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Short-term variation in phytoplankton and zooplankton assemblages across a seaweed-farming coastal gradient in Galesong, Sulawesi, Indonesia

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ABSTRACT

Information on short-term variation in phytoplankton and zooplankton assemblages in tropical seaweed farming environments is still limited. This study aimed to characterize the taxonomic composition, abundance, diversity and weekly spatial patterns of phytoplankton and zooplankton along a nearshore-seaweed farm-offshore gradient in Galesong, South Sulawesi, Indonesia. Sampling was carried out once a week for six consecutive weeks at three permanent stations representing nearshore waters, active *Kappaphycus alvarezii* farm and offshore waters. Samples were analyzed by means of Inverse Distance Weighted (IDW) interpolation to determine the microscopic identification, ecological indices and spatial distribution mapping. The total number of phytoplankton taxa was 10 and the assemblage was dominated by the diatoms *Chaetoceros* sp. and *Leptocylindrus* sp. The phytoplankton abundance was always higher than the zooplankton abundance and the Shannon–Wiener diversity ranged from 1.67 to 1.99. Five zooplankton taxa were recorded with unidentified crustaceans, *Tintinnopsis* sp. and *Balanus* larvae being numerically dominant. Zooplankton Shannon-Wiener diversity ranged from 1.02 to 1.09. The offshore station had highest total abundance in Weeks 1–3, the nearshore station had highest values in Weeks 4–6, and the seaweed-farm station did not show a consistently unique pattern of abundance or diversity. This pattern suggests that environmental variability may cause redistribution of plankton assemblages, although the mechanisms were not directly tested in this study. These results offer a preliminary baseline of phytoplankton and zooplankton assemblages in the region of study. Future studies should incorporate greater spatial and seasonal sampling and environmental measurements to better understand factors influencing plankton variability.

Key words: Galesong, plankton, seaweed, spatial variation, temporal dynamics

INTRODUCTION

In aquatic ecosystems, phytoplankton and zooplankton are complementary to each other. Primary producers, phytoplankton, transform inorganic carbon into organic matter by photosynthesis. Zooplankton transport the production of phytoplankton to higher trophic levels and play a role in pelagic food-web dynamics and biogeochemical cycling (Lubis et al., 2023; Ratnarajah et al., 2023; Calbet, 2024). Changes in the composition, quantity and variety of these assemblages may be indicative of environmental variability, for example alterations in nutrient availability, water-column conditions and ecosystem productivity. Phytoplankton and

zooplankton may react differently to environmental change as a result of their various ecological roles and life-history characteristics (Mariyati et al., 2020; Madjid et al., 2024).

Plankton assemblages are influenced by interacting physical, chemical and biological processes in space and time. Light availability, temperature, salinity, dissolved oxygen and concentration of nutrients can affect the growth and distribution of phytoplankton and the composition of the assemblage can be further modified by grazing, competition, microbial remineralisation and other trophic interactions (Buchan et al., 2014; McInerney et al., 2017; Sgarzi et al., 2019). These processes can take place at relatively small spatial and temporal scales in dynamic coastal environments resulting in substantial variability in phytoplankton and zooplankton abundance . However, distributional patterns alone are not sufficient to identify the mechanisms responsible without concurrent measurements of environmental and biological conditions.

Seaweed farming is an important coastal livelihood in eastern Indonesia and represents a major component of small-scale aquaculture in South Sulawesi (Zamroni, 2021). Seaweed cultivation may interact with surrounding coastal ecosystems through nutrient uptake, modification of local habitat structure, and changes in water movement around farming infrastructure (Duarte et al., 2017; Hardiana et al., 2024). These processes could potentially influence phytoplankton and zooplankton assemblages within and around cultivation areas. However, their magnitude and direction depend on farm characteristics, environmental conditions, and hydrodynamic exchange. Consequently, spatial observations of plankton within seaweed-farming areas should be interpreted cautiously unless seaweed biomass, nutrient dynamics, water properties, and hydrodynamic conditions are measured concurrently.

