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Comparative Bio-monitoring of Plankton and Benthos Communities along Coastal Infrastructure Projects: A Case Study of the Bali Beach Conservation Project (Nusa Dua and Tanjung Benoa)

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ABSTRACT

Coastal development projects can influence marine ecosystems by modifying sediment dynamics, water quality, and habitat characteristics. This study evaluated the ecological condition of coastal waters in Nusa Dua and Tanjung Benoa during the Bali Beach Conservation Project by assessing plankton and benthic communities as biological indicators. Community composition, abundance, and ecological indices were analyzed to characterize spatial variations in ecosystem conditions. Phytoplankton analysis identified 11 taxa, dominated by *Bacillariophyceae*, with higher abundance recorded in Nusa Dua (694.65 cells L⁻¹) compared with Tanjung Benoa (14.85 cells L⁻¹). Benthic assessment identified 22 taxa belonging to *Gastropoda*, *Bivalvia*, and *Polychaeta*. Ecological analysis showed that Tanjung Benoa exhibited a higher Shannon–Wiener diversity index ($H' = 2.30$) and evenness ($E = 0.95$) than Nusa Dua ($H' = 1.95$; $E = 0.68$), indicating a more balanced distribution of benthic individuals despite lower species richness. These variations suggest that plankton and benthic assemblages reflect spatial changes in environmental conditions associated with coastal activities. This study highlights the value of biological monitoring as a complementary approach to conventional water quality assessments and provides scientific support for sustainable coastal management and infrastructure development.

Contribution to Sustainable Development Goals (SDGs):

SDG 9: Industry, Innovation, and Infrastructure

SDG 13: Climate Action

SDG 14: Life Below Water

SDG 17: Partnerships for the Goals

1. INTRODUCTION

1.1. Research Background

The rapid development of coastal infrastructure in tropical regions has become one of the major challenges in marine environmental management [1]. Coastal areas around Nusa Dua and Tanjung Benoa, Bali, have experienced increasing anthropogenic pressure due to the implementation of the Bali

Beach Conservation Project (BBCP). While the project supports tourism and regional economic development, it also involves extensive coastal modifications, including sand filling, beach nourishment, and revetment construction. These coastal modifications can influence local hydrodynamic processes and sediment dynamics, which may subsequently affect the ecological conditions of the surrounding coastal waters. Achieving a balance between coastal infrastructure development and marine ecosystem conservation remains a key challenge in sustainable coastal management [2].



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Globally, coastal ecosystems are increasingly affected by marine urbanization, tourism expansion, and cumulative anthropogenic pressures [3]. Unlike isolated disturbances, cumulative impacts from multiple coastal activities may generate complex ecological responses through changes in hydrodynamics, sediment dynamics, habitat availability, and biological interactions. Tropical tourism regions are particularly vulnerable because intensive coastal development often occurs in environmentally sensitive areas with high ecological and economic value [4]. Therefore, integrated monitoring approaches that combine physical, chemical, and biological indicators are increasingly required to evaluate ecosystem responses and support adaptive coastal management.

In Indonesia, environmental impacts associated with development projects are monitored through the Environmental Management and Monitoring Plan (RKL-RPL), which are mandatory components of environmental approval mechanisms. Government Regulation No. 22 of 2021 concerning Environmental Protection and Management establishes the framework for environmental assessment, monitoring obligations, and environmental quality standards, including coastal and marine environments. However, the practical implementation of RKL-RPL monitoring in large-scale coastal infrastructure projects has traditionally emphasized physicochemical parameters, such as water quality, sediment characteristics, and pollution indicators [5]. Although biological monitoring is recognized within environmental assessment frameworks, its application is often limited to regulatory compliance rather than being fully utilized as an ecological assessment tool capable of detecting ecosystem level responses.

Among biological indicators, plankton and benthic organisms are widely recognized as reliable bioindicators because of their sensitivity and rapid responses to environmental disturbances [6]. Plankton represents the primary producers that sustain the marine food web, whereas benthic organisms reflect sediment quality and benthic ecosystem conditions [7]. The combined assessment of plankton and benthic communities provides complementary information regarding short-term water column responses and long-term habitat disturbances associated with coastal interventions.

