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Effects of Coastal Freshwater Discharge on Plankton Community Succession in Shallow Marine Waters

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Abstract: Freshwater discharge in the coastal area is a key factor that affects the physical, chemical, and biological properties of shallow marine ecosystems. Changes in the intensity of freshwater discharge may have an impact on salinity profiles, nutrients, water stratification, and phytoplankton growth, and consequently lead to a change in the planktonic succession. There is a need for such research as a result of increased variability of freshwater discharge due to rainfall and riverine contributions as well as coastal hydrology. The innovation of this research is in its approach to the study of the relationship between freshwater discharge properties, physicochemical properties of seawater, and plankton succession in the form of comparative ecological assessment. The methodology includes selection of the sampling stations in shallow marine areas exposed to the freshwater discharge as well as not exposed to it, seasonal water samples collection, plankton taxonomy, abundance evaluation, chlorophyll-a content analysis, physicochemical parameters evaluation, and statistical analysis, including diversity indices, correlation analysis, and multivariate community analysis. Phytoplankton and zooplankton composition and their abundance and seasonal distribution will be considered in the study. The analysis will concentrate on variations in salinity levels, nutrient concentration, stratification due to freshwater flow, and ecological relationships affecting community succession. The possible result will be acquiring new knowledge about the impact of coastal fresh water discharge on the development of planktonic communities.

Keywords: Coastal Freshwater Discharge; Plankton Community Succession; Shallow Marine Ecosystems; Salinity Gradient; Phytoplankton Diversity; Zooplankton Abundance; Nutrient Dynamics; Marine Ecological Monitoring.

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I. Introduction

Shallow marine water habitats are highly dynamic coastal zones that provide homes for diverse biological organisms and serve as arenas for various ecological functions. Among their major biological constituents, plankton populations participate significantly in the processes of primary production, nutrient cycling, energy flow, and marine food-web stability. Such populations include phytoplankton involved in photosynthetic activity, and zooplankton that controls energy transfer at upper trophic levels. Coastal fresh water discharge is one of the main environmental factors affecting the structure and dynamics of plankton populations (D'Alelio et al., 2022; Cozzi et al., 2020; Li et al., 2025). Fresh water flowing into the marine environment via river outflow, estuarine exchange, runoff, and coastal drainage impacts the salinity of water, nutrient concentration, suspended matter, and stratification of the water column. This factor can affect the processes of phytoplankton growth, zooplankton feeding, interspecies interactions, and seasonal dynamics of the population structure (Baek et al., 2025; Nardelli et al., 2023). The amount and seasonality of freshwater discharge can influence the degree of these ecological effects (Amadei Martínez et al., 2025; Jia et al., 2025). Less fresh water influx could lead to changes in salinity and nutrient levels, thus influencing the composition and abundance of plankton communities. This knowledge is necessary to evaluate how well the coastal ecosystems function under the given conditions of changing rainfall, hydrological regime, and human activities. Studying the plankton succession in zones of different influence will yield important data about ecosystem behavior (Lim et al., 2020). Moreover, fresh water discharge could result in distinct ecological gradients in the nearshore and offshore marine habitats due to which the spatial distributions of various planktonic species may differ. The increased amounts of freshwater may contribute to increased nutrient concentrations and hence increased production of phytoplanktons, but on the other hand, high amounts of suspended sediments may result in decreased availability of sunlight. Increased or decreased salinity could have an impact on the physiological tolerance, reproductive capacity, and survivability of various planktonic species. Therefore, zooplankton species would be impacted through the availability of

various plankton species. Seasonal observations on the abundances and diversities of plankton species will thus yield interesting results.

Problem Statement

Freshwater discharge from coastal zones affects the physicochemical environment of the shallow seas and may affect the abundance, species richness, and successions of planktonic community structures. However, the impacts of freshwater discharge intensity, salinity changes, enrichment of nutrients, turbidity, and stratification of the water column on the structure of the phyto- and zooplankton communities have not been adequately explored in most coastal zones. It is therefore challenging to establish the mechanisms of freshwater-induced environmental gradients that control seasonal successions of the planktonic community. Hence, systematic comparative studies are needed to explore the connections between the properties of the freshwater discharge and planktonic community successions.

Research Importance

The knowledge about plankton successions driven by fresh water will be useful for finding out the shifts that occur in coastal productivity, diversity, and organization of food webs. The research will be able to find out the environmental factors that cause the shifts in the plankton communities and gather baseline data about the reaction of coastal ecosystems to hydrological changes.

