DOI 10.15302/J-SSCAE-2019.06.008

Development of Technology for Antarctic Krill Fishing and Processing Equipment in China

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Abstract: Antarctic krill resources have great potential for development and utilization, and active participation in the Antarctic krill fishery can effectively promote China's pelagic fishery. Up-to-date technologies for professional fishing and processing equipment are the basic essentials and the guarantee of success in a modern Antarctic krill fishery. This paper introduces the development and application status of advanced krill ship equipment in other countries. It also summarizes the progress made by China in the research and development of equipment for Antarctic krill fishing as well as shrimp powder and oil manufacturing. Furthermore, it analyzes the gap between China and other advanced countries in professional equipment for Antarctic krill development and the underlying reasons for the discrepancy. In view of the low specialization, backward production technology, and lack of core technologies for fishery equipment for Antarctic krill boats in China, we propose some key research directions in relation to ecologically-friendly and efficient fishing, deep processing technology, and resource exploration and evaluation technology, and offer some suggestions for the efficient development and comprehensive utilization of an Antarctic krill fishery.

Keywords: Antarctic krill; fishery equipment; ecological fishing; deep processing; resource exploration

1 Introduction

As a potentially huge protein reservoir for human beings, Antarctic krill is the largest single biological resource on earth. Estimates put the resource reserve of Antarctic krill at nearly 1×10^9 t, and the annual fishing capacity at nearly 1×10^8 t, which is equivalent to the total annual fishing capacity of global marine fishery resources. Antarctic krill is rich in high-quality protein, omega-3, DHA, and all amino acids necessary for the human body. It is recognized as a future protein resource bank and described as the "sea ginseng" for human beings. Thus, it has great development and utilization potential. Antarctic krill resources are closely related to China's future economic development strategy and fulfillment of the demand for pure, natural, high-quality protein [1,2]. Given the general decline in fishery resources, the exploitation of Antarctic krill is attracting increasing attention from all over the world. In recent years, with a continual increase in international investment and the progress of technology, the countries with advanced fisheries have built the Antarctic krill fishery into a brand-new marine biological resources development and utilization industry supported by efficient fishing technology, boosted by high value-added products and integrated with fishing and deep processing on board, thus stimulating the desire for investment around the world. In an environment of increasingly fierce international competition for marine resources, the question is how to speed up the development of China's Antarctic krill resources. Strengthening and

Received date: July 15, 2019**; Revised date:** October 15, 2019

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Funding program: CAE Advisory Project "Research on Maritime Power Strategy by 2035" (2018-ZD-08)

Chinese version: Strategic Study of CAE 2020, 21 (6): 048–052

Cited item: Chen Zhixin et al. Game Theory Analysis of Marine Rights Protection. *Strategic Study of CAE*, https://doi.org/10.15302/J-SSCAE-2019.06.008

expanding the Antarctic krill industry is of great significance to the development of China's ocean fisheries, the development of new marine biological industries, the protection of food security, and the fight for rights and interests in Antarctic Ocean development [3,4].

2 Technical status and development trends in Antarctica krill equipment abroad

Globally, the commercial exploitation of Antarctic krill resources began in the 1970s. Traditional krill producing countries included the former Soviet Union, Japan, Poland, and South Korea. At present, the exploitation of Antarctic krill has entered a new period of development and resource competition. Currently, Norway, South Korea, China, Chile, Poland, and several other countries are engaged in Antarctic krill fishing.

2.1 Technical status of professional equipment for Antarctic krill boats abroad

2.1.1 Efficiency and ecology of Antarctic krill-fishing equipment

With continuous innovation in ship and fishing technology, the fishing capacity of Antarctic krill has been greatly improved, and the product types are increasingly diversified. The production mode mainly includes side frame trawling and single stern slipway net plate middle-trawling processing ships, and krill-fishing equipment increasingly embodies the characteristics of high efficiency, ecological responsibility, and automation. The high efficiency of Antarctic krill-fishing equipment is mainly due to continuous suction. The multiple broadside trawls and tail trawls are used combined with a high-efficiency pump to suck the krill into boats while towing without hoisting the net. The ecologically sound feature is the selective design of the net. This increases the separation net and escape port in the net body so that large aquatic animals are released naturally, and this achieves an effective combination of efficient and ecological fishing [5–7]. Japan and South Korea have both adopted the high-efficiency krill pump fishing technology. In addition, drag balance control and automatic control of net shape have been developed, and fishing depth is automatically adjusted through fishing-instrument detection signals. Norway, a newcomer to the krill industry, is the country with the greatest fishing efficiency. The SAGA SEA ship built by Norway is a large-scale krill-fishing and processing ship with the most professional and advanced technology in the world. Its fishing efficiency is more than 50% higher than that of traditional trawls. To cope with the characteristics of Antarctic krill, such as strong clustering and large range, underwater continuous pump suction fishing technology uses a suction pump and flexible pipe in the bag net to transport the captured krill to the ship continuously. This avoids the tedious work of hoisting and releasing the net, not only greatly reducing labor intensity, but also saving time and improving fishing [8].

