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Exploration of the Classification and Main Characteristics of Marine Ecosystems

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Abstract The role of marine ecosystems in human life is enormous, and their service functions and ecological value are important components of the Earth's life support system, as well as basic elements of social and environmental sustainable development. This study aims to conduct a comprehensive analysis and summary of the classification and characteristics of marine ecosystems. Specifically, this study will first introduce the classification methods and characteristics of marine ecosystems, including classification methods based on biological community and ecological functions, as well as in-depth exploration of the physical environmental characteristics of marine ecosystems, characteristics of regional ecosystems, species adaptability and ecological adaptability, in order to provide scientific basis for the protection and management of marine ecosystems.
Keywords Marine ecosystem; Classification; Characteristics; Marine organisms

The marine ecosystem is one of the largest and most complex ecosystems on Earth, carrying rich biodiversity and important ecological services. In recent years, with the rapid economic development and urbanization of coastal areas, human demand for marine ecosystem services has been increasing. However, as human demand for marine ecosystem services increases, the destruction of the marine ecosystem is also increasing, and some regions are experiencing a decline in ecosystem services. The protection and management of marine ecosystems have become a global challenge and task, as global marine resources are increasingly depleted and the marine environment continues to deteriorate.

The difficulty of dividing marine ecosystems is much greater than on land. The classification of terrestrial ecosystems is mainly based on biotic community. However, marine biotic community have a high degree of interdependence and mobility, and lack clear boundaries. Nevertheless, after years of research by scientists (Lin et al., 2021), there are many different divisions of marine ecosystems, each with its own characteristics. Due to the late start of research on marine ecosystems, there is currently no systematic classification scheme for marine ecosystems. Due to the late development of research on marine ecosystems, there is currently no specific plan for dividing marine ecosystems. After more than ten years of efforts by scientists, the coastal areas have been divided into estuarine ecosystems, inner bend ecosystems, and grassland ecosystems; The high seas are divided into oceanic ecosystems, upwelling ecosystems, and deep-sea ecosystems. Among them, there is a lot of research work on the above upwelling ecosystems, coastal and inner bay ecosystems, and estuarine ecosystems.

This study divides marine ecosystems from a broad perspective and summarizes their characteristics. A comprehensive understanding of the classification and features of marine ecosystems is of great significance for understanding the structure and function of marine ecosystems, predicting and responding to marine environmental changes, and formulating and implementing marine protection and management policies.

1 Classification of Marine Ecosystems

1.1 Classification of biological groups

The marine ecosystem is composed of various biological groups and abiotic substances and can be classified

according to different criteria such as biological groups and ecological functions. The classification of marine ecosystems based on biological groups mainly includes the marine planktonic ecosystem, the marine benthic ecosystem, and the deep-sea ecosystem. Among them, the marine planktonic ecosystem includes biological groups such as zooplankton, phytoplankton, and bacterioplankton (Figure 1), mainly distributed in the surface waters of the ocean. The marine benthic ecosystem includes zoobenthos and phytobenthos, as well as bacteriobenthos, mainly distributed in the seabed and coastal areas (Wang et al., 2022). The deep-sea ecosystem includes biological groups in the deep seabed and ocean floor, mainly facing extreme environments such as high pressure, low temperature, and low nutrients.

