Aqua Publisher®

International Journal of Marine Science, 2024, Vol.14, No.1, 6-13
http://www.aquapublisher.com/index.php/ijms

Review and Progress Open Access

Seasonal Changes and Influencing Factors of Floating Biological Communities on the Surface of the Ocean

Linglong Shao [1], Mengyue Chen [2], Wei Wang [2]

1 Ningbo City Commercial Management Co., Ltd, Ningbo, 315000, China

2 Cuixi Academy of Biotechnology, Zhuji, 311800, China

Corresponding author email: 2741098603@qq.com

International Journal of Marine Science, 2024, Vol.14, No.1, doi: 10.5376/ijms.2024.14.0002

Received: 19 Nov., 2023

Accepted: 28 Dec., 2023

Published: 20 Jan., 2024

Preferred citation for this article:

Shao L.L., Chen M.Y., and Wang W., 2024, Seasonal changes and influencing factors of floating biological communities on the surface of the ocean, International Journal of Marine Science, 14(1): 6-13 (doi: 10.5376/ijms.2024.14.0002)

Abstract Marine plankton is a special ecological group of marine plankton, which is a key component of the marine planktonic food web, material cycle, and energy flow. Its biomass level and population structure greatly affect the output rate of carbon cycle. Floating organisms mainly inhabit the surface layer of the ocean (including organisms inhabiting the surface facial mask and the air sea interface). Because this surface layer has a special physical and chemical environment and a complex and changeable community, and it is the place where many economic fish eggs and larvae are concentrated, it is of certain significance in theory and practice to study the community of marine surface plankton. This study focuses on the seasonal variation characteristics of marine floating organisms communities, specifically elaborating on the seasonal effects of light, temperature, salinity, and other human activities on surface floating organisms. Finally, it summarizes some relevant roles and protection strategies, providing scientific theoretical basis for marine ecosystem research.

Keywords Floating organisms; Ecological community; Seasonal changes; Food web

The ocean is one of the Earth's most extensive ecosystems, with its biological communities playing a crucial role in the functionality and stability of the Earth's ecosystem. In the ocean, the surface-floating biological community is a key ecological community, encompassing a wide range of species such as phytoplankton, zooplankton, and floating bacteria. These floating biological communities are involved in essential processes in the ocean, including photosynthesis, energy transfer, nutrient cycling, and carbon fixation. They play a vital role in the structure and function of marine food webs and ecosystems. However, the composition and structure of surface-floating biological communities in the ocean are not static; they change dramatically with the seasons. Seasonal changes are a common phenomenon in marine ecosystems and are influenced by various environmental factors, including temperature, salinity, light, and nutrients. Understanding the seasonal variations of surface-floating biological communities in the ocean and the influencing factors is of great significance for comprehending the functionality and responses of marine ecosystems.

This review aims to investigate the seasonal variations and influencing factors of surface-floating biological communities in the ocean, analyzing the changes in species composition, abundance, and diversity indices of surface-floating biological during different seasons (Liu et al., 2013). Additionally, it will examine the impact of various environmental factors, such as temperature, salinity, and light, on the seasonal variations of surface-floating biological communities, exploring their mechanisms and interactions. Furthermore, it will explore the roles of seasonal floating organic matter, including phytoplankton, zooplankton, and floating bacteria, within the surface biological community, as well as the effects of climate change and human activities on surface-floating biological communities.

By conducting in-depth research on the seasonal variations and influencing factors of surface-floating biological communities in the ocean, the dynamic changes and response mechanisms of marine ecosystems can be better understood. This is of significant importance in the fields of ecology, marine science, as well as environmental conservation and management. The research findings will provide a scientific basis for the preservation of marine biodiversity, ecosystem management, and the development of climate change adaptation strategies.

1 Seasonal Changes in the Composition and Diversity of Marine Surface Floating Biological

1.1 Seasonal variation in the composition of surface floating biological

The composition of marine surface-floating biological on the surface of the ocean undergoes significant changes in different seasons, primarily influenced by seasonal environmental factors, including temperature, salinity, light and nutrient salts. Spring is one of the seasons when the marine surface-floating biological community is the most diverse and abundant. In warm spring, due to increased light and nutrient availability, phytoplankton (Figure 1) such as diatoms, dinoflagellates, and green algae proliferate rapidly. These phytoplankton are essential components of the surface-floating biological community, as they undergo photosynthesis, absorbing carbon dioxide and releasing oxygen, thereby providing energy and oxygen to the marine ecosystem. Furthermore, spring is also a season for the reproduction of zooplankton, including pelagic zooplankton and animal plankton such as jellyfish. They feed on phytoplankton, forming a complex food web. During spring, both the variety and abundance of zooplankton significantly increase, providing rich food resources for upper-level organisms in the marine food chain.

