2,221,000 tons, respectively (Fishery Administration, MARA, 2021) (**Figure 1**). The main farming areas are located in Fujian, Shandong, and Liaoning provinces, accounting for 47%, 26%, and 18% of the national seaweed yield, respectively (**Figure 2**).



**Figure 1** The seaweed farming species of 2020 in China



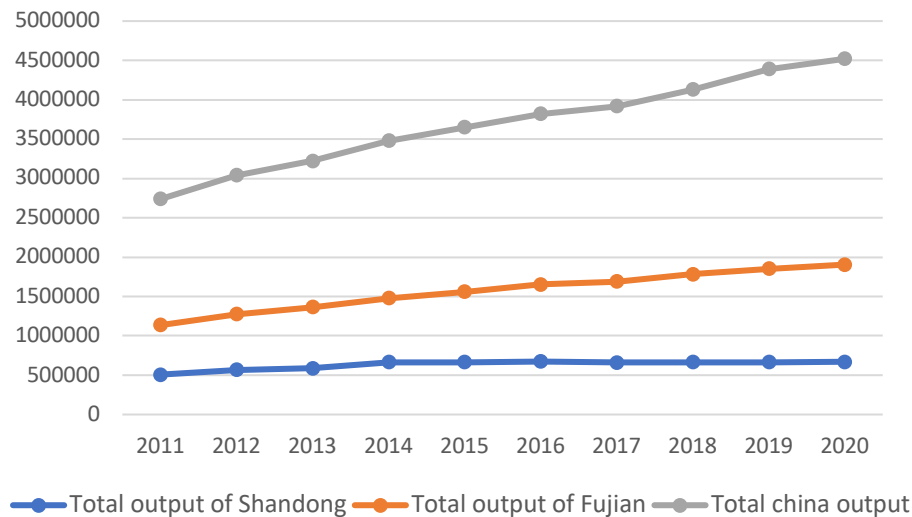
**Figure 2** The seaweed production of 2020 in China

## 1 A Comparative analysis of the seaweed industry in Shandong and Fujian

### 1.1 Analysis of production

From 2011 to 2016, seaweed production in Shandong and Fujian provinces showed an upward trend. Production in Fujian province has increased steadily since 2011, with seaweed

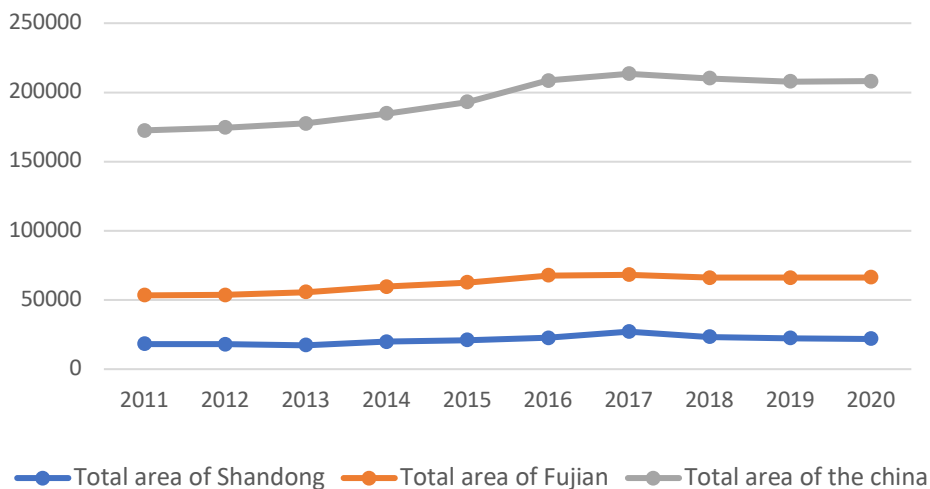
production in 2020 increasing by 96.6% compared to 2011; production in Shandong province has levelled off, with seaweed production in 2020 increasing by 31.9% (Fishery Administration, MARA, 2011-2021) (**Figure 3**).



