Phytoplankton and Zooplankton Diversity Analysis on Current Changing Coastal Marine Ecosystems

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Abstract: Marine plankton confronts unprecedented problems stemming from environmental variations, including ocean acidification, temperature increase, and eutrophication. Information regarding the impacts of concurrent environmental variations on intricate ecological systems within coastal habitats is scarce. The research conducted a systematic examination of environmental and biological features during the past 3 years, indicating that plankton populations exhibited divergent responses to the evolving coastal settings, characterized by a rise in phytoplankton (PP) and a decline in zooplankton (ZP). The variations in PP and ZP are attributed to the dual influence of acidification from declining pH and warmth from rising temperatures, both of which now favor PP over ZP. Water eutrophication, saltiness, and contaminants such as Hg, Zn, and As had varying effects on the movement of PP and ZP. Due to continuous climate change, the research demonstrated that PP and ZP are projected to decline due to the relationship between acidity and warmth. Marine plankton confronts unprecedented problems stemming from environmental variations, including ocean acidification, temperature increase, and eutrophication. Information regarding the impacts of concurrent environmental variations on intricate ecological systems within coastal habitats is scarce. The research systematically examined environmental and biological features during the past 3 years, indicating that plankton populations exhibited divergent responses to the evolving coastal settings, characterized by a rise in PP and a decline in ZP. The variations in phyto- and ZP are attributed to the dual influence of acidification from declining pH and warmth from rising temperatures, both of which now favor PP over ZP. Water eutrophication, saltiness, and contaminants such as Hg, Zn, and As had varying effects on the movement of PP and ZP. Due to continuous climate change, the research demonstrated that PP and ZP are projected to decline due to the relationship between acidity and warmth.

Keywords: Phytoplankton; Zooplankton; Marine Ecosystems; Diversity.

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I. Introduction

Based on trophic strategy, which categorizes animals that interact with surroundings similarly, marine planktonic living things are classified into two primary categories: photosynthetic phytoplankton (PP) (Henson et al., 2021) and heterotrophic zooplankton (ZP) (Ratnarajah et al., 2023). Marine PP constitutes over 50% of the world's primary consumption as the principal growers in the oceanic food chain. At the same time, ZP serves as a crucial intermediary between primary consumers and ocean mammals. The interaction between ZP and PP constitutes the basis of the aquatic food web, and variations in ocean plankton communities would affect worldwide biogeochemical processes. Numerous PP and ZP species exhibit sensitivity to variations in the marine setting, and their reactions directly impact marine ecosystem processes. For instance, elevated temperatures can diminish the overall cell size of PP, whereas increased salt will significantly decrease planktonic diversity.

PP species can sequester atmospheric CO_2 through transpiration, potentially enhancing the marine carbon cycle (Gurung et al., 2024). The plankton research primarily examined the impact of global warming on PP group architecture; a significant information vacuum existed regarding the interactions among PP and ZP across geographic distances and environmental fluctuations.

The different impacts of altered maritime conditions on PP and ZP movements within plankton groups are a significant concern, as these species are fundamental to several aquatic food webs and are integral to ecological functions. This study concurrently assessed the reactions of PP and ZP groups to contemporary changing conditions, emphasizing their structural factors, prosperity, and variety in the semi-closed Sea, a coastal area substantially influenced by anthropogenic environmental variations and critical to biogeochemical processes and fishing (Sahavacharin et al., 2022). The research suggests that shifts in coastal habitats significantly affect the movement of PP and ZP. The research anticipates that the results will offer insights into current and future studies on the changing patterns of ocean plankton ecosystems, particularly in coastal seas significantly impacted by human activity.