Figure 1 Marine phytoplankton (Image source: https://cn.bing.com/)

Summer is the peak season for marine surface-floating biological communities, with rising seawater temperatures and maximum light intensity, providing ideal conditions for the growth of phytoplankton. Large diatoms like diatomaceous diatoms, chain diatoms, and spiral diatoms reach their peak during summer, forming extensive phytoplankton communities known as algal blooms. These algal blooms play a crucial role in the photosynthesis and energy transfer within the marine ecosystem and also have a significant impact on the cycling of nutrients such as nitrogen and phosphorus in the marine ecosystem. Moreover, summer is a season of abundance for zooplankton, including pelagic zooplankton, animal plankton such as jellyfish, and pelagic shrimp. These zooplankton feed on phytoplankton and participate in the nutrient transfer within the marine food web.

As autumn approaches, the composition of marine surface-floating biological communities begins to change. The temperature and light levels gradually decrease, leading to a slowdown in the growth of phytoplankton. Additionally, influenced by monsoons and ocean currents, the supply of nutrients also relatively diminishes. This results in a reduction in both the quantity and variety of phytoplankton, as well as a decline in zooplankton.Winter is one of the seasons when the marine surface-floating biological community reaches one of its lowest points. Seawater temperatures further decrease, and there is reduced light, causing almost a complete halt in the growth of phytoplankton. Only a small number of cold-tolerant diatoms and dinoflagellates can survive in these low-temperature conditions. Consequently, the number of zooplankton also decreases, with many species entering a dormant state or migrating to warmer regions.

1.2 Seasonal diversity changes in surface floating biological communities

As the composition of seasonal marine surface-floating biological communities changes, their diversity also undergoes corresponding variations. Diversity typically involves species richness and the relative abundance of species (Sun and Liu, 2004). During spring and summer, increased light and nutrient availability lead to a significant rise in the quantity and variety of phytoplankton and zooplankton, resulting in peak diversity in seasonal surface-floating biological communities. Complex food webs are established between phytoplankton and zooplankton, with different species relying on each other, creating a high level of species diversity. Phytoplankton form the foundation of surface-floating biological communities, absorbing carbon dioxide and releasing oxygen through photosynthesis, providing energy and oxygen to the entire food web. Major phytoplankton species include diatoms, dinoflagellates, and green algae, utilizing photosynthesis to convert inorganic substances into organic matter, serving as the primary food source for other organisms. There is an interdependence between phytoplankton and zooplankton. Phytoplankton provide the energy and nutrients necessary for zooplankton, while zooplankton regulate their population density and composition by consuming phytoplankton. This interdependent relationship plays a crucial role in maintaining the stability and balance of surface-floating biological communities.

With the arrival of autumn and winter, changes in the marine environment lead to a decrease in the quantity and variety of phytoplankton and zooplankton, resulting in reduced diversity in seasonal surface-floating biological communities. During winter, most phytoplankton and zooplankton enter a state of dormancy or reduced metabolic activity, with only a few species adapted to cold environments remaining active. Autumn and winter are seasons in the ocean with relatively lower nutrient supply. During this period, reduced nutrient levels in the water, decreasing temperatures, and reduced daylight hours create unfavorable conditions for the growth and reproduction of phytoplankton. Phytoplankton have specific requirements for suitable temperature and light conditions, and when these conditions are not met, their physiological activities are inhibited, leading to a decrease in quantity and diversity, restricting phytoplankton growth. As the foundation of the surface-floating biological community, phytoplankton may face increased predation pressure during autumn and winter. Due to the reduced availability of nutrients and energy, other marine organisms may engage in more intense competition and predation on phytoplankton, potentially resulting in the reduction or disappearance of some phytoplankton species. This decrease in quantity and diversity can directly impact the presence and diversity of other organisms in the entire ecosystem.