2.1.2 Specialization and automation of Antarctic krill shipboard processing and comprehensive utilization

Japan successfully developed an Antarctic krill-fishing and processing ship in the early 1970s. This ship is equipped with multiple sets of equipment for the processing and production of frozen original krill, cooked shrimp, plastic shrimp meat, and shrimp powder used for feed and food. The highly efficient barrel shelling method is used to remove the Antarctic krill shell and can process 500 kg shrimp in one hour. This method uses the krill waste to produce food and recover protein from the wastewater when processing the shrimp. South Korea has developed the processing technology and a complete set of equipment for frozen shrimp, cooked shrimp, plastic shrimp meat, shrimp powder, and shrimp oil. Europe is equipped with a complete set of specialized deep processing equipment to carry out high-efficiency fishing. This has a high level of specialization and automation, and fully utilizes the industrial model of an automatic assembly line operation in processing. Some of the precooled shrimp products are made into frozen products for cold storage, but most of them are used for deep processing into shrimp powder and shrimp oil and even made directly into krill-pellet concentrate feed. The fishing capacity and added value of Norwegian krill-fishing vessels have been improved by highly efficient and automated shipboard processing equipment. The daily processing capacity of the equipment is more than 600 t, and the powder yield of shrimp powder is more than 40%.

2.1.3 Informatization of Antarctica krill resource exploration system

Many countries have actively promoted the application of ship industry technology and information technology in Antarctic krill professional ships while increasing their efforts in the exploration, investigation, development, and utilization of deep-sea fishery resources such as Antarctic krill. Their marine fishery equipment technology has achieved synchronous development with the shipping industry by taking advantage of developments in electronic information and equipment manufacturing technologies. For example, the Norwegian professional

DOI 10.15302/J-SSCAE-2019.06.008

krill-fishing boat ANTARCTICA SEA is equipped with specialized fish-detection instruments and information management systems based on satellite communications.

2.2 Development trend

At present, countries around the world are increasingly interested in the development and utilization of Antarctic krill and other polar fishery resources. While strengthening their efforts in the exploration, investigation, development, and utilization of Antarctic krill resources, they continue to promote the development of professional equipment and technology for Antarctic krill-fishing boats, making them increasingly large-scale, professional and information-based. To meet the requirements of polar environmental protection and ecological management, the following will be standard: integrated electric propulsion energy-saving technology, information-3D integrated detection technology for fishing equipment, a continuous and efficient ecological fishing mode, and a specialized and automatic shipborne intensive processing mode. Acoustic digital technology and multi-beam technology are being investigated for the detection and tracking of krill resources over long distances and in deep water. Selective fishing and automatic control technology are used to ensure the effective release of protected aquatic animals, if caught by mistake, and the continuous capture of krill in deep-water areas. Multi-layer reciprocating extrusion, swirl-drying technology, low-temperature refrigeration, and automatic control technology are used to achieve professional and efficient processing of krill. In addition, there is now a trend for the production of biological drugs, health products, and other high-value goods from Antarctic krill. In the future, shipborne processing equipment will be increasingly developed for shrimp primary oil extraction, shrimp powder, and shrimp meat deep processing.

3 Development status and gap of professional equipment for Antarctic krill boats in China

Technical research on specialized Antarctic krill-fishing and processing vessels in China started from the 12th Five Year Plan. In recent years, some key research and development have been carried out on the professional equipment of Antarctic krill boats, with the support of the Ministry of Finance, the Ministry of Agriculture, and the Ministry of Science and Technology. The main research progress is as follows:

3.1 Fishing technology and equipment

Recently, DH-256 special trawling gear for Antarctic krill and a horizontal expansion net plate for shallow-bottom speed krill trawling have been developed. The catch is significantly improved and is close to the level achieved by Japanese ships. A six-piece structure BAD13B00-TN01 Antarctic krill net has been developed, with an average energy consumption coefficient of 0.81 ($KWH/10^4m^3$). However, China has not yet caught up with Norway and other countries in advanced shrimp pump continuous fishing technology. A submersible shrimp suction pump has been designed for continuous krill fishing. The analysis and calculation of the krill pumping suction capacity were carried out using the computational fluid dynamic analysis method. An experimental simulation system for a krill pump was developed. The feasibility of the technology was verified, but the technical research needs to be further improved, and marketing of the product prototype is still some way off.

