

Research of Bioacoustic Characteristics in the Southern Ocean

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Abstract

Acoustic surveys of biological resources in the Southern Ocean are an important technical means for assessing Antarctic krill resources. However, copepods, polychaetes, jellyfish, pteropods, and other plankton often coexist in krill distribution areas, and their acoustic signals may interfere with krill echo identification and affect the scientific validity of resource assessment. Based on the literature attached to the project application, this paper adopts a narrative review method and summarizes Southern Ocean bioacoustic surveys, the target strength to body length relationship of Antarctic krill, multi frequency mean volume backscattering strength differences, the SDWBA target strength model, and preliminary multi frequency acoustic species identification. The review indicates that studies on the target strength and multi frequency acoustic characteristics of Antarctic krill are relatively mature, and differences between 38 kHz and 120 kHz acoustic images can be used for auxiliary identification. However, quantitative studies on the target strength of coexisting groups such as copepods, polychaetes, jellyfish, and pteropods remain weak, and preliminary multi frequency identification models are still incomplete. It is recommended to strengthen the construction of target strength libraries for multiple groups, standardized equipment calibration, spatiotemporal matching between acoustic and biological sampling, and field validation of multi frequency identification models, so as to improve the accuracy of acoustic surveys and assessments of biological resources in the Southern Ocean.

Keywords

Southern Ocean; Bioacoustics; Antarctic Krill; Target Strength; Multi Frequency Acoustic Identification.

1. Introduction

The survey and assessment of Antarctic krill and other biological resources in the Southern Ocean are of great significance for understanding the Southern Ocean ecosystem and promoting the sustainable use of biological resources. The Commission for the Conservation of Antarctic Marine Living Resources, CCAMLR, organizes multinational survey vessels to conduct acoustic surveys in the Southern Ocean and formulates fisheries management measures based on survey results[1], . Acoustic surveys have the advantages of continuous, rapid, and large scale observation and have become an important means for assessing Antarctic krill resources. However, krill distribution areas in the Southern Ocean are often accompanied by large numbers of copepods, polychaetes, jellyfish, pteropods, and other plankton. If these species cannot be identified in previous data processing, their acoustic signals may be mixed into krill echoes, thereby affecting the scientific validity of krill resource assessment.

The relationship between target strength, TS, and body length is a core parameter in acoustic resource assessment. For Antarctic krill, Wiebe et al. [2] combined scientific echosounders with

biological sampling to study acoustic image characteristics. Watkins et al. [3] used differences in mean volume backscattering strength, MVBS, between 38 kHz and 120 kHz acoustic images to identify Antarctic krill. Conti et al.[4] studied three frequency acoustic image characteristics and proposed an improved SDWBA target strength model. In China, Yang Quan et al. [5] used a light falling net and a scientific echosounder to synchronously collect biological and acoustic data of purpleback flying squid, providing a reference for combined acoustic and net surveys. However, reviews on the acoustic characteristics of coexisting plankton in the Southern Ocean and preliminary multi frequency identification are still limited. This paper aims to summarize the current status of research on bioacoustic characteristics in the Southern Ocean, analyze existing problems, and propose suggestions for future research.

2. Literature Sources and Methods

This paper is a narrative review, not a systematic review. The literature was obtained from the references attached to Chen Shuai's project application titled Biological Significance of Acoustic Survey Images of Biological Resources in the Southern Ocean. A total of 5 references were used, no new literature was added, and no systematic database search or bibliometric analysis was conducted. The included literature covers error estimation of krill biomass in the CCAMLR 2000 survey, sound scattering by live zooplankton and micronekton, verification of acoustic techniques for identifying Antarctic krill, parameterization of the SDWBA target strength model for krill, and acoustic assessment of purpleback flying squid in China. This paper does not report original survey data, and the relevant conclusions are limited by the number of references and are preliminary.