Although biological monitoring data are routinely collected under environmental monitoring programs, these datasets remain underutilized for evaluating cumulative ecological impacts and supporting adaptive management decisions [8]. This gap is particularly significant given the growing pressure from coastal development and increasing climate variability, which call for biodiversity based indicators to be integrated into infrastructure impact assessments [9]. Ecosystem-based monitoring frameworks that incorporate biological responses alongside conventional environmental data offer a promising approach to strengthen these assessments and improve understanding of coastal ecosystem resilience.

Based on this background, the present study evaluates the ecological condition of the coastal waters of Nusa Dua and Tanjung Benoa through a comparative biomonitoring approach. Plankton and benthic community data collected using standardized plankton net and sediment corer sampling methods were analyzed to assess the environmental condition of the Bali Beach Conservation Project area. The findings are expected to provide scientific evidence for supporting coastal environmental monitoring and management, while promoting the sustainable

implementation of coastal infrastructure development. In addition, this study highlights the importance of collaboration among project developers, environmental practitioners, and academic institutions in maintaining the long-term resilience of coastal ecosystems.

1.2. Literature Review

Coastal ecosystems offer significant value across ecological, economic, and social dimensions; however, they are increasingly threatened by rapid urbanization and industrial development [10]. These pressures can alter water quality, sediment characteristics, and habitat conditions, affecting marine ecosystem structure and functioning. Understanding these interactions requires an integrated approach combining biological assessments with effective environmental management to support sustainable coastal development.

1.2.1. Plankton and Benthos as Bioindicators of Marine Ecosystem Health

Biomonitoring is widely applied to evaluate the ecological condition and resilience of marine ecosystems affected by anthropogenic disturbances. Plankton particularly phytoplankton form the foundation of the pelagic food web and respond rapidly to changes in environmental conditions, including nutrient availability, turbidity, and water quality [7]. These organisms act as sensitive indicators of short-term ecological shifts, enabled by their short lifespans and high responsiveness to environmental variability. In contrast, benthic organisms provide valuable information on long-term environmental conditions because they are closely associated with seabed sediments and generally have limited mobility. Consequently, variations in benthic community composition reflect the cumulative effects of sedimentation, habitat modification, and other disturbances affecting the seabed [11]. Therefore, monitoring benthic communities provides important insights into sediment quality and the overall ecological condition of benthic habitats.

1.2.2. Coastal Infrastructure and Anthropogenic Stress

The Bali Beach Conservation Project involves large-scale coastal engineering activities, including sand filling, beach nourishment, and revetment construction, which modify the physical characteristics of the coastal environment. These interventions may increase water turbidity, alter local hydrodynamics conditions, and disturb sediment transport processes, potentially affecting both pelagic and benthic habitats. Previous studies have demonstrated that coastal infrastructure development can influence sediment dynamics, modify habitat characteristic, and contribute to ecological change in coastal ecosystems [12]. By examining the responses of plankton and benthic communities in Nusa Dua and Tanjung Benoa, this study evaluates the ecological implications of coastal infrastructure development while considering the need to maintain ecosystem functions in coastal areas that support tourism activities.

1.2.3. Integrating Monitoring for Sustainable Management

In Indonesia, Government Regulation No. 22 of 2021 (Implementation of Environmental Protection and Management) regulates marine environmental monitoring and establishes environmental quality standards, including those for coastal

waters [13]. However, assessments based solely on physical and chemical parameters may not fully capture the cumulative biological indicators; incorporating plankton and benthic communities into routine monitoring programs provides a more comprehensive evaluation of ecosystem conditions and supports evidence-based coastal management [14], [15]. Such an integrated approach also aids in the fulfillment of the Sustainable Development Goals (SDGs) by strengthening marine ecosystem conservation (SDG 14), supporting the development of resilient and sustainable coastal infrastructure (SDG 9), improving the early detection of climate related ecological changes (SDG 13) and promoting collaboration among government agencies, industry, and research institutions to enhance long-term coastal resilience (SDG 17).