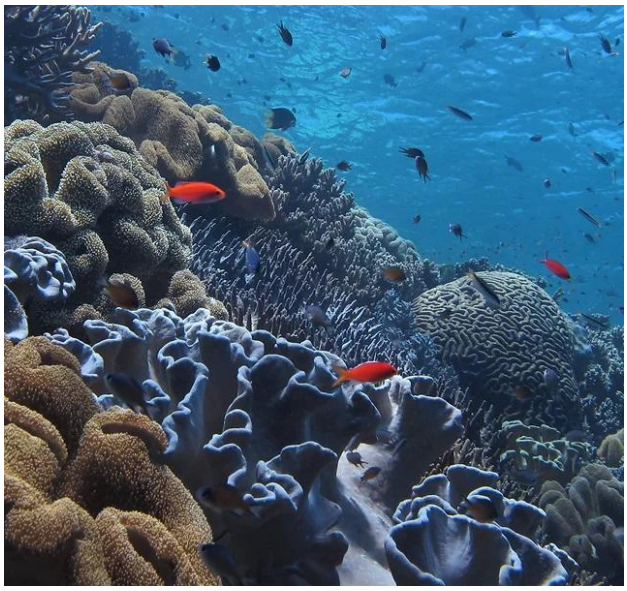

Figure 1 Marine biological community

1.2 Ecological function division

The classification of marine ecosystems based on ecological functions mainly includes the marine productivity ecosystem, the marine food chain ecosystem (Figure 2), and the mineral cycle of marine ecosystems. The marine productivity ecosystem refers to the production capacity and biomass of marine organisms, including the productivity and biomass of plankton and benthos. The marine food chain ecosystem refers to the food relationships and energy transfer among marine organisms, the food chain and food web between zooplankton and zoobenthos. The mineral cycle of marine ecosystems refers to the cycling and transformation of various mineral elements in the ocean, including carbon cycle, nitrogen cycle, phosphorus cycle, and silicon cycle, etc.

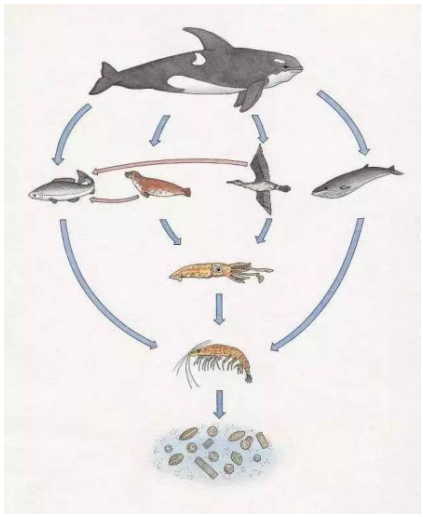

Figure 2 Food chain structure of marine ecosystems

The carbon cycle in marine ecosystems refers to the process of absorption, transformation, and release of carbon dioxide (CO_2) from the Earth's atmosphere to the marine system. Marine organisms convert CO_2 from the atmosphere into organic matter through metabolic processes such as photosynthesis and respiration. This organic matter serves as the foundation of the marine food chain and is ultimately transformed back into CO_2 and released into the ocean and atmosphere. Additionally, CO_2 in the ocean can dissolve in water and form carbonic acid, which affects the acidity and pH of seawater.

Specifically, the carbon cycle in marine ecosystems involves several stages. (1) CO_2 from the atmosphere enters the ocean through physical and chemical processes such as gas exchange, dissolution, reaction, and sedimentation. In the ocean, CO_2 is converted into organic matter. Phytoplankton and phytobenthos in the ocean absorb CO_2 and light energy through photosynthesis and convert them into organic matter. This organic matter is then transferred up the marine food chain and utilized by consumers. Organic matter is also broken down and respired by marine organisms, releasing CO_2 and water into the ocean. (2) CO_2 is released into the atmosphere. CO_2 in the ocean can be released into the atmosphere through physical and chemical processes such as gas exchange, dissolution, reaction, and sedimentation. (3) Carbonic acid balance regulation occurs. CO_2 in the ocean can dissolve in water and form carbonic acid, which affects the acidity and pH of seawater. Through processes such as absorption and release of CO_2, marine organisms and inorganic matter regulate the carbonic acid balance in the ocean, maintaining the stability and sustainability of marine ecosystems. The carbon cycle in marine ecosystems is a complex ecological process involving physical, chemical and biological interactions between the atmosphere and the ocean, and it plays a crucial role in maintaining the stability and functionality of marine ecosystems.

2 Characteristics of Marine Ecosystems

2.1 Biological characteristics of marine ecosystems

Marine ecosystems are complex ecological systems that include various biological groups, inorganic substances, and environmental factors. They are characterized by high biodiversity, high productivity and material cycling rates, high spatial heterogeneity and spatio-temporal variability, as well as high adaptability and resistance to disturbances.

Marine ecosystems are one of the most diverse ecosystems on Earth, encompassing various biological groups such as phytoplankton (Figure 3) and zooplankton, phytobenthos and zoobenthos, fishes, seabirds, seals, etc. These biological groups form complex ecological relationships and interactions in the marine ecosystem, maintaining its stability and functionality.

Figure 3 Marine phytoplankton

Marine biological groups in marine ecosystems have the characteristics of high productivity and material cycling rates, which is due to environmental factors such as abundant nutrients and light energy in marine ecosystems. Marine organisms convert nutrients into organic matter through metabolic processes such as photosynthesis and respiration, thus forming the productivity and biomass of marine ecosystems. The high productivity and material cycling rates of marine ecosystems are achieved through the joint action of various factors. Nutrients in the ocean

are abundant, and the ocean contains a large amount of nutrients such as nitrogen, phosphorus, and silicon, which are necessary for the growth, reproduction, and metabolism of marine organisms. Nutrients in the ocean come from various sources such as land input, submarine jets, river inflows, atmospheric deposition, marine organisms' death and decomposition, forming a complex material cycling.