The Galesong coastal area of Takalar Regency is an important centre of *Kappaphycus alvarezii* cultivation. The area is also exposed to coastal development, sediment transport, erosion, land-based inputs, and other human activities that may contribute to environmental variability (Risnawati, 2021; Umar et al., 2023; Tang et al., 2024). Previous research in Takalar has examined water quality and carrying capacity for seaweed cultivation (Rahadiati et al., 2017), while studies from other coastal and aquaculture systems have demonstrated spatial and temporal variability in phytoplankton and zooplankton assemblages associated with environmental gradients (Wei et al., 2018; Wei et al., 2022; Putro et al., 2023; Zhou et al., 2024). However, these findings cannot be directly extrapolated to Galesong because local farming practices, coastal morphology, and environmental conditions may differ.

Although seaweed farming is widespread in South Sulawesi, information remains limited on the spatial and short-term temporal patterns of phytoplankton and zooplankton assemblages

across seaweed-farming and adjacent coastal and offshore waters. This study therefore provides a descriptive baseline of plankton assemblages along a nearshore–seaweed farm–offshore gradient in Galesong. Specifically, the study aims to: (i) characterize the composition, abundance, and diversity of phytoplankton and zooplankton at three stations along the gradient; (ii) describe weekly variation in these assemblages over a six-week sampling period; and (iii) visualize station-based spatial patterns in plankton abundance using Geographic Information System-based mapping. The findings are intended to support future monitoring and hypothesis-driven research on plankton dynamics and seaweed-farming environments in coastal South Sulawesi.

MATERIALS AND METHOD

Study Area and Sampling Design

The study was conducted in the coastal waters of Aeng Batu-Batu Village, North Galesong District, Takalar Regency, South Sulawesi, Indonesia (Fig. 1). The study area included an active small-scale *Kappaphycus alvarezii* cultivation site using a floating longline system. The farming area comprised approximately ten longlines covering an estimated area of about 150 m², consisting of a 15 × 10 m floating line arrangement used by the farmer and representing a small-scale coastal aquaculture system.

Three sampling stations were purposively selected to represent positions along a nearshore–seaweed farm–offshore gradient. Station A was located in the intertidal area adjacent to the coastal settlement, Station B was located within the active *K. alvarezii* farm, and Station C was located farther offshore. The stations were selected to provide descriptive coverage of the three positions along the gradient rather than statistical replication of each habitat category. The geographic coordinates of each station were recorded using a Garmin GPSMAP 65s.

Sampling was conducted once weekly over six consecutive weeks, from 21 April to 25 May 2026, at approximately 08:00 Central Indonesia Time. During each sampling event, the three stations were visited within the same morning period to reduce variation associated with sampling time. The sampling period broadly coincided with the transition toward the early dry season in South Sulawesi..

Field Sampling and Sample Preservation

At each station and sampling week, approximately 100 L of surface seawater were collected using a 10-L bucket from an approximate depth of 30-50 cm. The bucket was filled ten times, and each 10-L portion was sequentially filtered through the same No. 25 plankton net