1.3. Research Objective

This study aims to evaluate the ecological impacts of the Bali Beach Conservation Project by assessing how coastal engineering activities, particularly sand filling and beach nourishment, influence the community structure of plankton and benthic organisms in Nusa Dua and Tanjung Benoa. We hypothesize that these activities modify local environmental conditions, particularly sediment dynamics and turbidity, resulting in measurable differences in plankton abundance, benthic diversity, and community composition between the monitoring sites.

2. MATERIALS AND METHODS

The study area encompasses the coastal waters of Nusa Dua and Tanjung Benoa, Bali, areas characterized by intensive coastal engineering activities under the Bali Beach Conservation Project. To evaluate the impacts of these activities, a spatial sampling approach was employed, involving two observations stations as illustrated in **Fig 1**. To represent a gradient of human-induced stress, these sampling locations ranged from areas experiencing direct coastal impact to relatively untouched, undisturbed environments. The sampling was carried out in April 2025 to capture the current ecological status of the study area. Plankton and benthic samples were collected at Nusa Dua (306326.00 E, 9026909.00 S) and Tanjung Benoa (304838.00 E, 9030839.00 S) using Universal Transverse Mercator (UTM) coordinates.

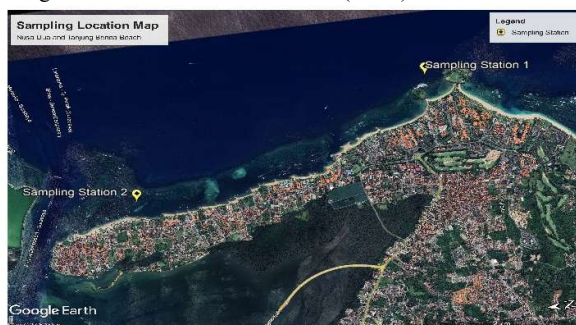


Fig 1. Geographic overview of the study region, including the location of all sampling stations

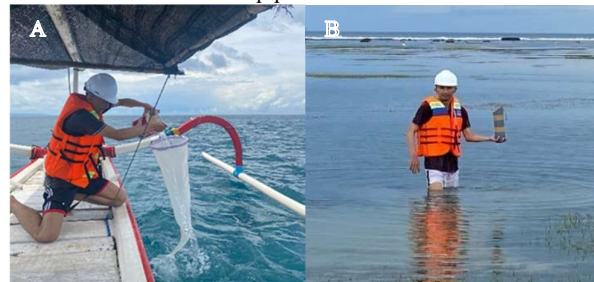
The present study adopted a comparative design between two monitoring stations representing different coastal conditions within the Bali Beach Conservation Project. While this design provides an initial assessment of ecological responses to coastal engineering activities, the limited number of monitoring stations may reduce spatial representativeness and statistical

generalizability. Future monitoring should therefore incorporate additional sampling transects, greater spatial replication, and repeated seasonal observations to strengthen ecological inference.

2.1. Data Collection

Plankton samples were collected by filtering seawater through a plankton net, repeating the filtration process 20 times at each location to ensure representative sampling; the concentrated samples were then transferred into sample bottles for laboratory analysis. Concurrently, benthic samples were obtained from the bottom substrate (sand and mud) using a pipe corer with a maximum capacity of two litres, reaching a depth approximately 30 centimeters, these sediment samples were then sieved through a 0.5 millimeters mesh to isolate benthic organisms, which were subsequently stored in plastic sample bags for further processing.

Fig 2. Field sampling activities: (A) plankton sample collection using a plankton net, and (B) benthos sample collection using pipe corer



2.2. Laboratory Analysis

All collected samples were transported to the Laboratory of the Faculty of Marine and Fisheries Sciences, Udayana University, Bali. Phytoplankton identification was performed using an Olympus CX21 microscope to determine species composition and abundance (cells L^{-1}), while benthic organisms were identified based on morphological characteristics by trained laboratory personnel using standard taxonomic procedures to ensure reliable identification of community composition.