**Figure 3** Total seaweed production in Fujian and Shandong from 2011-2020

*1.2 Comparison of farming area*

From 2011 to 2016, the seaweed farming area in Fujian province slightly increased. The farming area decreased in 2017 compared to 2016 and then stabilized. The seaweed farming area in Shandong province was in a shrinking trend from 2011 to 2013, then began to increase in 2014 before decreasing again after 2017. Generally, the farming area increased by 26.2% in Fujian and 20.6% in Shandong in 2020 compared to 2011, and the farming area in Fujian is twice that in Shandong (Fishery Administration, MARA, 2011-2021) (Figure 4).

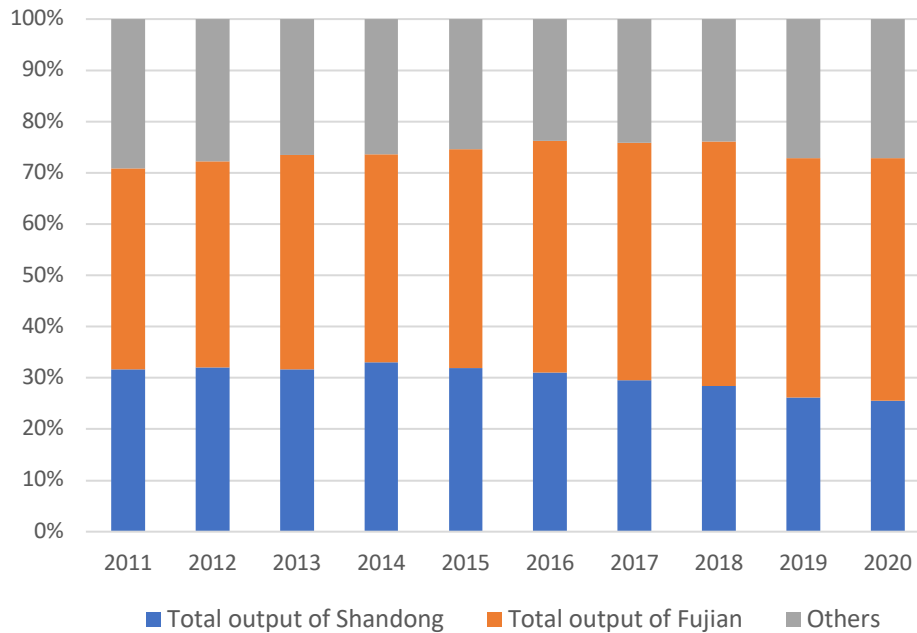


**Figure 4** Seaweed farming area in Fujian and Shandong from 2011-2020

*1.3 Production and farming area*

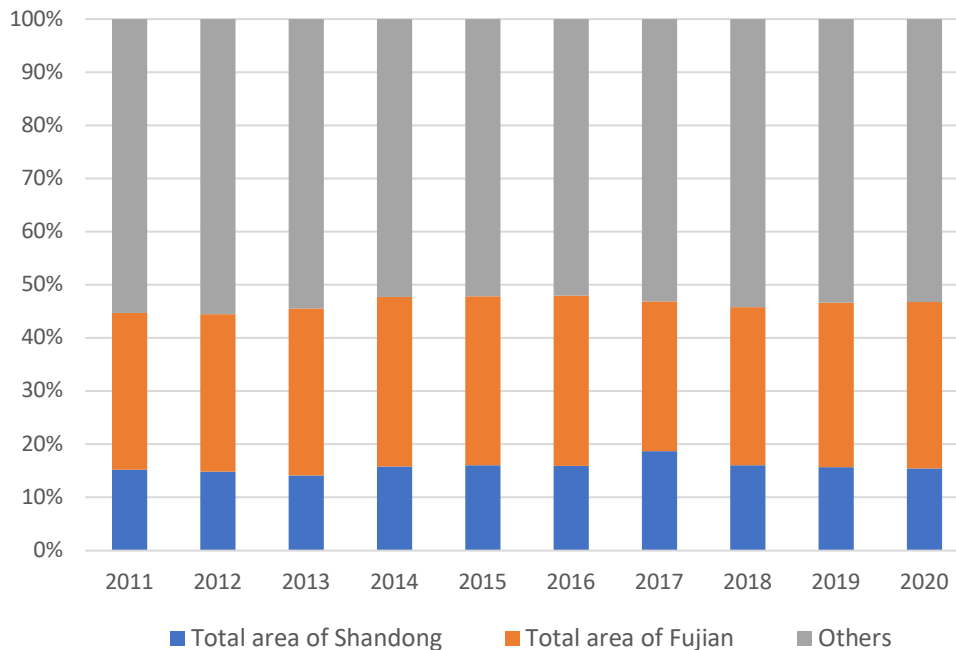
The total seaweed production in Shandong and Fujian provinces accounts for over 70% of the total output in China. From 2011 to 2016, the percentage of the total seaweed output in