2 The Influence of Environmental Factors on Marine Surface-Drifting biological Communities

2.1 The impact of light on surface-drifting biological communities

Light conditions have both direct and indirect effects on the marine planktonic community. Light serves as a crucial energy source for photosynthetic marine planktonic organisms. Planktonic plants absorb light energy and utilize photosynthetic pigments to convert it into chemical energy, thereby facilitating the synthesis of organic matter. These organic substances not only provide energy and nutrients for the planktonic plants themselves but also serve as a source of energy for other organisms within the entire food web. Consequently, the intensity and duration of light directly influence the growth and reproduction of planktonic plants (Mohammady et al., 2023), subsequently affecting the structure and function of the entire planktonic community. The intensity and transparency of light determine the depth to which light can penetrate. In the ocean, light gradually diminishes and eventually disappears at a specific depth, forming what is referred to as the light attenuation layer. Planktonic plants are typically found within the surface layer of light, where the light intensity is sufficient to support photosynthesis. Therefore, the depth and distribution of light play a critical role in the distribution and ecological niche selection of planktonic plants, directly impacting the spatial structure of the planktonic community.

Different planktonic organisms have varying light requirements and tolerance ranges, which are related to their light adaptation and light response mechanisms. Light adaptation refers to the ability of planktonic organisms to adapt to light intensity and spectrum. Some planktonic organisms exhibit characteristics adapted to strong light environments, while others are adapted to lower light conditions. Light response refers to the physiological and behavioral responses of planktonic organisms to changes in light conditions. For example, certain planktonic plants and animals may vertically migrate to deeper waters under high light conditions to avoid damage caused by excessive light. These light adaptation and light response mechanisms enable different planktonic organisms to thrive and reproduce in different light environments, thereby affecting the species composition and diversity of the planktonic community.

Light limitation and light saturation refer to the degree of impact of light on the growth and photosynthesis of phytoplankton. When light is insufficient, the photosynthesis of phytoplankton is limited, and their growth rate decreases. This situation typically occurs in deep-sea, nutrient-rich waters, or in areas covered by clouds or fog. On the other hand, when light intensity exceeds a certain threshold, the photosynthesis of phytoplankton reaches a saturation state, and further increasing light intensity has little effect on promoting growth. The presence of light limitation and light saturation can affect the ecological niche and competitiveness of phytoplankton, thereby influencing the overall structure and stability of the entire planktonic community. Some planktonic organisms in the ocean are mixotrophic, meaning they cannot perform photosynthesis and acquire energy and nutrients by ingesting other phytoplankton or organic debris. The presence and abundance of these mixotrophic organisms are directly influenced by light conditions. Furthermore, phytoplankton can adapt to different light conditions by adjusting their pigment composition. Different pigments have absorptive abilities for different wavelengths of light, allowing phytoplankton to adapt to varying light conditions. Pigment adaptation mechanisms play a significant role in the survival and competitive ability of phytoplankton and have an impact on the structure and function of the entire planktonic community.

2.2 The impact of temperature on surface planktonic communities

Temperature is a crucial environmental factor in the marine planktonic ecosystem, and it has both direct and indirect effects on the physiology, ecology, and geographical distribution of planktonic organisms (Figure 2). Temperature directly impacts the physiological processes of planktonic organisms, and different species have different adaptability to temperature. Some planktonic organisms have a wide range of temperature tolerance, enabling them to survive and reproduce over a broad temperature range, while others are more sensitive to temperature fluctuations. Changes in temperature can affect key physiological processes of planktonic organisms, such as metabolic rates, respiration, enzyme activity, and photosynthesis. High temperatures can accelerate biological metabolism and growth rates, but excessively high temperatures can lead to protein denaturation, cell membrane damage, and death. Conversely, low temperatures can reduce biological metabolism and growth rates and can even result in freezing and cold damage. Therefore, the physiological adaptability of planktonic organisms to temperature directly influences their survival and reproductive capacity.