Section Overview

The paper highlights the ecological importance of coastal freshwater outflow as well as the possible impact that this type of outflow can have on plankton populations. The literature review focuses on freshwater-induced environmental gradients and plankton succession and at the same time points out the weaknesses in the current body of knowledge in this area. The methodology section describes the framework for the proposed research, including the sampling procedure, laboratory work, and statistical analysis methods. The rest of the paper analyzes the ecological associations, differences between habitats, and distributions.

II. Literature Review

Freshwater discharge from the coast is considered one of the major factors controlling the environmental variability in shallow marine ecosystems (Su et al., 2025). Coastal runoff and riverine input add freshwater, nutrients, suspended particles, and organic matter to marine ecosystems. These processes create gradients in salinity and change characteristics of the water column, thereby affecting biological productivity and the community structure of planktons. Phytoplankton communities react quickly to environmental changes due to their dependence on nutrients, light, temperature, and salinity. Increased nitrogen and phosphorus levels caused by freshwater discharge could stimulate the growth of phytoplankton communities. On the other hand, increased amount of suspended particles could decrease light penetration in the water, thus reducing the possibility of photosynthesis. The ecological response to the freshwater discharge depends on the discharge rate, nutrients in it, the time spent, and environmental conditions of the season. Zooplankton communities will be affected by freshwater discharge indirectly through changes in the phytoplankton community, salinity levels, environmental conditions, and predation.

Changes in the type and abundance of plankton communities that result from environmental factors characterize community succession. Seasonal precipitation, discharge, variations in temperatures, and the availability of nutrients could potentially affect the succession from one phytoplankton community to another and its respective zooplankton community (Wang et al., 2025). It is crucial to be aware of such ecological succession in studying coastal productivity and food web stability. Current studies of ecology offer plenty of information on the relationship between freshwater input, nutrient dynamics, salinity, and productivity of plankton communities. However, further assessment needs to include discharge variability, physicochemical gradients, and phytoplankton-zooplankton succession. Furthermore, freshwater outflow could play a role in determining the spatial distribution and dominance of certain types of planktons in the

coastal regions. Those organisms that are more tolerant of saltwater levels will tend to dominate in coastal regions near rivers, while those adapted to marine environment will dominate in locations where the influence of fresh water is less pronounced. Differences in nutrient enrichment could also have an effect on bloom formation among phytoplanktons and consequently influence feeding behavior of zooplanktons. Observations over a long period of time are needed to detect differences in seasonal succession and separate them from disturbances caused by human activities.

Identified Research Gap

Despite considerable research on freshwater runoff and plankton productivity separately, the effects of both these factors acting together on seasonal changes in plankton communities are understudied. Specifically, the interactions between the strength of the discharge, salinity gradients, availability of nutrients, water turbidity, and phyto- and zooplankton community interactions still require more study within varying coastal zones. Seasonally differing amounts of freshwater runoff may result in biological changes that are not easily explained by the environmental variables alone. The current study attempts to bridge this knowledge gap using a combination of sampling, environmental monitoring, plankton enumeration, and multivariate statistics.

III. Methodology and Proposed Research Architecture

Proposed System Architecture

This suggested research framework includes freshwater discharge evaluation, coastal water sampling, physicochemical analysis, plankton identification, and ecological data interpretation. Sampling locations will be set up at gradients of freshwater and marine coastal zones. Seasonal surveys will account for the variation in discharge rate and environmental factors. In lab studies, the abundance and diversity of phytoplankton and zooplankton communities will be assessed. The statistical analysis will correlate biological and environmental data in order to determine associations between the presence of freshwater and plankton succession.