the national production increased slightly, with a more significant increase in Fujian Province and a stable increase in Shandong Province. From 2017 onwards, the national share of output in both provinces has decreased (Fishery Administration, MARA, 2011-2021) (Figure 5).



**Figure 5** The seaweed production in Fujian and Shandong provinces from 2011-2020 in China

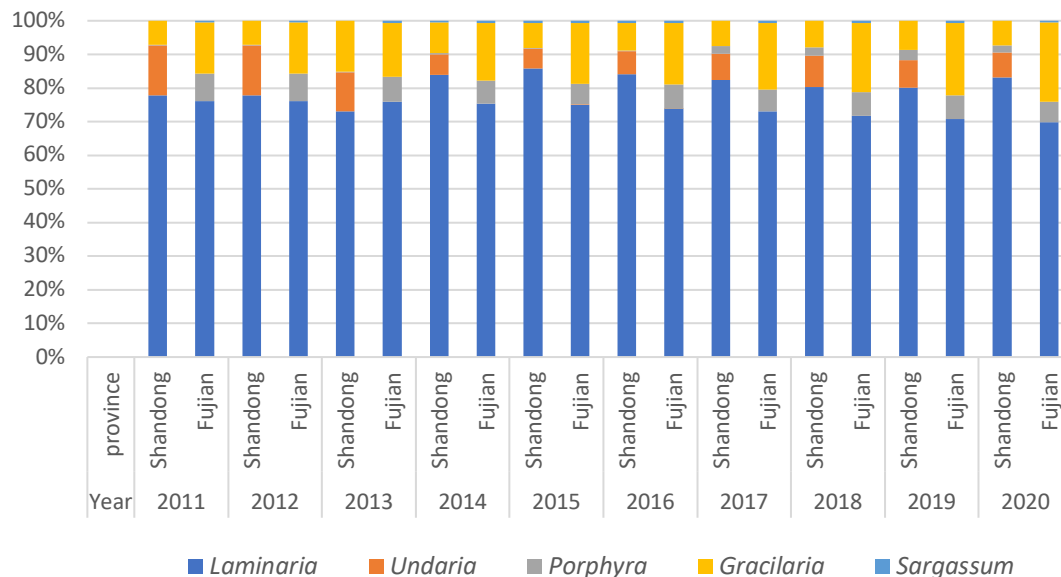
Concerning the proportion of farming area, both provinces showed a slight increase from 2011 to 2020, with 5.07% in Shandong Province and 8.54% in Fujian Province (Fishery Administration, MARA, 2021). Sharing 50% of the national seaweed farming area, Fujian and Shandong contributed over 70% of the seaweed production of the country (Figure 6).



**Figure 6** Seaweed farming area in Fujian and Shandong Provinces as a percentage of the national total from 2011-2020

#### 1.4 Comparison of species structure

The species of seaweed farmed in the two provinces are similar, mainly including *L. japonica*, *Undaria pinnatifida* Suringar, *Porphyra*, *Gracilaria* and *Hizikia fusiforme*. As the most-produced farming species in both regions, kelp occupies more than 70% of the seaweed production in Fujian. In comparison, it contributed to over 80% of that in Shandong in 2014, a historic high. *Undaria* is the only species with higher production in Shandong than in Fujian, accounting for 7.49% of the total. *Porphyra* is an important seaweed species in Fujian, with a stable proportion of 6%~8%, while its share in Shandong is only about 0.3%. The production of *Gracilaria* has been increasing year by year in Fujian, accounting for 23.4% in 2020 and only 7.4% in Shandong. The production of *Sargassum* in both Fujian and Shandong is 0.6% (Fishery Administration, MARA, 2021) (**Figure 7**).