II. Background

A significant issue in comprehending this intricate, bidirectional connection is the capacity to evaluate and forecast the responses of plankton populations to the continuously fluctuating oceanic surroundings, such as acidification, global warming, and eutrophication. Numerous laboratory and modeling studies have offered intriguing insights into the effects of warming temperatures on plankton neighborhoods; however, conflicting results arise primarily because the overall impact of one or multiple artificial motorists is contingent upon additional environmental factors or their relationships (Lutfi et al., 2022). Despite the increasing comprehension of the effects of concurrent environmental shifts on oceanic plankton motion, ambiguities persist, partly due to the scarcity of rigorous real-time field data detailing plankton structural characteristics. There is increasing proof that the effects and magnitude of marine plankton in reaction to future environmental changes vary significantly both within and between populations. In the North Sea, algae blooms have significantly advanced further in response to warming temperatures than their ZP grazing animals (Sarker et al., 2020). Prolonged research on the coastline of the East China Sea has demonstrated that diatoms and dinoflagellates exhibit divergent responses to heating and eutrophication, resulting in a decline of diatoms and a proliferation of dinoflagellates. Diverse reactions induce variations in plankton group makeup and functional groupings, including the emergence of hazardous algae blooms, which can negatively impact ecological stability, marine aquaculture, and the health of humans. Research has examined the comparative impact of various assembly procedures on species turnover rates and has demonstrated that the neighborhood process of assembly significantly affects organism dispersion and community organization (Seibold et al., 2023). Notwithstanding these preliminary investigations, the relationship between it and the PP and ZP groups in extensive maritime habitats remains largely unexplored. Studies developed a process for Interdomain Environmental Networks (IDEN) research to deduce the relationships between two taxonomic categories (i.e., underground plants and belowground microbes) in ecological studies (Burcham et al., 2024).

Evidence regarding the impacts of changing surroundings on intricate natural ecosystems remains scarce. Therefore, prudence is essential when evaluating the reactions of various plankton populations to concurrent environmental variations and their complicated interactions involving many variables, whether in experimental settings or field investigations.

III. PP and ZP Display Unique Characteristics

The connections between coastal the environment ZP and PP populations were illustrated through a Non-Metric Dimensional Scale (NMDS) of constructed dissimilarities, revealing that the ZP and PP groups across the 12 sites established different groups, as corroborated by similarity evaluation, permutational multivariate examination of variation, and multi-response combinations process. The data suggested that the organism richness of both PP and ZP groups varied significantly across the 12 testing locations.

To elucidate the biogeographic distributions of PP and ZP populations and the determinants of plankton beta variety, the research assessed the Distance-Decay Relations (DDRs) among beta variation and geographical locations. The gradients of both DDRs indicated geographical turnover speeds at which planktonic differences markedly escalated with geographic distance. The combination test showed that the geographical turnover velocity (slope) of the ZP group was substantially steeper than that of the PP group, implying that the ZP group exhibited more significant variability than the PP across wider dimensions.

3.1. Sampling

PP specimens were obtained using horizontal trawls utilizing a shallow water type-III plankton net (~25 µm mesh diameter). ZP specimens were gathered vertically using a shallow seawater type-I plankton net with an opening size of approximately 75 um. Every plankton net was fitted with a validated flow meter to quantify the quantity of filtered saltwater. The gathered plankton net specimens were then preserved in 600 mL polyethylene bottles, treated with a 5% formaldehyde mixture, and conveyed to the testing facility for additional analysis. Chlorophyll a was extracted and quantified from 600 mL saltwater specimens gathered on Whatman GF/F filtration under low vacuum conditions, with the filters being kept at -24°C until testing. All documented biological and ecological factors were assessed using water obtained from identical Niskin bottles.

3.2. Statistical Examination

Mean values are presented as values of Standard Deviations (SD). Linear regression and t-tests were employed to investigate the dynamic patterns in diverse biological and ecological characteristics. Pearson correlation evaluation and least squares were utilized to determine the correlations between data sets. Canonical Communication Assessment (CCA) and Applied Boosted Trees (ABT) evaluation were conducted to evaluate the connections between ecological factors and plankton groups (i.e., PP and ZP), as well as to measure the influence of significant environmental factors on biological variables. Graphical Additive Modeling (GAMs) was employed to investigate the reactions of plankton groups to critical explanation factors, including marine acidity and heating. The ABT and GAM studies were conducted in R utilizing the "gbmplus" program with 600 promoting trees and the "mgcv" package employing a smoothing estimate. All statistically significant thresholds were established at $p < 0.05$.

