Impact of Island Nuclear Power Project on the Spatial Distribution Pattern of Mariculture: A case Study of Niushan Island, China

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Abstract—Nuclear power generation is being promoted globally as a clean energy source and is one of China’s key tools for addressing carbon peaking and carbon neutrality. The Niushan Island of China was selected as the research area and conducted detailed seasonal surveys at sea to explore the spatial distribution pattern of marine aquaculture around nuclear power project and analyze the potential impact of island nuclear power project construction on major marine aquaculture species. The results showed that, the spatial distribution pattern of mariculture around the Sea Island Nuclear Power Project is closely related to the aquaculture environment and seasonality. The main mariculture activities include Porphyra cultivation, mudflat breeding and ponding aquaculture. The envelope area of suspended sediment greater than 10 mg/L is 13.0565 km² during the construction of the project, which may have an impact on the Porphyra cultivation. The average half-moon tide 1.0°C temperature rise envelope is 31.30 km² in summer and 2.64 km² in winter for the 6×AP1400 nuclear power units. The temperature rise caused by human factors may have an impact on the breeding activities of “Jiluo Sanniu Marine Ranch”.

1. Introduction

In recent years, in order to develop clean energy project vigorously in China, the island nuclear power project have been promoted and demonstrated in coastal areas of China[1][2]. During the construction of nuclear power project, the suspended sediment discharged into the sea can cause an increase in seawater turbidity in local waters, reducing the transparency of the sea water column. This leads to a decrease in the concentration of phytoplankton cells and ultimately affects the primary productivity of the water, indirectly affecting the abundance and biomass of zooplankton that depend on phytoplankton as their main food source[3][4][5]. Additionally, suspended sediment can also adsorb various inorganic nutrients in the water, preventing primary producers from fully utilizing these nutrients[6][7]. Therefore, during the construction of nuclear power project, particular attention should be paid to the impact of suspended sediment diffusion on the surrounding marine environment, especially on aquaculture species.

During the operation period of island nuclear power project, a large amount of cooling water, i.e., warm discharge water, is released through the outlet with increased temperature due to the use of seawater as a circulating water source[1][2][8]. Typically, the summer warm discharge water volume of 6×CAP1400 nuclear power units is approximately 500m³/s (including the circulating water system and the plant water system). The discharge of warm water can have important impact on the aquaculture organisms in the surrounding waters[9]. Therefore, during the operation of nuclear power project, particular attention should be paid to the physiological effects of temperature rise caused by warm discharge water on aquaculture species.

This study selected Niushan Island of China as the research area and conducted detailed seasonal surveys at sea to explore the spatial distribution pattern of marine aquaculture around nuclear power project and analyze the potential impact of island nuclear power project construction on major marine aquaculture species. Feasible recommendations are provided for the ecological adaptability between island nuclear power project and marine aquaculture organisms, while assessing the ecological and environmental risks of nuclear power project construction.

2. Research area and method

In this paper, the surveys of the current state of mariculture in the sea area within 15 km in diameter (mainly including two areas in Songmen Town and Shitang Town) affected by the Sea Island Nuclear Power...
Project (Niushan Island) were carried out in summer (August 19-22, 2020), autumn (November 24-27, 2020), winter (January 13-16, 2021) and spring (April 20-23, 2021) (Fig. 1). The spatial distribution pattern of mariculture in the survey area was integrated and mapped. The survey of the spatial distribution pattern of mariculture was carried out by means of unmanned aerial photography[10]. For the influence of the suspended sediment generated during the construction period and the warm water discharged during the operation period on the mariculture species, the calculation results of the mathematical model under the operating conditions of 6×CAP1400 nuclear power units were used to superimpose the spatial distribution pattern map of mariculture for comprehensive analysis[11][12].

3. Result and Discussion

3.1 Spatial distribution pattern of mariculture near the Sea Island Nuclear Power Project

According to the survey results of four seasonal cruises, the spatial distribution pattern of mariculture around the sea area of the Sea Island Nuclear Power Project is shown in Table1 and Fig. 1.

3.1.1 Within 5 km from the Sea Island Nuclear Power Project

The main fishery activities in this sea area are: fishing activities with fixed nets in larger areas are found in the northwest and south of Niushan Island in Shitang Town, and in the southeast and north of Waidiaobang Island, which mainly focus on catching the larva of Anguilla japonica, and also catching nekton species of Pampus argenteus, Collichthys lucidus, Nibea albiflora, Miichthys miuy, Charybdis japonica, Portunus trituberculatus. In addition, in the south of Niushan Island and the north of Sansuan Island, there is a Marine Ranch Demonstration Zone in the sea area of "Jiluo San Niu"[13], and the area of Marine Ranch Demonstration Zone is 198 hm² (Table1, Fig. 1).

3.1.2 In the Sea Island Nuclear Power Project more than 5 km away, within 15 km range

From Table 1 and Fig. 1, it can be seen that:

1) In the Songmen Town around the Hengmen Island, Jiudongmen Island and Beishahuo Island, there is a certain size of the Porphyra cultivation area, the total aquaculture area of about 1.083 km².

2) A continuous ponding aquaculture area was found near the mudflats in the east of Songmen Town center, with farmers mainly farming Scylla paramamosain. In the adjacent Mudflat breeding area, Sinonovacula constricta, Tegillarca granosa, Meretrix meretrix were also farmed, with a farming area of about 1.502 km² and 0.195 km² in the mudflat and ponding aquaculture areas, respectively.

3) Other areas of mudflat breeding are mainly concentrated in the sea area of Aiwan Bay in Shitang Town, and there is also a small area located southwest of Shitang Town Center, with a total breeding area of about 3.554 km².