**Figure 7** Seaweed species composition in Fujian and Shandong Provinces from 2011-2020

## 2 Developmental of kelp industry in Shandong and Fujian

### 2.1 Kelp industry in Shandong

In Shandong, kelp aquaculture in Shandong is mainly distributed in four cities, Qingdao, Yantai, Weihai, and Rizhao. In 2020, the kelp farming area was 15,200 hectares, with an output of 509,100 tons, accounting for 69.9% and 76.1% of the province's total algae aquaculture, respectively. The annual production of kelp seedlings is about 8 billion plants. The kelp is processed into lightly dried and salted products. The lightly dried vegetables have a better texture with greater market demand (Zhang et al., 2017). Shredded kelp, kelp stipe, kelp edge, and kelp clip are the main varieties of salted kelp, which were chemically processed with lower prices and smaller market share. In addition, products such as algae fertilizer, edible seaweed condiments, and seaweed noodles have also been developed (Yang et al., 2017).

### 2.2 Kelp industry in Fujian

In Fujian, kelp aquaculture is located at Putian, Xiapu, and Lianjiang. In 2020, the kelp farming area and output were 20,900 hectares and 827,800 tons, respectively, making up 47.2% and 66.9% of the province total, respectively. The annual production of seedlings is about 30 billion plants. The primary kelp processing and utilization forms are light dryings, salting, kelp food, and feed for sea cucumber and abalone (Tang et al., 2003). The drying methods are hang-drying and rack-drying. The salting process and salted products are similar to those in

Shandong. The direct use as feed for sea cucumber and abalone accounts for about 30% of fresh vegetable production (Philippsen et al., 2014).

### **3 Development discrepancy of kelp industry in Shandong and Fujian**

The kelp farming technology in Fujian mainly originates from Shandong, while the feature of kelp industry development is formed due to technological innovation and regional characteristics after long-term farming practice. The differences in the development of the kelp industry between the two provinces are mainly reflected in:

#### *3.1 Producing process*

##### *3.1.1 Parent kelp*

In Shandong, seedlings are collected on the same or the next day when the parent kelp was retrieved from the sea and then maintained for about 70 days; In Fujian, the parent kelp is transferred from the sea area to indoor cultivation to avoid typhoons and reduce spots, usually at the end of June when the water temperature reaches 27 °C. Seedlings are collected in late September and maintained for about 50 days (Bertocci et al., 2015).

##### *3.1.2 Seedling curtain*

In Shandong, the substrate for seedlings collection is palm rope. Taking Li Island Haikou kelp breeding ground as an example, the production cost of a single seedling curtain is about 150 RMB. In Fujian, nylon rope has been used since 1988 (Suganya et al., 2015). Taking the Fujian Xiapu Yijia kelp seedling corporation as an example, it costs about 90 RMB for a single seedling curtain.

##### *3.1.3 Harvest*

In Shandong, kelp is harvested by hired workers plant-by-plant at sea. In Fujian, kelp is harvested using a shipboard wheel-slide (winch) by electric harvesting and hoisting. Harvest is performed at intervals, with one whole rope collected every two ropes, beginning mid-March every year.

#### *3.2 Industrial chain*

The industrial chain in Shandong includes a nursery, farming, food processing, and chemical industry, with the amount of kelp used in the chemical industry accounting for about 50% of the total. In contrast, the industrial chain in Fujian includes a nursery, farming, and food processing.

#### *3.3 Industrial subject*

In Shandong, companies dominate the kelp industry. Large enterprises implement the integrated development of nursery, farming, and processing and build their own cold-air storage, with solid processing and storage capacities; In Fujian, the kelp industry is mainly family-oriented, with a farming area of around a few hectares. Farming and processing are separated, and the processing and storage capacities are relatively weak.