3. Overview of Acoustic Surveys of Biological Resources in the Southern Ocean

Large scale surveys organized by CCAMLR are important practices in acoustic surveys of biological resources in the Southern Ocean. Demer 1 analyzed the error in the CCAMLR 2000 survey estimate of krill biomass, indicating the importance of acoustic survey error assessment for the scientific validity of resource assessment results. Acoustic surveys in the Southern Ocean usually use scientific echosounders for continuous observation to obtain acoustic images of biological resources, while biological sampling nets are used to obtain species composition and body length structure. By matching acoustic data with biological data, the biological significance of acoustic images is interpreted. Survey vessels are usually equipped with multi frequency scientific echosounders, using frequencies such as 38 kHz and 120 kHz to cover the main scattering signals of krill and coexisting plankton. Because the survey vessel hull is large and the surface is complex, standard sphere calibration is difficult, and equipment calibration status directly affects the reliability of target strength measurement and resource estimation.

4. Acoustic Characteristics of Antarctic Krill

4.1. Target Strength and Body Length Relationship

The target strength to body length relationship is the basis of acoustic assessment of krill. Wiebe et al. 2 used a dual beam acoustic system to study sound scattering by live zooplankton and micronekton. They found that within the depth range of 0 to 250 m, the volume backscattering strength S_v at 120 kHz differed from that at 38 kHz by 2 to 16 dB, and they provided an empirical relationship between Antarctic krill target strength and body length.

$$TS(L)=-127.45+34.85\log_{10}L+10\log_{10}(k/k_{120\text{kHz}}) \quad (1)$$

In the equation, TS_L is the target strength of a single Antarctic krill in dB relative to 1 square meter. L is body length in mm. k is the wave number ratio, equal to $2\pi f$ divided by c . f is transducer operating frequency in kHz. c is sound speed in m per s. $k_{120\text{kHz}}$ is the wave number ratio corresponding to 120 kHz. This relationship indicates that krill target strength increases with body length and is affected by frequency, providing an empirical basis for interpreting field acoustic images.

4.2. Multi Frequency MVBS Difference

Watkins et al. [3] studied 120 kHz and 38 kHz acoustic images from a Simrad EK500 scientific echosounder around South Georgia in 1996. They found that the MVBS difference of Antarctic krill was 2 to 12 dB and corresponded well with krill samples from the sampling net. The regression relationship was MVBS difference equal to 0.94 and r^2 equal to 0.99. This study showed that multi frequency MVBS difference can reflect acoustic differences between krill swarms and other scatterers and is an important indicator for acoustic identification of krill. However, MVBS difference is affected by species composition, body length structure, posture, and environmental conditions and must be interpreted together with synchronous biological sampling.

4.3. SDWBA Target Strength Model

Conti et al. [4] studied acoustic image characteristics of Antarctic krill using 38, 120, and 200 kHz three frequency scientific echosounders and proposed and improved the krill target strength SDWBA model, namely the stochastic distorted wave Born approximation model. This model considers krill body length, posture, and frequency response and is currently one of the target strength models designated for use by CCAMLR, with wide application. The SDWBA model improves the parameterization level of krill target strength, but it mainly targets Antarctic krill and still lacks directly applicable parameterized models for coexisting groups such as copepods, polychaetes, jellyfish, and pteropods.

5. Acoustic Characteristics of Coexisting Plankton and Preliminary Species Identification

5.1. Acoustic Interference from Coexisting Groups

In krill distribution areas of the Southern Ocean, copepods, polychaetes, jellyfish, pteropods, and other plankton are abundant. Different groups differ in morphology, size, posture, and acoustic scattering characteristics, and their echoes may fall within the interpretation range of krill acoustic images. If all echoes are interpreted only with the krill target strength model during data processing, krill resources may be overestimated or misjudged. Therefore, studying the target strength to body length relationship, frequency response, and acoustic image characteristics of coexisting groups is key to improving the scientific validity of krill resource assessment. However, the literature attached to the project application does not provide quantitative target strength results for these groups, and relevant research still needs to be supplemented.