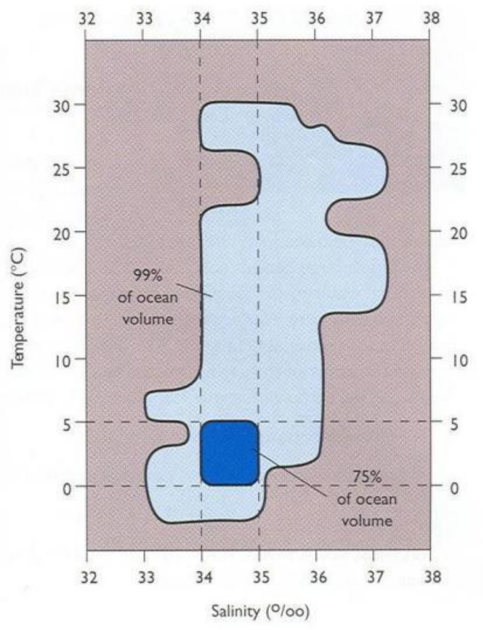

Figure 2 Changes in ocean temperature distribution (Image source: https://cn.bing.com/)

Planktonic organisms play critical roles in marine food webs, including primary producers, grazers, and decomposers. Temperature changes can influence the growth rates, feeding habits, ingestion rates, and reproductive strategies of planktonic organisms, thereby altering their positions and influence within the food web. For instance, an increase in temperature may accelerate the growth rates of phytoplankton, which in turn affects the grazing pressure and competitive relationships among zooplankton. Furthermore, temperature also impacts various biological interactions among planktonic organisms, such as symbiosis, predation, and competition, further reshaping the structure and ecological functions of the entire planktonic community.

Temperature is one of the key factors regulating the reproductive rates and seasonal life cycles of planktonic organisms. The reproductive and developmental processes of many planktonic organisms are closely tied to seasonal temperature changes. Elevated temperatures can stimulate the reproduction and development of planktonic organisms, reducing metabolic cycles and generation times. Conversely, lower temperatures can delay reproduction and development, leading to constraints on the breeding season and adjustments in life cycles. The impact of temperature on the reproduction and life cycles of planktonic organisms directly determines the dynamics of their populations and geographic distribution. Different species of planktonic organisms have varying temperature tolerance ranges and preferences, thus, their geographic and vertical distribution is influenced by temperature limitations (Xie et al., 2019). For example, some phytoplankton and zooplankton prefer warmer waters, while others thrive in cooler waters. Furthermore, temperature fluctuations can also affect the seasonal migration behaviors of planktonic organisms, some species migrating to higher latitude or deeper waters during warmer seasons to avoid the impacts of excessive heat. Changes in temperature can directly influence the structure and functioning of marine ecosystems through shifts in the geographic distribution and migration patterns of planktonic organisms.

2.3 The impact of salinity on surface floating biological communities

Salinity is a critical environmental factor in marine surface floating biological communities, affecting the physiological adaptation, feeding and nutrition, ecological functions, and geographic distribution of planktonic organisms. Different species of plankton have varying adaptability to salinity, with some capable of surviving and reproducing within a broad salinity range, while others are more sensitive to salinity fluctuations. Changes in salinity can influence vital physiological processes in planktonic organisms, such as cell osmoregulation (Figure 3), ion balance, metabolism, and nutrient ingestion. High salinity levels can lead to cell dehydration and disrupt ion balance, while low salinity may result in cell swelling and insufficient ion concentration. Planktonic organisms adapt to different salinity environments by regulating the concentration of solutes inside and outside cells and the accumulation of osmotic regulating substances in cells.

Figure 3 Cell proliferation of marine plankton (Image source: https://cn.bing.com/)

Plankton primarily mainly obtain energy and nutrients by ingesting dissolved organic matter, suspended particles, and other planktonic organisms. Changes in salinity can affect the feeding behavior, food selection, and ingestion rates of planktonic organisms (Sun and Ning, 2005). Some planktonic species exhibit stronger feeding capabilities under high salinity conditions, while others may have a competitive advantage under lower salinity conditions. Furthermore, salinity can impact the efficiency of nutrient absorption and utilization by plankton. For instance, some planktonic organisms may have more efficient absorption and utilization of nutrients such as nitrogen and phosphorus in high salinity environments. Planktonic organisms play crucial roles in marine food webs, including photosynthesis, predators, and decomposers. Salinity fluctuations can influence their growth rates, biomass, and population structure, thereby altering their positions and impact within the food web. Under high salinity conditions, certain planktonic plants may exhibit higher growth rates, which can affect the grazing pressure and competitive relationships among planktonic animals. Salinity also influences biological interactions among planktonic organisms, such as symbiosis, predation, and competition, further leading to changes in the overall structure and ecological functions of plankton communities.