3. RESULT AND DISCUSSION

3.1. Plankton Community Structure and Ecological Response

The phytoplankton community identified in the study area is summarized in **Table 1**. A Total of 11 phytoplankton taxa were recorded across the two sampling locations. Bacillariophyceae (diatoms) dominated the community, including *Amphipleura sp.*, *Nitzschia sp.*, *Cyclotella sp.*, *Skeletonema sp.*, *Amphora sp.*, and *Tabellaria sp.* Other groups, specifically *Cyanophyceae* and *Zygnematophyceae* were also present. The dominance of diatoms is typical in tropical coastal waters, likely driven by their high adaptability, rapid growth rates, and ability to efficiently utilize fluctuating nutrient levels, which allows them to persist across varying environmental conditions [16].

Phytoplankton abundance showed a marked spatial variation between the two sampling sites. Nusa Dua recorded a total abundance of 694.65 cells L^{-1} , whereas Tanjung Benoa recorded only 14.85 cells L^{-1} an approximately 47-fold difference. At Nusa Dua, the community was dominated by *Amphipleura sp.* (226.05

cells L⁻¹), followed by *Nitzschia* sp. (174.90 cells L⁻¹), *Synedra* sp. (80.85 cells L⁻¹), and *Skeletonema* sp. (51.15 cells L⁻¹). These high counts suggest that environmental conditions at Nusa Dua, likely characterized by favorable light penetration and nutrient availability, supported robust phytoplankton growth. In contrast, Tanjung Benoa exhibited consistently low abundance across all taxa, with *Amphipleura* sp. and *Synedra* sp. reaching only 3.30 cells L⁻¹ each. The absence of several species, such as *Skeletonema* sp., *Staurastrum* sp., *Tabellaria* sp., and *Cylindropermopsis* sp., indicates differences in environmental suitability and community development between the two locations.

Table 1. Abundance of identified phytoplankton species at the two sampling stations

No.	Phytoplankton Species	Abundance (cells L ⁻¹)	
		Station 1 (Nusa Dua)	Station 2 (Tanjung Benoa)
1	<i>Nitzschia</i> sp.	174.9	1.65
2	<i>Synedra</i> sp.	80.85	3.3
3	<i>Amphipleura</i> sp.	226.05	3.3
4	<i>Navicula</i> sp.	42.9	1.65
5	<i>Cyclotella</i> sp.	29.7	1.65
6	<i>Staurastrum</i> sp.	33	—
7	<i>Skeletonema</i> sp.	51.15	—
8	<i>Oscillatoria</i> sp.	16.5	1.65
9	<i>Amphora</i> sp.	13.2	1.65
10	<i>Tabellaria</i> sp.	4.95	—
11	<i>Cylindropermopsis</i> sp.	21.45	—

These spatial discrepancies indicate that the two sites offer vastly different conditions for primary productivity. The higher abundance at Nusa Dua suggests more favorable environmental conditions for phytoplankton growth, whereas the lower abundance at Tanjung Benoa may reflect environmental constraints affecting phytoplankton development. These differences are likely tied to the coastal engineering activities associated with the Bali Beach Conservation Project. Operations such as dredging, sediment excavation, and the installation of anthropogenic modifications often increase suspended sediment concentrations in the water column [17]. Elevated Total Suspended Solids (TSS) reduce water transparency and limit light penetration, thereby reducing photosynthetic activity and phytoplankton primary productivity. This relationship is supported by previous assessments of water quality in Nusa Dua and Tanjung Benoa, where suspended solids and turbidity were identified as important physical parameters affecting coastal water conditions [18]. Therefore, changes in sediment dynamics caused by coastal activities may influence phytoplankton productivity and community structure. Consequently, the simplified community observed at Tanjung Benoa serves as a clear ecological signature of anthropogenic disturbance.

However, differences in phytoplankton abundance may also be influenced by other interacting environmental factors, including hydrodynamic circulation, flushing rates, water residence time, and localized nutrient availability. Variations in these processes can affect nutrient retention, phytoplankton accumulation, and community development at each site. Therefore, the contrasting phytoplankton patterns observed between Nusa Dua and Tanjung Benoa likely represent the combined influence of sediment dynamics, hydrodynamic conditions, and local environmental characteristics. The

simplified community structure observed at Tanjung Benoa may indicate greater environmental constraints associated with coastal disturbance, although further monitoring with concurrent physicochemical measurements is required to confirm these ecological mechanisms.

