Survey of Macrobenthos on Multiple Lithofacies in the Intertidal Zone of Jimo in spring and autumn

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Abstract. Jimo is a district under the jurisdiction of Qingdao City, located in the southern Jiaodong Peninsula and bordering the Yellow Sea. The project is to investigate the distribution of benthic animals in the scattered lithofacies environment when the overall environment of the intertidal zone is sandy tidal flats, and to make a preliminary statistics of the species in the region, in October 2018 and April 2019, two benthic animal surveys were conducted at the same sampling point in an intertidal zone near Aoshanwei Town, Jimo District, Qingdao. A total of 32 species of macrobenthos in the intertidal zone were collected in six sections. There are obvious differences in ecological data in different lithofacies sections and winter and summer. The results of this survey can provide references for the study of macrobenthos in special lithofacies.

1. Introduction
The intertidal zone is an interlaced zone of terrestrial ecosystems and marine ecosystems. It belongs to one of the most sensitive ecosystems in the biosphere, and is also the region with the most serious human activities and disturbances [1,2,3]. Due to its special environment, it has been paid much attention as a research hotspot. Jimo is located in the southwestern part of Shandong Peninsula. It is a municipal district of Qingdao, Shandong Province. It faces the Yellow Sea to the east and has a coastline of 183.01 kilometers. Jimo belongs to a temperate monsoon climate, and the type of coastal tides is a regular half-day tide with a tidal range of 1.9 to 3.5 m [4]. Previously, there have been a large number of intertidal lithofacies benthic zoobenthos diversity surveys in Qingdao. The results of these study have provided a wealth of data for the study of the littoral intertidal biodiversity in Qingdao and the protection and sustainable use of coastal landscapes. However, the researches carried out in the past usually choose typical environments, that is, sandy, muddy tidal flats or complete lithofacies environments, and pay less attention to others such as artificial lithofacies and isolated reefs.

The situation in the intertidal zone is sometimes more complex and is not entirely a single environmental type. In the previous ecological survey, several representative cross sections were generally selected for the study. If there were tide pools and water accumulation areas, separate stations were set up. The area visited this time is quite special, that is, the low tide area is almost composed of sandy tidal area, and its environment is diverse. The middle and high tidal area has a variety of lithofacies, and the environment is diverse, which has certain exploration and protection...
The study attempts to investigate the distribution of benthic animal communities, especially gastropods, bivalves, and arthropods, in sporadic lithofacies when the overall environment is sandy beach.

2. Materials and Methods

Six representative intertidal lithofacies cross sections were selected in the coastline of the survey area, including 2 breakwater sections, 2 artificial steers sections, and 2 reef sections. Each section is provided with 2 sampling points in the high tide area and 3 sampling points in the middle tide area. The lithofacies targeted in this study are not distributed in the low tide area, so high tide area and middle tide area are set up. In the same section, samples were taken in October 2018 and April 2019, and 30 samples were taken each time, for a total of 60 samples.

![Sketch map of six sampling sites](image)

**Figure 1** Sketch map of six sampling sites (Bw: Breakwater; St: Steers; Re: Reefs).

| lithofacies | Description |
|-------------|-------------|
| Breakwater  | It is an artificially laid marble surface. The surface is unpolished, rough but flat. It’s been around for about ten years. |
| Steers      | The surface of the artificially laid marble is similar to the breakwater. Because there is little interference from human activities, a large amount of organisms have been attached to the surface. Roughly the same age as the breakwater. |
| Reefs       | Natural reef, irregular in shape, and has existed for a long time. They are the oldest lithofacies of this site. |

Due to the dense facies community, a 10×10cm quantitative frame was selected. Use a SLR camera with an external flash to take photos of the lithofacies and communities in the quantitative frame.
Some gaps or corners are taken separately. After observation, scrape with a small shovel, a chisel and a screwdriver to scrape all the organisms in the sample. Put them back in a sealed bag and take it back for further counting.

In addition, surveys are complemented by qualitative sampling. Choose the night when the tide has just receded and collect different species in 5 sections. It mainly includes some rare or unsuitable recordings of species such as *Charybdis japonica*, *Acanthochitona dissimilis* and *Palamon gravieri*, etc. During the qualitative sampling, pay attention to the non-lithologic organisms near the lithofacies, such as *Batillaria spp.* [9], *Nassarius spp.* [9], *Periglypta petechialis*, etc., as supplementary data. The survey method is in accordance with GB 17378.7-2007 Marine Monitoring Code, Part 7: The intertidal bio-ecological survey method is conducted in the offshore pollution ecological survey and biological monitoring.