However, the high productivity and material cycle of marine ecosystems are facilitated by various factors, such as good light conditions, complex interactions between biological groups, and physical, chemical, and biological processes. Light is an important driver of photosynthesis in marine ecosystems, which is a crucial process for productivity and material cycle in marine ecosystems. Under good light conditions, phytoplankton and phytobenthos in the ocean can undergo sufficient photosynthesis, converting CO_2 and nutrients into organic matter, thus forming productivity and biomass. There are complex interactions between biological groups in the marine ecosystem, including food chains, competition, symbiosis, and predation relationships. These interactions can accelerate the material cycle and enhance the productivity of the marine ecosystem. The physical, chemical, and biological interactions in the marine ecosystem form complex ecosystem functions. For example, the flow and mixing of water masses in the ocean can promote the transport and distribution of nutrients, microorganisms and biological groups in the ocean can promote the cycle and transformation of nutrients, and gas exchange and photochemical reactions can affect the absorption and release of CO_2.

The high spatial heterogeneity and spatio-temporal variability of marine ecosystems mean that different marine ecosystems in different regions and periods have different biological compositions, material cycle, and ecological functions due to differences in environmental factors and biological groups. Biological groups in marine ecosystems have the characteristics of high adaptability and resistance to disturbances, and they can adapt to extreme conditions such as high pressure, low temperature, and low nutrients in the marine environment, and have certain restoration and disturbance resistance capabilities. This provides marine ecosystems with a certain degree of resistance to disturbance and restoration, and maintains the stability and sustainability of the ecosystem.

High adaptability and resistance to disturbances are also formed by the joint action of various factors. Under extreme conditions in the marine environment, such as high pressure, low temperature, and low nutrients, these conditions are not suitable for most organisms. However, under these extreme conditions, biological groups in the marine ecosystem have evolved and adapted to form a high degree of physiological and behavioral adaptability, enabling them to survive and reproduce under these conditions.

2.2 Physical environmental characteristics of marine ecosystems

The water temperature and salinity in the ocean are important physical environmental characteristics of marine ecosystems. There are significant vertical and horizontal variations in water temperature and salinity in the ocean, which have important impacts on the growth, reproduction, and distribution of marine organisms. For example, different biological groups in the ocean have different physiological adaptability and ecological habits under different water temperature and salinity conditions. The physical environmental characteristics of ocean currents and circulation have important impacts on nutrient transport and distribution, water mass mixing and diffusion, and the distribution and migration of marine organisms. For example, ocean current and circulation can transport nutrients to eutrophic areas, promoting the increase of productivity. At the same time, they can also carry biological groups to different areas, promoting the maintenance of biodiversity.

The light and transparency in the ocean have important impacts on photosynthesis in the ocean, the growth and reproduction of phytoplankton and phytobenthos, and the distribution of biological groups in the ocean. Photosynthesis in the ocean can promote the increase of productivity and biomass in marine ecosystems. Meanwhile, light and transparency can also impact the visual and physiological adaptability of marine organisms.

There are various sound sources in the ocean, including environmental sound, biological sound, and anthropogenic sound. These sound sources have important impacts on the hearing, communication, navigation, and ecological behaviors of marine organisms. For example, dolphins and whales use acoustic signals for communication and navigation, and fish in the ocean use acoustic signals for mating and defense.

Therefore, the physical environmental characteristics of marine ecosystems include water temperature and salinity, ocean current and circulation, light and transparency, and acoustic environment, etc. These physical environmental characteristics have important impacts on productivity, biodiversity, and ecological functions in marine ecosystems, and are important factors that cannot be ignored.

2.3 Regional ecological characteristics of marine ecosystems

The regional ecological characteristics of marine ecosystems refer to the characteristics and differences of ecosystems in different marine areas and regions, including the impacts of geographical location, water temperature, salinity, nutrient content, tides, ocean currents, and other factors on ecosystems (Zhai, 2012). Tropical marine ecosystems are located near the equator, with high water temperature, high salinity, low nutrient content, abundant light, and strong ocean currents. In this environment, phytoplankton and phytobenthos in marine ecosystems reproduce rapidly, forming highly productive marine ecosystems with rich biodiversity.