IV. Effectiveness Analysis

4.1. Effectiveness of Resource Utilization by PP

The model applied to PP resource-use effectiveness data indicated that Resource Utilization of PP (RU-PP) exhibited an annual pattern from late January to early May, alongside a quadratic long-term trend throughout the research timeframe. RU-PP exhibited a linear decline with increasing sampling levels and positively correlated with water temperatures and upwelling factors. RU-PP was associated with taxonomy variation, demonstrating a positive correlation with PP diversity and a negative correlation with PP uniformity. The analysis of forecasters for RU-PP, utilizing proportionate marginal variation breakdown, revealed that taxonomic variety and diversity (60.2%) were the most significant forecasters of RU-PP interactions, whereas external variables were of lesser value. Incorporating variance modeling as an exponential factor of variables yielded improved fits. RU-PP dispersion diminished with uniformity, which served as the most effective variance covariate. A rise of 0.2 units in PP uniformity diminished RU-PP variation by 20.7%. The RU-PP exhibited no significant residual trends.

4.2. Effectiveness of Resource Utilization by ZP

The framework applied to ZP resource-use effectiveness data indicated that Resource Utilization of ZP (RU-ZP) exhibited a seasonal cycle, increasing from late January to early May, with a declining trend observed from 2005 onwards. RU-ZP enjoyed a positive correlation with water temperatures and demonstrated a nonlinear association with the upwelling indicator. RU-ZP was associated with ZP taxonomy diversity, exhibiting a negative correlation with richness and a positive correlation with uniformity. In RU-ZP, taxonomy variety and richness emerged as the most significant predictor for RU-ZP, accounting for 65.2%, while external variables assumed a subordinate role. Incorporating a variance model as an exponential function of variables yielded improved fits. The dissemination of RU-ZP diminished with richness, which served as the most effective variance. A rise of 10 units in ZP diversity diminished RU-ZP volatility by 16.1%. The RU-ZP modeling exhibited no significant residual patterns.

4.3. Supplementary Analysis

Models employing alternative computations of RU-PP, specifically incorporating chlorophyll and primary cultivation, and calibrated to data spanning the entire period while limiting the PP organisms to the 55 taxa constantly discovered over thirty years, yielded structures similar to those previously described employing positioned stock as an indicator of PP biomass generation.

4.4. Analysis of Variety

Plankton variation was evaluated regarding taxonomy diversity per lake throughout Arctic zones and α diversity between ecological zones. Data from the principal continental areas of Arctic Canada and Russia were limited, and the remainder of the covering was spatially inconsistent, except for Norway.

The species-level taxonomic diversity of PP exhibited no substantial variation among Arctic regions. Correspondingly, the average taxonomic diversity was 14.2, 17.2, and 11.8 organisms in the subarctic in nature, lower Arctic, and upper Arctic. Elevated taxonomic richness was confined to the subarctic areas. Among all the chemical characteristics, only 10 were sufficiently represented by lakes for comparative analysis across Arctic zones. Among them, total phosphorus, dissolved oxygen, pH, magnesium, chlorine, and potassium exhibited considerable disparities among Arctic regions, with their highest mean levels observed in the higher Arctic. A notable gap existed in mean rainfall annually throughout Arctic groups, with subarctic locations exhibiting more excellent moisture than the upper and lower Arctic regions.