4) The surveys also found that there are more fixed net fishing activities in the waters around the project, which are mainly found in the south of Jiudongmen Island, the east of Beishahuo Island, the surrounding areas of Nanshahuo Island (East, West and South), the east of Zhidashan Island and the south of Xietou Island in Songmen Town; and mainly in the south of Yisuan Island and the south of Ersuan Island and Sansuan Island in Shitang Town. In addition, a small amount of set fixed nets were also found in the waters of Aiwan Bay.

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Mariculture area</th>
<th>Location</th>
<th>Mariculture species</th>
<th>Size of mariculture area (km²)</th>
<th>Distance (D) from nuclear power project location (km)</th>
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<tbody>
<tr>
<td>A1</td>
<td>Porphyra cultivation area</td>
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<td>5&lt;D&lt;15</td>
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<td>B2</td>
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<td>Songmen Town</td>
<td><em>Scylla paramamosain</em></td>
<td>0.195</td>
<td>5&lt;D&lt;15</td>
</tr>
</tbody>
</table>

*Fig.1 The current distribution pattern of mariculture in the sea near the project in all seasons*
3.2 Analysis of the impact of suspended sediment dispersion on mariculture during the construction period of the Sea Island Nuclear Power Project

The high concentration of suspended sediment generated by the construction activities of the Sea Island Nuclear Power Project may have an impact on mariculture activities (including marine ecology) in the surrounding waters. The coverage of large particles of suspended sediment on benthic fish, especially the young larvae with weak escape ability and sedentary shellfish, etc., will destroy their habitat and lead to a reduction in production or death, resulting in a direct harmful effect. Suspended sediment has a clogging effect on the respiratory organs of marine animals. High concentration of suspended sediment particles can cause mechanical damage to fish and other nektont, block gill holes, stimulate gill filaments and mucous membranes, resulting in physiological hypoxia and even death by suffocation[3][4][5].

According to the calculation results of the suspended sediment dispersion mathematical model during the construction period of the nuclear power project. After the construction work of the nuclear power project starts, the suspended sediment entering the sea water will not only fall into the silt, but also disperse in the water near the construction site under the action of the tide and water mass. As can be seen from Fig. 2, the envelope area of suspended sediment greater than 10 mg/L is 13.0565 km² during the construction period. The main impact area is the fishing activities of the fixed net around Niushan Island[14]. This production activity can be transferred by cutting the fixed net offsite, and the production behavior can be continued in other sea areas, and the impact on it is acceptable[14][15].

For other farming activities such as Porphyra cultivation, Mudflat breeding, as the spread of suspended sediment may be related to the seasonal flow of the eastern seawater mass and ocean currents, the southwest eastern seawater mass may roll with the construction suspended sediment into the Porphyra cultivation area north of Niushan Island during the summer construction period under the influence of southeast monsoon. Therefore, the construction unit of the nuclear power project should consider the impact of suspended sediment generated by the summer construction on the Porphyra cultivation area.

3.3 Analysis of the impact of thermal drainage discharge on marine aquaculture during the operation period of the Sea Island Nuclear Power Project

As the sea area of the sea island nuclear power project belongs to the enrichment area, the sea water quality requirements need to meet the second category of sea water quality standards, that is, the sea water temperature rise caused by man-made does not exceed 1℃ in summer and 2℃ in other seasons[16]. And when the temperature rise caused by man-made reasons (temperature drainage from nuclear power unit cooling) in the project sea area is 1-2℃, it will have a certain negative impact on mariculture activities[1][2][8].

As can be seen from Fig. 3, according to the results of the temperature and drainage mathematical model for the Sea Island Nuclear Power Project, the average half-moon tide 1.0℃ temperature rise envelope is 31.30 km² in summer and 2.64 km² in winter for the 6×AP1400 nuclear power units. The overall area of temperature rise contour in summer is larger than that in winter. The impact of the temperature and water drainage from the nuclear power project during the operation period on the aquaculture activities in the nearby sea area mainly includes the fixed open net fishing activities near Niushan Island and Waidiaobang Island (blocks of C8, C9 and C10), and the Marine Ranch Demonstration Zone in the sea area of "Jiluo Sanniu" to the south of Niushan Island, which has been included in the national marine ranch demonstration area construction plan. The demonstration area construction project has been included in the "National Marine Ranch Demonstration Area Construction Planning (2017-2025)", the East China Sea area of Zhejiang offshore waters national marine ranch demonstration area planning and construction. As the future project is completed, it will have a certain impact on the activities of "Jiluo Sanniu Marine Ranch Demonstration Zone ". Therefore, these impacts need to be considered during the construction process of island nuclear power project[1][2][8][9].
Fig. 2 Suspended sediment envelope extent and nearby mariculture during construction.
4. Conclusion

Based on the previous results and discussions, the following conclusions were obtained:

(1) The spatial distribution pattern of mariculture around the sea area of the Sea Island Nuclear Power Project is closely related to the aquaculture environment and seasonality. The main mariculture activities include Porphyra cultivation, mudflat breeding and ponding aquaculture.

(2) The envelope area of suspended sediment greater than 10 mg/L is 13.0565 km² during the construction of the Sea Island Nuclear Power Project, which may have an impact on the Porphyra cultivation.

(3) The average half-moon tide 1.0°C temperature rise envelope is 31.30 km² in summer and 2.64 km² in winter for the 6×AP1400 nuclear power units. The temperature rise caused by human factors may have an impact on the breeding activities of "Jiluo Sanniu Marine Ranch".

Acknowledgments

This work was financially supported by the National Key R & D Program of China (2022YFF0802203) and the Scientific Research Fund of the Second Institute of Oceanography, MNR (JG 1610).
References