Polar marine ecosystems are located in the seas around the North and South Poles, with low water temperature, low salinity, lower nutrient content, weaker light, and fewer ocean currents. In this extreme environment, biological groups in marine ecosystems have strong adaptability. For example, phytoplankton and phytobenthos in polar oceans can undergo photosynthesis at extremely low temperatures, while fishes and mammals in polar oceans have thick fur and fat layers to adapt to the cold environment.

Inland sea ecosystems refer to seawater lakes or brackish lakes located in inland areas (Figure 4), which generally have higher water temperatures, slightly lower salinities, and higher nutrient levels. In this environment, phytoplankton and phytobenthos in marine ecosystems reproduce rapidly, forming highly productive marine ecosystems with unique ecosystems and biodiversity.

Figure 4 Lake seawater in inland areas

Coastal marine ecosystems are located at the interface between land and sea, and are influenced by land hydrology and human activities. Environmental factors such as water temperature, salinity, nutrient content, and light vary greatly. In this environment, biological groups in marine ecosystems have strong adaptability. Some phytoplankton and phytobenthos in coastal marine ecosystems can adapt to eutrophic environments, while fishes and crustaceans in coastal oceans are important fishery resources for humans.

The regional ecological characteristics of marine ecosystems are formed by the joint effects of geographical location, water temperature, salinity, nutrient content, tides, ocean currents, and other factors in the marine environment. Different marine ecosystems have different characteristics and differences, which have important impacts on the growth, reproduction, and distribution of marine organisms.

3 Ecological Services and Values of Marine Ecosystems

Marine ecosystems provide humans with rich ecological services and values (Wang and Tang, 2010). For example, food resources. Marine ecosystems are important food resources for humans, providing a large number of marine

products such as fishes, mollusks, and seaweeds. These marine products are the main source of protein for humans and are of great significance for maintaining human survival and health. Ecotourism: marine ecosystems have high ecological and tourism value. Landscapes such as coral reefs, marine protected areas, and beaches in marine ecosystems attract a large number of tourists for tourism, sightseeing, and leisure, bringing considerable economic income (Guo and Ma, 2019). Biodiversity conservation: marine ecosystems are one of the largest biodiversity repositories on Earth, containing many rare and endangered species. Protecting the biodiversity of marine ecosystems can not only maintain the health of ecosystems but also protect human cultural and natural heritage (Zhang, 2007). Climate regulation: marine plants and plankton in marine ecosystems absorb a large amount of carbon dioxide through photosynthesis, reducing the impact of global climate change. At the same time, ocean currents and circulation in the ocean also play an important role in climate regulation. Ecological governance (Duan, 2020), Marine ecosystems have high ecological stability and self-repairing ability, which can effectively absorb and decompose pollutants and waste generated by human activities. Therefore, protecting marine ecosystems is of great significance for achieving ecological governance and environmental protection.

4 Summary and Progress

Different classification methods have their own advantages and disadvantages in describing marine ecosystems. The classification method based on biological groups is more intuitive and easy to understand, and is of great significance for describing the biodiversity and ecological functions of marine ecosystems. However, this classification method may overlook the ecological relationships and interactions between different organisms. The classification method based on ecological functions emphasizes the ecological functions and services of marine ecosystems, and is of great significance for evaluating and managing the sustainability of marine ecosystems. However, this classification method may overlook the differences between biological groups and their ecological adaptability.

Therefore, different classification methods for marine ecosystems have their own advantages and disadvantages, and appropriate classification methods should be selected based on specific research purposes and questions. At the same time, the comprehensive application and analysis of different classification methods will help to more comprehensively and deeply understand the structure and function of marine ecosystems.

Discussion and research on the classification and characteristics of marine ecosystems can lead to a better understanding of the ecological environment, biological communities and ecological functions of different ecosystems, so as to formulate more scientific and effective conservation measures. Different protection measures can be formulated for different marine ecosystems, including the establishment of marine protected areas and fishing restrictions, to protect marine biodiversity and the health of marine ecosystems. Protecting the stability and health of marine ecosystems promotes marine scientific research, sustainable development, and enhances international cooperation.

Authors' contributions

WJN was the main author of the review, responsible for collecting and analyzing relevant literature, and writing the initial draft of the paper, as well as participating in the analysis and organization of literature. JLF was the project initiator and leader, guiding the writing of the paper. All authors read and approved the final manuscript.

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