The study of animal community diversity is analyzed using the following formula:

Margalef richness index(D):

$$D = (S - 1) / \log_2 N$$

(1)

Shannon-Wiener diversity index(H):

$$H = \sum_{i=1}^{n} P_i \log_2 P_i$$

(2)

Pielou evenness index(J):

$$J = H / \log_2 S$$

(3)

Berger-Parker dominance index(d):

$$d = N_{\text{max}} / N$$

(4)

S is the number of species, N is the total number, P_i is the proportion of the i species, and N_{\text{max}} is the number of individuals in the dominant species.

3. Results

3.1. Composition of biological groups

A total of 32 species of large benthic organisms were collected in the surveyed area, and the largest number of individuals are arthropods, most of which are barnacles, including *Chthamalus challengeri*, *Fistulobalanus albicostatus*, and *Hemigrapsus penicillatus*. There are 11 species of arthropods, accounting for 34.38% of the total species. Mollusks have the most kinds of species, with a total of 19 species, accounting for 59.38%. The typical examples are *Mytilus galloprovincialis*, *Crassostrea gigas* and *Littorina brevicula*. Coelenterates and annelids are few, with only one species respectively, which are *Haliplanella luciae* and *Perinereis spp.*, each accounting for 3.13% of the total species. In this area, arthropods and mollusks are the main species of lithofacial intertidal benthos, which is similar to the results of previous studies [11]. The proportion of various groups is shown in Figure 2.
3.2. Vertical distribution of creatures

3.2.1. Impact of tidal zone on species. Tide is an important factor affecting the vertical distribution of biological species in the intertidal zone [4,6,11]. In this spring survey, a total of 7 species were collected in the high tide area, 13 species were collected in the middle tide area, and more species were collected in autumn, but they have similar characteristics. There are 8 species in the high tide area and 24 species in the middle tide area. Whether in spring or autumn, the number of biological species in the mid-tidal zone was significantly higher than that in the high-tidal zone.

3.2.2. Analysis of dominant species in different seasons and tidal regions of lithofacies. Table 2 lists the dominant species and their dominance in different lithofacies and tidal regions. It can be seen that Chthamalus challengeri are dominant species under all the different circumstances. In the high tide area, the dominant species are relatively simple, almost all of them are Chthamalus challenger. The dominant species in the middle tide area are relatively large, but there are still several species occupy the majority of the total number of individuals. Commonly, they are Chthamalus challenger, Fistulobalanus albicostatus, Mytilus galloprovincialis and so on.
Table 2 Dominant species and Berger-Parker dominance index of different lithofacies and tidal regions in spring and autumn.

| Season | Lithofacies | High tide zone | High tide zone |
|--------|-------------|----------------|----------------|
|        | Breakwater | Chthamalus challengeri(0.98) | Chthamalus challengeri(0.58), Mytilus galloprovincialis(0.18) |
|        | Steers     | Chthamalus challengeri(0.97) | Chthamalus challengeri(0.47), Fistulobalanus albicostatus(0.25), Mytilus galloprovincialis(0.19) |
|        | Reefs      | Chthamalus challengeri(0.18) | Chthamalus challengeri(0.14), Mytilus galloprovincialis(0.46), Littorina brevicula(0.13) |
|        | Breakwater | Chthamalus challengeri(0.77) | Chthamalus challengeri(0.59), Fistulobalanus albicostatus(0.16) |
|        | Steers     | Chthamalus challengeri(0.90) | Chthamalus challengeri(0.49), Fistulobalanus albicostatus(0.24) |
|        | Reefs      | Chthamalus challengeri(0.57), Mytilus galloprovincialis(0.11) | Chthamalus challengeri(0.16), Mytilus galloprovincialis(0.29) |

3.3. Effects of lithofacies on macrobenthos

3.3.1. Impact of lithofacies on numbers of species. The species of the breakwater and the steer are basically similar, while the number of species in the reef area is slightly richer than the former two. In spring, there are 5 and 10 species of breakwater high tide and mid-tidal areas, respectively, and there are 5 and 10 species of steer high-tide and mid-tidal areas, respectively, and 7 and 11 of reef high-tide and mid-tidal areas. It was found that there are 4 and 15 species in the high tide area and mid-tide area of the breakwater, 6 and 15 kinds in the steer high-tide area and mid-tide area, and 8 and 18 kinds in the reef high-tide area and mid-tide area. The reef area has the largest number of species, and the number of species in the reef and breakwater areas are similar.