Research Workflow and Methodology Pipeline

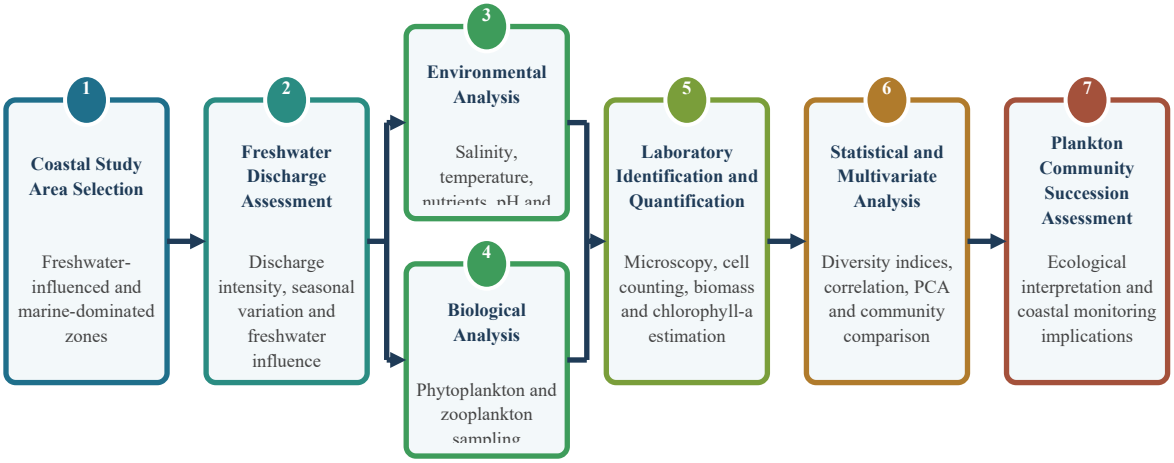


Figure 1: Proposed Methodological Architecture for Freshwater-Driven Plankton Succession

Figure 1 depicts the suggested research design framework for studying the impact of freshwater input from the coast on plankton communities' succession dynamics. The process starts with station selection as freshwater-affected and marine-dominated, respectively, and continues with discharge estimation. Subsequent environmental and biological data collection occurs in parallel and is further analyzed using laboratory identification and quantification methods. The multivariate statistical analysis combines the

obtained datasets and identifies the correlations between hydrological dynamics and community succession. The last stage is ecological interpretation and practical implementation perspectives of the study results.

Study Area Selection and Sampling Procedures

The research will examine coastal shallow marine environments that are affected by differing freshwater discharge regimes. The sampling stations will be positioned on a gradient from freshwater discharging points to areas more controlled by marine waters. In this way, comparisons can be drawn between sites which are affected by various amounts of freshwater influence.

There are three sampling groups:

- High freshwater influence: Sites closer to the mouth of rivers or freshwater discharge points.
- Moderate freshwater influence: Sites exposed to both freshwater and seawater.
- Low freshwater influence: Sites farther away from freshwater points.

Samples of water will be collected at various depths and intervals within different seasons. It is recommended that sampling occurs monthly for at least one year. Also, further sampling is recommended after large discharge events if possible.

The quantity of freshwater discharge will be measured based on flow measurements of the river or other discharge methods. Sampling points, tidal data, rainfall and sampling times will be recorded.

Physicochemical and Biological Assessment

The environment will be characterized based on water temperature, salinity, pH, dissolved oxygen, turbidity, electrical conductivity, and nutrient levels. The study will focus on dissolved inorganic nitrogen, phosphate, and silicate since these are nutrients involved in the growth of phytoplanktons and their communities. Water stratification will be assessed through vertical measurements of water temperature and salinity. Phytoplankton will be sampled using appropriate water sampling equipment and preserved for microscopic examination. Abundance will be determined through the use of appropriate counting chambers. Zooplanktons will be sampled using plankton nets whose mesh sizes are known. Laboratory analysis will follow to determine abundance. Major phytoplankton groups will be identified, and species richness and community composition determined.

Statistical and Ecological Modelling

All the biotic and abiotic factors observed will be incorporated into a well-structured database. The following parameters will be determined: Shannon Diversity, Simpson Diversity, Species Richness and Evenness, which will allow the determination of the characteristics of the plankton community. Correlation and regression analysis will determine the effect of freshwater discharge on plankton abundance. Analysis of Variance (or any other non-parametric method) will allow the comparison of the response of organisms in different influence categories of freshwaters. The Principal Component Analysis (PCA) will establish the dominant environmental gradients, and Non-Metric Multidimensional Scaling (NMDS) will allow the determination of the difference in plankton community composition. Redundancy Analysis (RDA) can be employed in order to test the relation between environmental predictors and community structure.

IV. Ecological Dynamics of Freshwater-Driven Plankton Succession

Influence of Freshwater Discharge on Plankton Distribution

Discharge of freshwater to the sea affects the distribution and physiological characteristics of marine plankton because it changes the properties of seawater. Discharge of freshwater creates gradients of salinity and affects the distribution and physiology of organisms and communities of marine plankton. Environmental changes caused by discharge of freshwater create specific ecological conditions near the places of discharge in comparison with distant areas of the ocean. Nutrient enhancement is one of the major ways that freshwater affects the productivity of plankton. River water carries nitrogen, phosphorus, silicate,

and dissolved organic matter to the coastal area. These nutrients may affect the growth of phytoplankton under favorable environmental conditions. However, the magnitude of the effect is dependent on the availability of nutrients, light, temperature of the water, and residence time. Changes in salinity caused by the freshwater influx may favor certain groups of phytoplankton and inhibit organisms that require stable salinity conditions. For instance, diatoms may be stimulated under certain availability of nutrients and silicate, while other phytoplankton groups become dominant under certain environmental conditions.