Salinity is one of the key driving factors for the mixing and stratification processes in oceanic water. Variations in salinity can affect water density and stability, subsequently influencing vertical mixing and the formation of water masses. These mixing and stratification processes directly impact the distribution and geographical dispersion of planktonic organisms. Salinity gradients can result in vertical stratification and spatial heterogeneity in the marine environment, leading to the existence of different types of planktonic communities under varying salinity conditions. Some planktonic organisms are better adapted to the high-salinity surface waters. This vertical distribution and spatial heterogeneity have significant implications on the ecological processes and population dynamics of plankton, including growth, reproduction, and migration (Gasol et al., 2003).

3 The Impact of Human Activities on Surface Floating Biological Communities

Human activities have caused a large amount of pollutants (including acoustic pollution) and carbon dioxide to enter the ocean, such as chemicals, petroleum products, pesticides, industrial wastewater, waste, and noise generated by marine engineering activities (Figure 4). These pollutants have direct or indirect impacts on surface floating biological communities (Barry et al., 2023). Toxic substances can cause damage to the survival and reproductive abilities of plankton, leading to population declines or extinctions. Pollutants may disrupt the ecological functions of plankton, such as photosynthesis, feeding, and decomposition, thereby affecting the stability of food webs and nutrient cycling. The influx of significant amounts of carbon dioxide into the atmosphere, a portion of which is absorbed into the oceans, results in ocean acidification. Ocean acidification has a particularly noticeable impact on surface floating biological communities. Acidified seawater can reduce the calcification ability of planktonic organisms' shells and skeletons, affecting their biological structure and function. Organisms like corals and foraminifera are especially sensitive to acidification, putting their survival and reproductive capacities at significant risk.

Figure 4 Marine microplastic pollutants (Image source: https://cn.bing.com/)

Overfishing can also reduce the number of many species in the ocean and alter population structure, further impacting the composition and interactions of surface floating biological communities. Overfishing activities can reduce the numbers of predators for certain planktonic organisms, causing some plankton populations to grow rapidly and creating an imbalance in the ecosystem. The instability of marine ecosystems is also related to human activities that cause ocean eutrophication. The input of a large amount of nutrients causes a rapid increase in the number of toxic phytoplankton. For example, the excessive nutrition of nitrogen and phosphorus elements leads to the outbreak of toxic algae, which can release toxic compounds and cause harm to other plankton and marine animals. They can also compete for food and light resources, alter plankton population structures and interactions, and, in severe cases, lead to the formation of dead zones and the shortening of the lifespan of the marine environment, with significant consequences for surface floating biological and the entire ecosystem.

4 Ecological Functions and Services of Surface Floating Biological Communities in the Marine Environment

Surface floating biological communities play an indispensable role in marine ecosystems, providing a wide range of ecological functions and ecosystem services, and playing a crucial role in maintaining the health and balance of marine ecosystems. Many surface floating biological, such as phytoplankton and zooplankton, are capable of photosynthesis, converting light energy into chemical energy and absorbing carbon dioxide for carbon fixation. These organisms sequester significant amounts of carbon dioxide, making important contributions to the carbon cycling and carbon reservoirs within the marine system (Ding et al., 2010). This helps mitigate global warming and climate change (Lewandowska et al., 2014).

Surface floating biological communities serve as a vital foundation for marine food webs. Phytoplankton, as primary producers in the food web, provide energy and nutrients to other organisms. Zooplankton, in turn, serve as the primary food source for various organisms, including fish and marine mammals, helping to transfer energy to higher trophic levels. Additionally, surface floating biological contribute to the marine ecosystem by generating oxygen through photosynthesis. They actively participate in the nitrogen and phosphorus cycling processes in the ocean, absorbing and utilizing dissolved nitrogen and phosphorus compounds, converting them into biologically available forms. This process supplies a significant source of oxygen to the marine environment. The richness and diversity of surface floating biological communities play a crucial role in maintaining nutrient balance and material cycling in marine ecosystems, directly influencing the structure and stability of the entire marine food web.

Some planktonic organisms within surface floating biological communities have the capability to ingest and decompose organic waste. By studying and monitoring these communities, they can serve as ecological indicators for assessing the health of marine ecosystems and environmental quality. These organisms play a crucial role in removing organic waste from the ocean, including plant debris, animal carcasses, and toxic substances, preventing the accumulation of these wastes and their negative impact on ecosystems. The composition and structure of surface floating biological communities are highly sensitive to changes in the marine environment, making them valuable sources of information about the health and biodiversity of marine ecosystems. This information provides a scientific basis for marine conservation and management efforts.