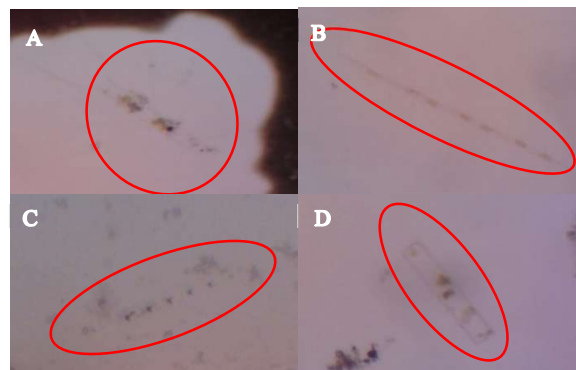


Fig 3. Representative phytoplankton species identified in the study: (A) *Chaetoceros* sp., (B) *Nitzschia* sp., (C) *Skeletonema* sp., and (D) *Rhizosolenia* sp.

3.2. Benthic Community Structure and Habitat Response

Benthic sampling identified a total of 34 individuals across the two study locations, consisting of 16 individuals in Nusa Dua and 18 individuals in Tanjung Benoa, representing 22 taxa distributed among *Gastropoda*, *Bivalvia*, and *Polychaeta* classes (Table 2). *Gastropoda* were the most common group at both sites, which is likely due to their high tolerance for the fluctuating conditions typical of coastal habitats. Different *gastropoda* taxa may occupy distinct ecological roles, including grazing, carnivory, and scavenging, allowing them to persist under varying sediment characteristics and food availability. Nusa Dua showed slightly higher species richness, with 14 recorded taxa, whereas Tanjung Benoa had 11 taxa and a higher total number of individuals (18 individuals). The frequent occurrence of taxa such as *Trivia arctica* and *Pyramidella* sp. in Tanjung Benoa indicates differences in habitat suitability and resource availability between the two locations.

Comparative analysis of benthic community structure revealed significant spatial variation. Tanjung Benoa displayed a higher Diversity Index ($H' = 2.30$) and Evenness Index ($E = 0.95$) compared to Nusa Dua ($H' = 1.95$ and $E = 0.68$). Although Tanjung Benoa had lower species richness than Nusa Dua, the higher diversity value indicates that individuals were distributed more evenly among taxa. In contrast, Nusa Dua exhibited greater species richness but lower evenness, suggesting that several taxa contributed disproportionately to community structure. These results show that biodiversity patterns depend not only on the number of taxa present but also on how individuals are distributed and how abundant they are within the community.

The observed diversity richness pattern highlights the complexity of ecological responses in disturbed coastal environments. A community with fewer taxa may exhibit higher diversity when individuals are distributed more equally, whereas a species rich community may show lower diversity when certain taxa become dominant. The relatively high evenness observed in Tanjung Benoa may reflect a community structure with reduced dominance and greater coexistence among taxa under the prevailing environmental conditions. This pattern may be

associated with ecological mechanisms such as intermediate disturbance, where moderate levels of environmental stress prevent competitive exclusion and allow multiple taxa to coexist. These ecological mechanisms offer plausible explanations for the observed pattern, although further confirmation across a broader range of monitoring sites would help clarify their generality.

The differences in benthic community composition are likely associated with site specific habitat conditions influenced by coastal engineering activities. Since benthic organisms are closely linked to bottom sediments, they are particularly sensitive to substrate modification, sediment deposition, and physical disturbance. Activities related to the Bali Beach Conservation Project, including sediment dredging, beach nourishment, and coastal structural modifications, may alter sediment characteristics and subsequently affect habitat suitability for benthic organisms [19]. The occurrence of taxa restricted to specific locations further reflects differences in environmental conditions and habitat preferences between Nusa Dua and Tanjung Benoa. In addition, the presence of different functional groups provides further ecological insight into community responses. Carnivorous gastropods such as *Trivia arctica* and *Conus* sp. suggest suitable feeding conditions and available ecological resources within the habitat, while deposit-associated organisms such as *Platynereis* sp. may reflect differences in sediment characteristics and benthic habitat conditions. *Platynereis* sp. is commonly associated with deposit-feeding behavior, utilizing organic particles within sediments, and its occurrence may therefore provide additional information regarding variations in benthic habitat quality.