3.2 Shipborne processing technology and equipment of Antarctic krill

The shipborne technology and equipment for processing krill are still relatively backward. The processing of krill meal on board is based on the ground-based wet processing technology of fish meal, and the equipment is mainly repurposed from fish-meal processing equipment. Compared with Norway and other developed countries, there is still a big gap in the quality and output rate of krill meal. The output rate of krill meal is only 14:1, about one-half of the advanced international level. Moreover, the quality of krill meal is poor, and the loss of active substances is considerable, so it is impossible to obtain high-quality krill oil. The Institute of Fishery Machinery and Instruments has carried out research and development of Antarctic krill shipborne shelling and processing equipment and the optimization of process parameters. Sea trials and performance tests show that the maximum processing capacity of krill-processing equipment was 1000 kg/h per machine, and the average yield of shelled krill was 20 %. The shelled production line of Antarctic krill is initiated in China, which fills a gap in the field of research and development of krill-specialized processing equipment, and has been recognized as a high-tech achievement transformation project in Shanghai in 2018. At present, this krill meat processing equipment has been

installed on the “Shen Lan” krill-fishing and processing ship, currently being built in China, and this is a key step in achieving the localization of krill-processing equipment [9–12].

3.3 Probing technology of Antarctic kill

The investigation and evaluation of Antarctic krill resources have proceeded gradually along with the development of Antarctic scientific research in the 1980s. China’s fishery resources acoustic assessment and polar remote sensing technology research are relatively systematic, and significant achievements have been made. However, research on the equipment and technology supporting the exploration of deep-sea fishery resources such as the polar regions in China is seriously lagging behind, and the high-end acoustic detection instruments adapted for the exploration and resource evaluation of modern pelagic fishing are still to be developed in China. At present, China’s Antarctic krill exploration instruments all rely on foreign fish finder or classified beam scientific fish detectors. The exploration and catching of Antarctic krill in China is mainly focused on field investigation and fishing, and remote sensing methods for exploring polar biological resources are still in the initial stages [13~15].

Due to the late start of its Antarctic krill industry, a smaller body of scientific research, weak basic research, and intellectual property barriers, China’s Antarctic krill ships are mainly foreign second-hand large-scale trawlers, which are simply repurposed for the krill-fishing industry and suffer from lack of specialized technology and equipment. The R & D and market development of krill products is still behind, the core technology of processing on board has not been mastered completely, the production technology is backward, and the fishing efficiency and processing capacity are lower than that of developed countries. China has an understanding of the basic situation, key technologies, and industrial development trends in the Antarctic krill industry through research over the past 10 years since the start of its krill fishery. However, there is still a huge gap between China and foreign countries with respect to the international level of advanced krill equipment.

4 Development direction of China’s Antarctic krill-fishing and processing equipment

The integrated design of fishing and ship processing should be carried out based on the key equipment that is restricting large-scale development of Antarctic krill resources in China. The research should focus on efficient new ecologically sound fishing equipment for Antarctic krill, the development of high-value deep processing technology for krill on board, and information technology for the exploration of krill resources.

4.1 New types of efficient fishing equipment for Antarctic krill

Current studies are focusing on combining fluid drive, aerodynamics and automatic control technologies, research and development of selective fishing technology, automatic control technology for krill trawling, and non-damage continuous fishing technology. The efficient development and utilization capacity of Antarctic krill resources can be improved through system integration.

4.2 High-value deep processing technology of krill on board

To achieve high-value utilization of Antarctic krill by processing on board, the technologies of multi-layer reciprocating extrusion, swirl-drying, low-temperature refrigeration, automatic control, and other technologies should be adopted, and research is being carried out into system developments for shelling and meat extraction of krill, plus efficient processing and freezing of shrimp oil. Professional and efficient processing modes for krill will be developed in order to further capitalize on the comprehensive benefits of the Antarctic krill industry.

4.3 Exploration assessment and information support of Antarctica krill resources

Digital acoustic detection of Antarctic krill and other new resources is being studied so as to achieve accurate three-dimensional detection and fish-group prediction of deep-sea fishery resources such as those in the polar regions. The logistics support and information management systems for Antarctic krill will be based on the Internet of Things technology through the integration of fish detection and prediction, logistics support, fishing fleet equipment and operator management, fishing log, catch traceability, and other information.

5 Countermeasures and suggestions

5.1 Strengthen cooperation, innovate and accelerate the localization of Antarctic krill professional fishing boats and equipment

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We should strengthen cooperation with relevant research institutions in China and abroad, innovate in the research and development mode, and establish a mixed research and development mode, in order to improve China's scientific research and design capacity in the field of Antarctic krill professional ship equipment. Through the introduction, digestion, and absorption of new techniques, localized production of large-scale specialized fishing boats and equipment will be accelerated, and the combination of national scientific support and industrial development will be strengthened.

5.2 Policy guidance to encourage independent innovation of scientific institutions and fishery equipment manufacturing enterprises

The technological and equipment barriers that restrict the efficient development and utilization of krill should be overcome as soon as possible. It is important to strengthen cooperation between industry and academia to promote collaborative innovation between enterprises and scientific research institutions. The prototype of a specialized Antarctic krill-fishing boat should be created as soon as possible to drive industrial development.

5.3 Implement strategy for training and recruiting talent

Through cultivating a multiplicity of talents, it will be possible to build a professional research team for the design and construction of advanced krill-fishing boats. We will accelerate the training of fishery practitioners and enhance their professional skills, as well as improving the level of scientific research to provide technical support and expertise for the development of China's ocean fisheries.

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