![Comparison of species numbers in different rock sections.](image-url)
3.3.2. Impact of Rocks on Diversity. As shown in Table 3, some ecological parameters of the breakwater, steers and reefs are listed in the table. It can be seen that the reef section is higher in the species richness, diversity, and uniformity index than the breakwater and steers, and the latter two are numerical similar. In addition, there are many species in the reef section that are not found in other section types, such as Acanthochitona dissimilis.

Table 3 Ecological parameters of different sections in different seasons.

|          | Breakwater | Steers | Reefs |
|----------|------------|--------|-------|
|          | Spring     | Autumn | Spring | Autumn |
| D        | 0.83       | 1.31   | 0.72   | 1.25   |
| H        | 1.33       | 2.00   | 1.63   | 1.84   |
| J        | 0.39       | 0.51   | 0.49   | 0.46   |
| S        | 11         | 15     | 10     | 16     |

3.4. The effect of seasons on community
As shown in Figure 5, the species richness and diversity in autumn are higher than in spring; in terms of uniformity, the reef section is higher in autumn than in spring, and there is little difference in the steer section, and it is higher in spring than in natural reef area.

Figure 5 Comparison of ecological parameters of different sections in different seasons.
4. Analysis

4.1. Impact of tidal zone on benthic animals
The effect of the tide area on the number of species is relatively obvious, and most of the species in the high tide area are also found in the middle tide area. Within the scope of this survey, the richness and diversity of macrobenthos increased from high tide areas to middle tide areas, which is similar to some previous studies on lithofacies, that is, the middle and low tide areas are more abundant than the high tide areas degree [8,11]. However, since there are no lithofacies in the low-tidal zone in this area, the number of species in the intertidal zone varies with the tide level and is limited to the high-mid-tidal zone. But some previous studies have shown the opposite rule. For example, the richness shown in the study of large benthic animals in the intertidal zone of Qingdao Bay by Ji Xiangxing gradually decreased from high tide to low tide [7]. There are indeed different rules for the influence of districts on richness. In addition, the survey situation is also different. The main environment of the Qingdao Bay intertidal survey is sandy bottom, and the selected section is related to the plot and the sewage outlet. The main contribution of abundance is the indicator species of organic pollution such as microcephala [7].

4.2. Impact of lithofacies on biodiversity
It is also found in this survey that species diversity and richness are also closely related to lithofacies. Under similar interference conditions, the diversity and richness of reef lithofacies are significantly higher than those of breakwater lithofacies and steer lithofacies, and the latter two conditions are roughly the same. It is speculated that it may be related to the age of reef formation. The reason may be that the reefs have existed for the longest time, and after a long period of weathering and succession, more complex communities have gradually formed. In contrast, breakwaters and steers have only existed for about ten years, so their community types are relatively simple. In addition, because the reef is more irregular in shape than artificial lithofacies, it is speculated that it can provide a variety of habitats for more living things, and because the environment such as the breakwater is simple and single, the evenness is higher and has low diversity.

In addition, in the selection process of reef samples, not all reef species were included, such as the species of Charybdis japonica and Palaemon graviori, which were easily frightened during the sampling process, so there were very few of these species in the sample; Some species, such as the Acanthochitona dissimilis, are more concealed during the daytime sampling process, and the dense hiding area is not included in the random sampling process, so there is no record in the sample. This may differ from the actual situation.

4.3. Seasonal effects on benthic species diversity
The investigation found that the species richness index and diversity index of all sections in autumn were higher than those in spring, which may be related to the local climate. Temperature changes will also affect the extent of individual distribution, which in turn will cause changes in biodiversity [10]. Because the cold winter weather in the coastal areas of Shandong will lead to biological migration or dormancy, the diversity and richness of various sections will decrease. When the weather is warmer in spring, the species begin to colonize again, the species diversity and richness rebound, and develop to a higher value in autumn, so the species diversity and richness in autumn are significantly higher than in spring. In addition, the temperature in winter in this area is not conducive to the survival of intertidal organisms, which may also be the reason that the diversity and richness of intertidal animals in spring is less than that in autumn.

5. Conclusion
In this survey, a total of 32 species of interfacial lithofacies large-scale benthic organisms were collected, of which the number of arthropods was the largest, barnacles were the most dominant species, and the number of mollusk species was the largest. Among them, Chthamalus challengeri,
Mytilus galloprovincialis, Crassostrea gigas and Littorina brevicula are the dominant species in this region. Research shows that there are obvious differences in species diversity and richness on different sections of lithofacies, which are mainly related to the age and environmental diversity of them. In addition, there are also significant differences in species diversity and richness in the spring and autumn seasons, including spring is significantly smaller than in the fall. From the research, we can see that the types of lithofacies and seasons have great impacts on benthic animal communities, which deserves further study.

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