5 Summary

This review provides a comprehensive analysis of the seasonal variations in surface floating biological communities and explores the factors that may influence these changes. The study reveals a close relationship between seasonal variations and several environmental factors. These environmental factors have a significant impact on the composition and abundance of surface floating biological communities during different seasons. However, it is important to note that there are complex interactions among these factors, and their effects may vary in different geographical regions and marine environments.

Marine planktonic communities are the core components of the marine food web, playing a crucial role in energy and material conversion. By studying the structure, composition, and function of plankton communities, it is possible to reveal the interactions between different organisms, the construction process of food chains, and the patterns of energy flow (Woodhouse et al., 2023). This helps everyone to better understand the structure and function of marine ecosystems, and predict and evaluate their response to environmental changes.

The future protection of marine plankton communities will require comprehensive measures, involving policy development, scientific research, monitoring, and management. Establishing marine protected areas is one of the important measures to protect marine biological communities. By designating no-fishing zones and protected areas and setting up long-term monitoring networks for plankton communities, continuous observation and research on their changes can be conducted, limiting human interference, and reducing the impact of land-based and marine pollution on plankton communities. This approach is critical for providing a relatively safe environment for plankton to grow, reproduce, and migrate. Such protected areas can also promote the maintenance and restoration of biodiversity. Increasing public awareness and knowledge about marine plankton communities through education and outreach can encourage public attention and involvement in marine conservation. By promoting environmentally friendly behaviors and advocating for sustainable use of marine resources, individuals can contribute to the protection of plankton communities.

Acknowledgments

This review would like to express gratitude to Ms. Yeping Han for her valuable suggestions and revisions to the paper, which contributed to the depth of this exploration.

References

Barry P.J., Beraud C., Wood L.E., and Tidbury H.J., 2023, Modelling of marine debris pathways into UK waters: Example of non-native crustaceans transported across the Atlantic Ocean on floating marine debris, 186: 114388.
https://doi.org/10.1016/j.marpolbul.2022.114388

Ding L., Xing L., and Zhao M.X., 2010, Applications of biomarkers for reconstructing phytoplankton productivity and community structure changes, Advances in Earth Science, 25(9): 981-989.

Gasol J.M., Giorgio P.A.D., and Duarte C.M., 2003, Biomass distribution in marine planktonic communities, 42(6): 1353-1363.
https://doi.org/10.4319/lo.1997.42.6.1353

Lewandowska A.M., Boyce D.G., Hofmann M., Matthiessen B., Sommer U., and Worm B., 2014, Effects of sea surface warming on marine plankton, Journal of Plankton Research, 17(5): 614-623.
https://doi.org/10.1111/ele.12265

Liu Z.S., Du Z.M., and Zhang J., 2013, International research advances in marine zoo plankon, Acta Oceanologica Sinica (Haiyang Xuebao), 35(4): 1-10.

Mohammady M.E., Soaudy M.R., Ali M.M., El-ashry M.A., El-Karim M.S.A., Jarmołowicz S., and Hassaan M.S., 2023, Response of Nile tilapia under biofloc system to floating or sinking feed and feeding rates: Water quality, plankton community, growth, intestinal enzymes, serum biochemical and antioxidant status, 29: 1014849.
https://doi.org/10.1016/j.aqrep.2023.101489

Sun J., and Liu D.Y., 2004, The application of diversity index in marine phytoplankton research, Acta Oceanologica Sinica, 26(1): 63-74.

Sun J., and Ning X.R., 2005, Specific growth rate of marine phytoplankton communities, Advances in Earth Science, 20(9): 939-945.

Woodhouse A., Swain A., Fagan W.F., Fraass A.J., and Lowery C.M., 2023, Late Cenozoic cooling restructured global marine plankton communities, 614: 713-718.
https://doi.org/10.1038/s41586-023-05694-5

Xie F.W., Song X.Y., Tan Y.H., Tan M.T., Huang Y.D., and Liu H.X., 2019, Impact of simulated warming and nutrients input on plankton community metabolism in Daya Bay, 38(2): 48-57.