Changes in the environment affect zooplankton communities in both direct and indirect ways, through physiological responses and food web interactions. The variation in phytoplankton numbers and species composition will lead to variations in food supply and feeding possibilities for the zooplankton organisms. There might also be differences in tolerance levels among different zooplankton communities towards salinity variations. Another ecological factor that can play a role is the stratification of the water column. As fresh water enters the coastal water masses, it will form a less dense surface layer above a denser bottom layer. This stratification can affect the transport of nutrients within the water column and phytoplankton photosynthesis.

Seasonal Succession and Plankton Community Responses

Plankton community succession involves changes in the quantity, richness, and taxonomic composition of planktons. In shallow marine systems, the occurrence of such succession is often linked with seasonal rains, freshwater inflow, variations in temperature and nutrients, as well as biological interactions. During times when there is more freshwater inflow, the water becomes less saline while there will be an increase in nutrient concentration and particulate matter. Such occurrences can lead to an advantage for some phytoplankton species, causing a change in the communities that exist. When nutrient loading is coupled with adequate sunlight, then there can be an increase in the quantity of phytoplankton.

In case of low freshwater outflows, the coastal areas may become relatively stable in terms of salinity. Thus, it becomes possible for the development of plankton communities adapted to marine environment. Nutrient availability may have an effect on the succession process due to the impact of their changes on the relationships of competition between different groups of phytoplanktons. Zooplankton succession depends directly on the processes associated with phytoplankton. Availability of food resource for zooplankton changes depending on the abundance of primary producers, whereas temperature and salinity conditions have an effect on reproduction, development and distribution of zooplankton. There may be some time lags in the processes of phytoplankton and zooplankton succession since biological growth and development do not necessarily coincide.

Comparative Assessment of Coastal Environmental Conditions

Table 1: Expected Physicochemical and Biological Characteristics Across Freshwater Influence Zones

Parameters	**High influence**	**Intermediate influence**	**Low influence**
Salinity	Generally lower	Variable	Generally higher
Freshwater input	High	Moderate	Low
Nutrient availability	Potentially elevated	Variable	Site-dependent
Turbidity	Potentially high	Variable	Often lower
Water stratification	Potentially strong	Variable	Often weaker
Phytoplankton composition	Freshwater-tolerant and coastal groups	Mixed assemblages	Marine-adapted groups
Zooplankton composition	Salinity-sensitive groups may vary	Mixed assemblages	Marine-associated groups
Chlorophyll-a	To be measured	To be measured	To be measured
Community succession	To be evaluated	To be evaluated	To be evaluated

The characteristics listed in table 1 may differ between various types of coast based on the amount of freshwater input. Possible variations may occur in the amount of salinity, nutrients, turbidity, stratification, and phytoplankton composition. This is a basis for the analysis of biological differences between these coasts. The biological effect depends on hydrology, seasons, the ratio of nutrients, availability of light, and other environmental factors of each particular species. All biological effects must be confirmed experimentally.