Table 2. Distribution of Benthic Macrofauna Species at the Study Sites

Genus	Species	Nusa Dua	Tanjung Benoa
<i>Latirus</i>	<i>Latirus</i> sp.		1
<i>Pyramidiella</i>	<i>Pyramidiella</i> sp.		2
<i>Trivia</i>	<i>Trivia arctica</i>		4
<i>Smaragdia</i>	<i>Smaragdia souverbiana</i>	1	2
<i>Smaragdia</i>	<i>Smaragdia viridis</i>		1
<i>Persicula</i>	<i>Persicula</i> sp.		2
<i>Colombella</i>	<i>Colombella</i> sp.		1
<i>Cerithium</i>	<i>Cerithium balteatum</i>	1	2
<i>Epitonium</i>	<i>Epitonium acapulcanum</i>		1
<i>Epitonium</i>	<i>Epitonium</i> sp.	1	2
<i>Mitrella</i>	<i>Mitrella intexta</i>		
<i>Hemitoma</i>	<i>Hemitoma tricarinata</i>	1	
<i>Granata</i>	<i>Granata imbricata</i>	1	
<i>Subulina</i>	<i>Subulina octona</i>	2	
<i>Conus</i>	<i>Conus</i> sp.	2	
<i>Littorina</i>	<i>Littorina</i> sp.	1	
<i>Euplica</i>	<i>Euplica festiva</i>	1	
<i>Tectura</i>	<i>Tectura antillarum</i>	1	
<i>Ctenoides</i>	<i>Ctenoides dunkeri</i>	1	
<i>Sasakina</i>	<i>Sasakina</i> sp.	1	
<i>Donax</i>	<i>Donax</i> sp.	1	
<i>Platynereis</i>	<i>Platynereis</i> sp.	1	
Number of Species/Taxa		14	11
Total Number of Individuals		16	18
Shannon–Wiener Diversity Index (H')		1.946	2.303
Pielou's Evenness Index (E)		0.678	0.954
Simpson's Dominance Index (D)		0.082	0.123

Although the Dominance Index (D) remained relatively low at both sites ($D = 0.08$ in Nusa Dua and $D = 0.12$ in Tanjung

Benoa), the disparity in evenness serves as a primary ecological indicator of disturbance. The higher diversity and evenness in Tanjung Benoa suggest a more balanced community structure, whereas the uneven distribution in Nusa Dua is likely indicative of anthropogenic stress. Overall, these findings demonstrate that benthic assemblages are highly responsive to local environmental perturbations, providing critical insights into the cumulative influence of coastal infrastructure development on seabed ecosystems.

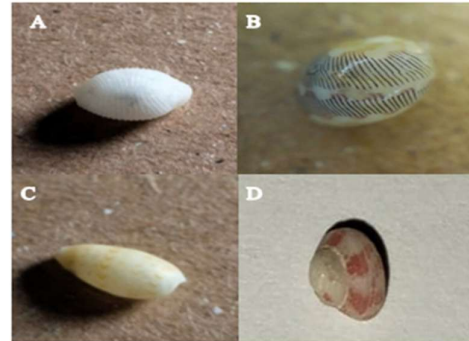


Fig 4. Representative benthic species identified in the study area: (A) *Trivia arctica*, (B) *Smaragdia souverbiana*, (C) *Persicula* sp., and (D) *Granata imbricata*

3.3. Ecological Condition Assessment and Ecosystem Resilience

Evaluating ecological indices provides an integrated perspective on the condition and stability of coastal ecosystems. Differences in plankton and benthic community characteristics between Nusa Dua and Tanjung Benoa indicate that ecosystem health depends not only on species richness but also on community composition, abundance distribution, and ecological balance. In the benthic community, Tanjung Benoa exhibited higher diversity and evenness values, indicating a more equitable distribution of individuals among taxa. In contrast, the lower evenness observed at Nusa Dua suggests that specific taxa contributed disproportionately to the community structure. These variations demonstrate that changes in community stability serve as critical ecological signals of environmental stress, even in areas where species richness remains relatively high. Consequently, biological indices provide essential data for assessing ecosystem responses to anthropogenic pressures in coastal environments.