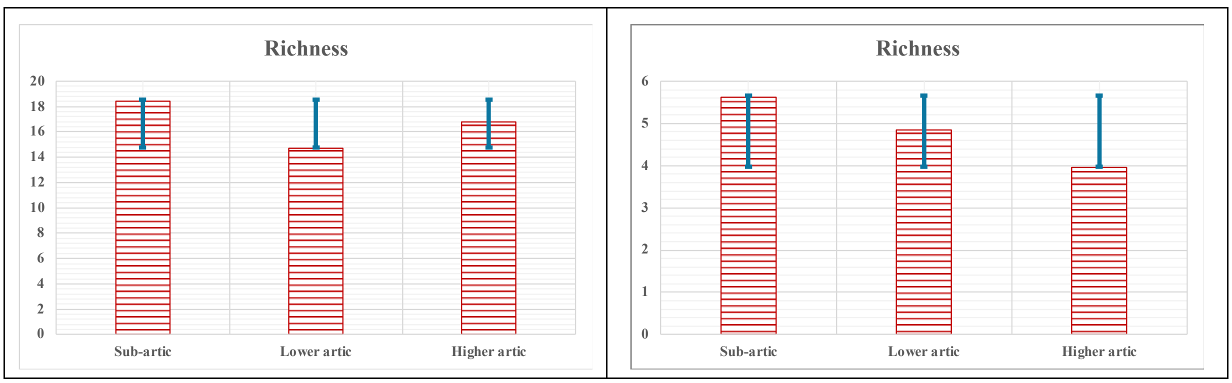

Figure 1: Richness Analysis (a). PP and (b). ZP

The taxonomic diversity of crustacean ZP varied greatly among Arctic regions. The lowest biodiversity was seen in the higher Arctic, which exhibited considerable differences between the subarctic and lower Arctic areas. Figure 1 shows the richness analysis of PP and ZP. The taxonomic diversity in the low Arctic was markedly inferior to that in the subarctic region. Calanoid copepods constituted the most species-rich category in the subarctic and lower Arctic, measuring around 50% of the overall species.

The three categories were similarly distributed in the upper Arctic. The ZP database revealed considerable variations in geographic and meteorological variables throughout Arctic zones and in phosphorus and conductance levels. Like the PP database, average annual air temperatures, average summertime air temperatures, and average yearly precipitation were most significant in the subarctic and least in the higher Arctic. At the same time, mean phosphorus levels and conductivity were elevated in the higher Arctic compared to other regions. The average lake width was most significant in the subarctic and least in the higher Arctic, with few lakes exceeding 1 km^2.

4.5. Constraints of the Study

The research possesses several limitations. They have not considered potential variations in cell size over time that could skew biomass estimations, as size is anticipated to diminish with rising temperatures. The research recognizes that the research has engaged with an insufficient number of animals. Traditional sample procedures are known to potentially overestimate PP variety; the research employed a unique assemblage that rendered the database more uniform over time. This ensemble was typical, as evidenced by the correlation between chlorophyll a and PP carbon, encompassing the most prevalent species in this location during each identified upwelling, unwinding, and downwelling stage. This ensemble effectively elucidated variation in PP and ZP as determined by chlorophyll a. The description of Resource Utilization (RU) was predicated on the measurement of the generation of biomass through an ongoing stock measurement, thereby excluding gross manufacturing; however, employing an accurate gauge of primary manufacturing (as secondary manufacturing was unavailable), the research observed analogous structures in the fluctuation of RU-PP. These supplementary studies indicate that the observed trends are resilient. The research asserts that the uniformity of the sampling techniques over the three many years, along with the analogous results derived from various RU computations, suggests that the factors mentioned earlier impact the impact of the dimensions of the designs, potentially diminishing the impact of particular species, albeit not altering the course of the consequences. The research posited a singular resource constraint (nitrate); additional research is required to examine the significance of colimitation or numerous resource limitations about upwelling behaviors.

V. Conclusion

Global environmental change primarily results from human activity. It is closely associated with simultaneous variations in acidification of the oceans, becoming warmer, eutrophication, classification, hypoxia, and other factors, which have extensive and significant environmental and biogeochemical consequences in the marine environment. Plankton in aquatic environments is undoubtedly influenced by the ongoing climate changes, as variations in plankton populations are primarily driven by fluctuating chemical, biological, and predatory conditions. The present research systematically examined biological and ecological features on the coastline during the previous three years, indicating that plankton populations exhibited varied responses to the changing coastline settings. The plankton populations reacted to coastal ecological variations by augmenting PP and diminishing ZP. These variations account for acidity, rising temperatures, eutrophication, saltiness, and contaminants such as Hg, Zn, and As. The interplay between acidity and warming is crucial in influencing the development of PP and ZP. The research anticipated a future decline in PP and ZP due to the interplay of acidity and heating. The reduction in plankton ecosystems must be considered in future global climates.

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