5.2. Preliminary Multi frequency Acoustic Identification

Multi frequency scientific echosounders can obtain acoustic images of the same target group at multiple frequencies. Different species have different MVBS differences and frequency responses due to differences in acoustic scattering characteristics. Using multi frequency image differences such as those between 38 kHz and 120 kHz, combined with biological sampling to determine species composition, is a feasible approach for preliminary species identification in acoustic data post processing. The MVBS difference study by Watkins et al. [3] provided an example for krill identification. The three frequency study by Conti et al. [4] further illustrated

the role of frequency information in krill target strength parameterization. However, multi frequency identification models require stable equipment calibration, synchronous biological sampling, and sufficient target strength data as a foundation.

5.3. Reference to Related Domestic Research

Yang Quan et al. [5] used a light falling net and a scientific echosounder to synchronously collect biological and acoustic data of purpleback flying squid in the Nansha Islands sea area from April to May 2011. They calculated an empirical formula between mantle length and field target strength and explored a survey method combining acoustics and light falling nets. Although this study is not a Southern Ocean krill study, its technical approach of acoustic observation, net sampling, and target strength fitting has methodological reference value for research on acoustic characteristics of coexisting groups in the Southern Ocean and preliminary multi frequency identification.

6. Existing Problems and Research Prospects

6.1. Existing Problems

- 1) Target strength data for coexisting groups are lacking. Existing studies mainly focus on Antarctic krill, while quantitative results on the target strength to body length relationship and frequency response of copepods, polychaetes, jellyfish, and pteropods are insufficient, limiting the biological interpretation of acoustic images.
- 2) Preliminary multi frequency identification models are still incomplete. Multi frequency MVBS differences can assist krill identification, but statistical classification models and software implementations for multi group coexistence are still limited, and field validation of models is insufficient.
- 3) Equipment calibration and spatiotemporal matching of sampling are difficult. Standard sphere calibration of scientific echosounders on survey vessels is limited by hull conditions. Biological sampling requires precise control of trawl depth and must ensure that sampled water bodies correspond in time and space to acoustic detection water bodies.
- 4) The SDWBA model has limited applicable objects. This model mainly targets Antarctic krill and is difficult to directly extend to coexisting plankton. Multi group acoustic scattering models need to be developed.

6.2. Research Prospects

It is recommended to advance from the following aspects.

- 1) Establish a target strength to body length relationship library for important biological groups in the Southern Ocean, covering Antarctic krill and copepods, polychaetes, jellyfish, pteropods, and other groups.
- 2) Strengthen multi frequency and broadband acoustic observation and use frequency response differences to improve species discrimination.
- 3) Standardize equipment calibration and spatiotemporal matching procedures between acoustic and biological sampling to improve data comparability.
- 4) Develop statistical classification and preliminary identification programs in post processing software such as ECHOVIEW and validate them with field synchronous sampling data.
- 5) Strengthen the combination of tank experiments and field surveys to obtain target strength parameters under controlled conditions and support field acoustic image interpretation.

7. Conclusion

Research on bioacoustic characteristics in the Southern Ocean is relatively mature in terms of target strength and multi frequency identification of Antarctic krill. Differences between 38 kHz and 120 kHz acoustic images and the SDWBA model provide important support for krill resource assessment. However, quantitative research on the target strength of coexisting groups such as copepods, polychaetes, jellyfish, and pteropods remains weak, preliminary multi frequency identification models are still incomplete, and equipment calibration and spatiotemporal matching between acoustic and biological sampling remain key links restricting data quality. Future work should strengthen the construction of target strength libraries for multiple groups, the development of multi frequency acoustic identification models, and field validation, so as to improve the scientific validity and accuracy of acoustic surveys and assessments of biological resources in the Southern Ocean.

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