3.4. Synthesis of Infrastructure Impacts on Ecological Response

The observed differences in plankton and benthic communities between Nusa Dua and Tanjung Benoa suggest that coastal engineering activities associated with the Bali Beach Conservation Project significantly influence local ecological conditions. Coastal infrastructure development generates multiple environmental pressures, including sediment disturbance, modifications to seabed characteristics, and alterations to water column conditions. Activities such as dredging, sediment excavation, and installing coastal structures increase sediment resuspension, directly affecting habitat suitability for various aquatic organisms. Higher suspended sediment concentrations reduce light availability in the water column, potentially limiting phytoplankton photosynthesis and primary productivity. At the same time, changes to bottom substrates disrupt the habitat of benthic organisms that rely on

specific sediment characteristics to survive. The contrasting responses observed between the study locations that manifested in differences in phytoplankton abundance and benthic community balance, indicate that local hydrodynamic conditions and habitat characteristics are primary determinants of ecosystem response. These findings highlight that coastal development initiatives must be accompanied by continuous ecological monitoring to mitigate potential impacts on marine biological communities.

3.5. Strategic Implications for Sustainable Coastal Governance

The findings of this study emphasize the importance of integrating biological indicators into sustainable coastal management strategies. Monitoring plankton and benthic communities provides complementary ecological information to conventional physicochemical water quality assessments by revealing biological responses and cumulative environmental changes associated with coastal infrastructure activities. Within the Indonesian environmental management framework, integrating biological monitoring into the RKL-RPL system can strengthen adaptive management by supporting early detection of ecological changes, evaluating mitigation effectiveness, and providing scientific evidence for decision-making throughout the implementation and post-construction phases of coastal projects.

This approach contributes to SDG 14 (Life Below Water) by strengthening marine ecosystem monitoring and conservation efforts, while also supporting SDG 11 (Sustainable Cities and Communities) by developing environmentally responsible coastal infrastructure. Furthermore, applying ecological assessments strengthens climate-resilient coastal management in line with SDG 13 (Climate Action) and promotes collaboration among government institutions, project developers, researchers, and environmental practitioners, as encouraged by SDG 17 (Partnerships for the Goals). Future coastal engineering projects should incorporate environmentally responsive strategies, including improved sediment management, consideration of local hydrodynamic processes, and continuous biological monitoring to minimize ecological disturbances. Integrating comprehensive ecological assessments into planning, implementation, and monitoring frameworks ensures that coastal protection objectives can be achieved while maintaining the long-term resilience and integrity of marine ecosystems.

4. CONCLUSION

This study assessed the ecological condition of coastal waters in Nusa Dua and Tanjung Benoa by evaluating plankton and benthic communities as biological indicators of environmental responses associated with the Bali Beach Conservation Project. The findings revealed distinct spatial differences in community structure between the two locations. The phytoplankton community consisted of 11 taxa and was dominated by *Bacillariophyceae*, with Nusa Dua recording a considerably higher abundance (694.65 cells L⁻¹), compared with Tanjung Benoa (14.85 cells L⁻¹). In contrast, the benthic community comprised 22 taxa belonging to *Gastropoda*, *Bivalvia*, and *Polychaeta*. Although Nusa Dua supported higher species richness, Tanjung Benoa exhibited a more balanced benthic community, reflected by higher diversity ($H'=2.30$) and Evenness

($E=0.95$) values. These findings indicate that plankton and benthic assemblages respond differently to variations in local environmental conditions and habitat characteristics influenced by coastal activities. Integrating biological indicators provides valuable ecological insights for assessing the impacts of coastal development and supporting sustainable coastal management. Long-term ecological monitoring is recommended to ensure future coastal infrastructure projects balance coastal protection needs with the preservation of marine ecosystem integrity.

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