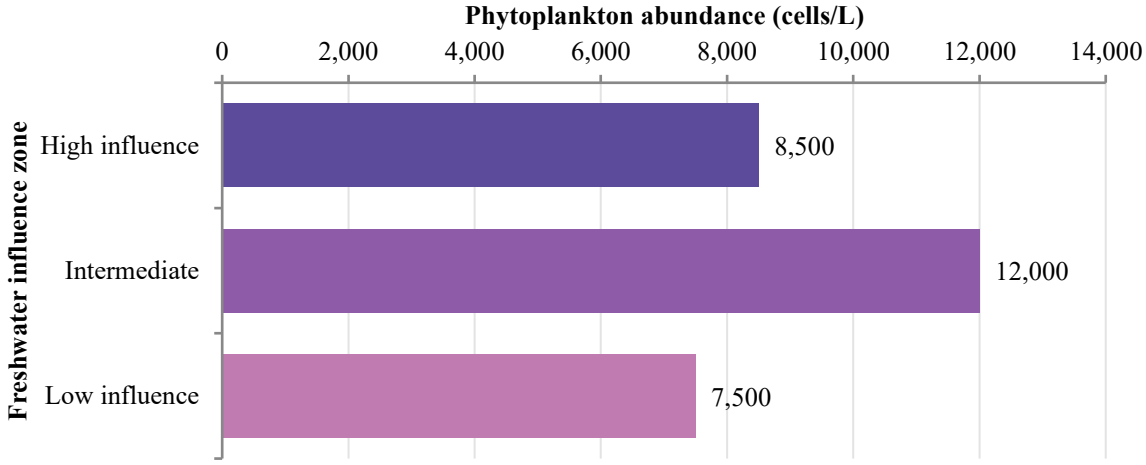


Figure 2: Comparison of Phytoplankton Abundance Across Freshwater Influence Zones

A comparison between the abundance of phytoplanktons in different coastal zones with high, medium, and low freshwater effects is presented in figure 2. As indicated in this conceptual framework, moderate amounts of freshwater may contribute to relatively high abundance of phytoplanktons due to good supply of nutrients and stable environment. However, heavy freshwater influx can affect productivity, which depends on such factors as turbidity, stratification, and nutrient supply. These figures are purely illustrative to show how graphs should be formatted.

V. Discussion

The suggested study offers an integrative method of studying the effects of the discharge of freshwater from the coast on the succession of plankton communities in shallow seas. Freshwater discharge can affect salinity levels, nutrients, turbidity, and water stratification. These can create various environmental conditions in the coastal area and affect the productivity of phytoplankton and, consequently, the number of zooplankton due to changes in food sources. Seasonal changes in hydrology can also play a role in the shifts of plankton community structure. With the use of physicochemical measurements, microscopic plankton identification, estimates of chlorophyll-a, and multivariate statistics, these relations can be found. It is worth noting that a rise in freshwater discharge does not always mean a rise in plankton productivity due to high turbidity and stratification.

Future Research Recommendations

Future research studies can include long-term season observations to detect changes in the succession process in response to changing conditions of freshwater discharge. Future research studies can include the application of advanced methods of taxonomic identification, such as DNA metabarcoding, to enhance taxonomic precision and increase knowledge about plankton diversity. Satellite data can be applied to estimate chlorophyll-a concentrations, turbidity and position of the freshwater plume along the coast. Researches need to explore the joint effect of climate change, unusual precipitation, pollution of the coast and nutrient loading on the plankton community.

Research Challenges

Some issues that can impact the process of studying the succession of plankton under the influence of freshwater will include the following. The variability in the rainfall and river runoff in terms of their seasonality will make the sampling problematic due to the unpredictability of environmental factors. Special microscopic analysis will be necessary to identify plankton species since some of the species can have similar morphological features. Turbidity of the water and presence of sediments can also affect the sampling process and measurements of chlorophyll-a. Moreover, differentiation between the effect of freshwater discharge and other environmental factors such as temperature, nutrients, tides, and grazing is needed.

VI. Conclusion

Aims of This Study

The aim of this study is to study the effect of discharge of freshwater into shallow sea on plankton community succession. The importance of such ecological research is connected with understanding of coastal productivity and biodiversity. Novelty of this research is determined by its comprehensive nature that includes evaluation of characteristics of discharge of freshwater into the sea, physicochemical environment gradients, and response of the phytoplankton and zooplankton communities. The proposed research design includes not only the spatial differences in the effect of discharge but also the seasonal ecological dynamics of plankton succession. The research methodology is based on the selection of the coastal stations with high, moderate, and low influence of freshwater. Collection of water samples during seasons, physicochemical measurements, microscopy identification of plankton species, abundance estimations, and chlorophyll-a concentration measurement will be carried out. These expected findings will help understand the dynamics of plankton abundance, diversity, community structure, and seasonality in different areas of freshwater influence. It is also expected that the study will reveal the role played by changes in salinity, nutrients availability, turbidity, and water stratification in shaping plankton communities. In general, this study lays a scientific foundation to understand how freshwater impacts shallow marine ecosystems. These findings, if confirmed through field observations, can potentially be useful in monitoring coastal biodiversity, assessing environmental impact, and managing marine resources sustainably. The study can also serve as the starting point for further research on the ecological effects of altered patterns of freshwater outflow and coastal environment. Note on final research preparation: This paper is written as a proposal for ecological research, not an actual experimental study. The values on the graph are imaginary and cannot be reported as the results. Real field data, statistics, and references should be added before publishing the paper in the journal.

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