#### *3.4 Selling mode*

In Shandong, kelp enterprises are characterized by a large production scale and strong processing capacity with more stable sales avenues and a focus on bulk trading of products (Maria et al., 2015). In comparison, kelp enterprises in Fujian are smaller in scale, with weaker processing and storage capacities. They concentrate on capital flow and market sales and have a stronger sense of market expansion.

#### *3.5 Market groups*

In Shandong, kelp seedlings mainly meet the needs of the province itself and Dalian, contributing to about 50% of the Dalian market; kelp has a long growth period with good

quality and high nutrition and mainly targets food and chemical use (Wijesinghe et al., 2012). In Fujian, kelp seedlings are also distributed to Shandong and Dalian in addition to meeting the needs of the province itself. Fujian's seedlings account for about 30-40% of the Dalian market. As for the main consumer, kelp is used for food and cucumbers and abalone feed in Fujian (Sade et al., 2006).

#### **4 Recommendations for the development of Shandong kelp industry**

##### *4.1 Implement the technological innovation project of seed industry*

The kelp industry has increasingly shown its food and chemical market value, especially in the ecological field, with its continuous development in recent years. Therefore, it is recommended to accelerate the growth of the modern seed industry and establish a multi-disciplinary innovation research team to implement the technological innovation and automation of this industry. This team should focus on the industrialization of kelp germplasm resources, which specifically deals with germplasm, environment, and breeding. Seed selection and breeding are also recommended for the purpose of automation, edibility and ecologization, so that new germplasm and breeding materials with outstanding target traits and excellent comprehensive traits can be created. Special efforts should be made to breed and industrialize new kelp varieties that are "high-quality and specialized, green and efficient, resistant to adversity and suitable for mechanization."

##### *4.2 Upgrade the mechanization of the kelp industry*

The rapid rise in employees' wages has driven the rise in the production cost of the entire kelp industry. Taking the kelp nursery as an example, the total annual production cost of the enterprise is about 3.1 million, with 1.4-1.5 million of the labor cost accounting for nearly 50% (McHugh et al., 2015). Moreover, high labor costs have seriously squeezed the production profits of enterprises, with the employment situation getting even worse. Therefore, it is suggested to establish an interdisciplinary joint-research mode to focus on the kelp industry chain, emphasizing breakthroughs of mechanized operation techniques in kelp seedling, harvesting and drying. Meanwhile, supporting facilities and equipment for kelp harvesting, drying and soup processing should be developed so that the traditional manpower-based production mode could be shifted step by step to a mode combining human and machine power.

##### *4.3 Improve public services for the kelp industry*

Establish a "big data" database and a germplasm resource bank for kelp in Shandong to provide continuous information and germplasm support for industrial development. Explore the establishment of various marketing models, such as direct sales, enterprise-supermarket connection and e-commerce, to broaden the sales channels by direct supply of raw materials, cooperation in research and development. The role of the leading enterprises in kelp farming will be brought into play by applying the "big fishermen leading small fishermen" mode to improve the degree of industry organization and build close links among production, distribution, processing, export and domestic sales. Promote the industrial brand along with regional tourism promotion to help put Shandong's kelp brand on the map. To boost the prosperous development of kelp enterprises, farming insurance should be enforced in pilot operations so that appropriate financial service products can be developed.

##### *4.4 Strengthen services of seaweed industry association*

Since its establishment, the Jiangsu Nori Association has externally assisted enterprises to propose investigations and identify trade barriers in nori import, which urges breaking trade barriers in the import of striped nori. Meanwhile, internally it has fought for policies, explored markets and secured favourable conditions for the development of the industry. Therefore, it is recommended to draw on the experience of the Jiangsu Nori Association to build a platform

for cooperation between universities, institutes and enterprises and accelerate the transformation and application of scientific and technological achievements. A public service platform for the nursery, breeding, farming, processing and marketing of kelp and other economic seaweed varieties should be built to optimize the production environment, strengthen quality testing, improve sales network and organize market competitions.

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