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学位論文内容の要旨

博士の専攻分野の名称：博士（水産科学）　　氏名：賈川 CHUAN JIA

Study on the monitoring methods for early warning of harmful organisms such as jellyfish and macroalgae near the water intake of the nuclear power plant

（原子力発電所取水口の周辺海域におけるクラゲ類・海藻類等有害生物の早期警戒のための
モニタリング手法に関する研究）

1. Introduction

Nuclear energy has been seen as an essential alternative for guaranteeing global energy supply and cannot be ignored due to its high capacity, mature technology, cleanliness, and environmental protection. It has lately begun to be regarded as a means of mitigating climate change. Most nuclear power plants (NPPs) are constructed near coastlines to facilitate access to cooling water. The water intake is an important source since it provides cooling water for many pieces of equipment. The stability of the cooling water directly impacts the security and economics of NPPs. However, occasionally, the cooling water intake system could be clogged by biotic and abiotic substances. Macroalgae and jellyfish are the primary sources of biological blockage in the incidents of cooling water intake. There is no better countermeasure than monitoring differential pressures and flow rates of the cooling water intake system yet. This study aims to develop monitoring methods for early warning of harmful organisms, such as jellyfish and macroalgae, near the water intake of the Hongyanhe NPPs in the Liaodong Bay of Bohai Sea, China.

2. Materials and Methods

The monitoring experiments for macroalgae were conducted using the quadrat method every seven days from March to August in 2018-2019. The experiments for medusa were conducted using an anchor drift net by a vessel in coastal waters every three days from June to September in 2018-2020. Ten relatively intact individuals were randomly selected from each net as sub-samples, and the wet weight and bell diameter were measured. Furthermore, we conducted dive surveys to understand the growth and distribution of macroalgae in the subtidal zone. For jellyfish, experiments of station selection and gear selection were conducted to discuss their patchy distribution and characteristics in different life history stages. During the gear selection experiment, five kinds of plankton nets were used to sample ephyra. While for medusa, bursiform and plane anchor drift nets were employed.

Generalized linear model (GLM) and Multiple regression analysis were conducted for the estimated biomass of macroalgae as the objective variable with environmental factors. GAM (generalized additive model) was used to analyze the influence factor on the biomass and the bell diameter of medusa. Additionally, the influence of macroalgae and jellyfish biomass on the interception and backwash sampling was identified using GLM analysis.

3. Result

Macroalgae monitoring

Dominant species were the green algae *Enteromorpha linza* and *Ulva pertusa*, the brown algae *Sargassum thunbergii* and *Punctaria latifolia*, and the red algae *Ceramium kondoi* and *Gelidium* sp.. The proportion of green algae and brown algae was about 80%. Brown algae began to decline at 20°C, and green algae started to decrease at 25°C or higher. Green algae biomass was similar in intertidal and subtidal zones. However, brown algae biomass

was much higher, especially in the subtidal zone, and the algae length was also longer.

Jellyfish monitoring

The relative biomass and bell diameter of *Aurelia coerulea* (*Ac*) increased from June to July and showed a gradual downward trend at the beginning of August. For *Nemopilema nomurai* (*Nn*), these had an increasing trend from June to late August and decreased in September. The bell diameter of *Ac* was mainly affected by water temperature, salinity, DO, and eastward currents. For *Nn,* the bell diameter decreased when the eastward or westward currents increased. The relative biomass of *Ac* was mainly affected by water temperature, salinity, PH, and eastward currents. For *Nn*, the relative biomass was more affected by DO than PH.

Moreover, it was appropriate that the stations were set up 5 km far from the shore. The gear selection experiment indicated that the mean abundance was inversely proportional to mesh size, with the cone net of the smallest mesh size exhibiting the highest catchability coefficient (63.8%). For the small medusa and *Ac* large medusa, a bursiform net with a 16 mm mesh size would be superior to a plane net in preserving the integrity of individuals. The plane net with a mesh size of 100 mm was more effective for capturing *Nn* large medusa.

Correlation between marine organisms and cooling water system

The biomass on the south and north side had a higher correlation with backwash sampling than the area near the water intake. The biomass of *U. pertusa* was most strongly correlated with backwash sampling. For *N. nomurai*, the biomass was significantly correlated ($p<0.05$) with the interception of trash-blocking nets. The biomass of *A. coerulea* was significantly correlated with the backwash sampling.

4. General Discussion

The significant increase of macroalgae began in May when the water temperature reached about 15°C and peaked around June. In July, the macroalgae declined as the water temperature rises above 25°C. Macroalgae thrived at 10°C - 15°C. The statistical analysis suggested that green algae were more sensitive to environmental conditions than brown and red algae. Water temperature was not the only factor affecting macroalgae growth, but the monthly condition of water temperature conditions affected their growth. The distribution of macroalgae near Hongyanhe NPPs was investigated, mainly in the intertidal and subtidal zones with reef and gravelly texture.

For jellyfish, the results of continuous monitoring showed that the bloom timing of jellyfish ranged from early July to mid-August. According to GAM analysis, the north-south currents had a strong influence on the bell diameter of *Nn*. The water temperature, salinity, and month significantly impacted relative biomass. From the gear selection experiment results, mesh size (< 200 μm) was considered as the primary determinant of the catchability coefficient for ephyra. For small medusa, more intact individuals were sampled more intact in a bursiform net, and a smaller mesh size showed superior sampling performance. On the other hand, a large-meshed plane net was preferable to sample large medusa of *Nn* by reducing the filtration pressure around meshes. Different from macroalgae, jellyfish are zooplankton, and their aggregation is more affected by currents. By the analysis of currents, the location of jellyfish larvae was inferred, and the effect of currents on the population fluctuations of jellyfish was discussed.

From these results, we recommended the optimal monitoring methods for early warning of harmful organisms. These methods allow us to know accurate information about the growth and distribution of marine organisms that affect the safety of cooling water systems. It also provides suggestions for improvement of the first protective measure of the cooling water intake system - trash-blocking nets installation. This study would be a pioneer in biomonitoring for the safe operation of NPPs. In addition, the monitoring methods developed in this study could also be applicable to other coastal facilities, such as thermal power plants that require seawater for cooling purposes.