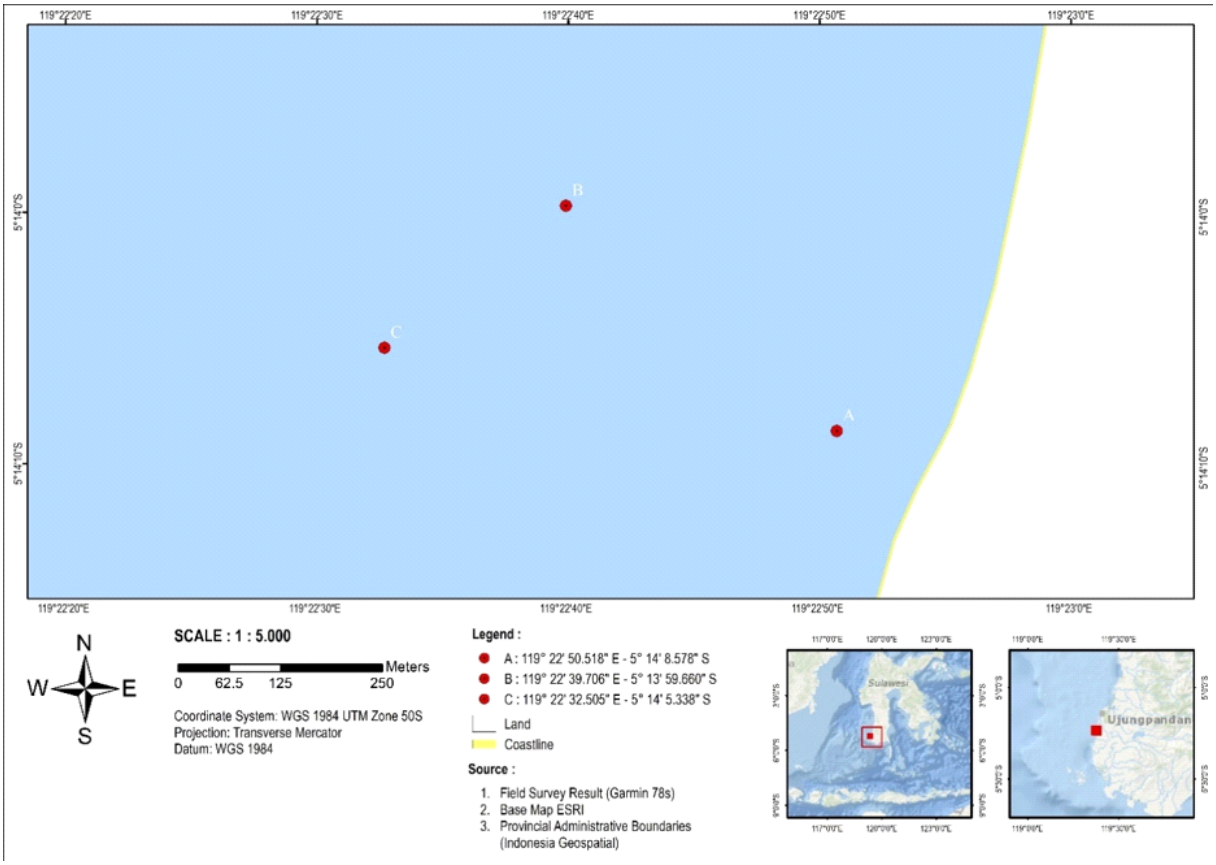

Figure 1. Map of sampling stations in the coastal waters of Aeng Batu-Batu Village, North Galesong District, Takalar Regency, South Sulawesi.

with a mesh size of 64 µm. The ten bucket collections therefore produced one composite plankton sample for each station-week.

The plankton concentrate was collected in a 100-mL cod-end bottle attached to the net following procedure of Baird & Bridgewater (2017). Immediately after collection, the samples were preserved with Lugol's iodine solution at a final concentration of approximately 1% by adding 1 mL of Lugol's solution per 100 mL of sample. The preserved samples were transported to the laboratory at Universitas Hasanuddin for identification and enumeration.

One composite sample was obtained from each of the three stations during each of the six sampling weeks, resulting in 18 station-week samples. The sequential bucket collections and microscope fields were treated as components of the sampling and counting procedures, respectively, and not as independent ecological replicates.

Data Analysis and Spatial Interpolation

In the laboratory, preserved samples were gently homogenized by inversion before subsampling. A 1 mL subsample was transferred into a Sedgwick–Rafter Counting Cell (SRC; 50 x 20 x 1 mm). Plankton were identified and enumerated under a compound microscope at

40× total magnification (4× objective and 10× ocular). Counts were conducted in multiple fields of view systematically distributed across the SRC chamber to obtain a representative mean density.

Phytoplankton and zooplankton were identified to the lowest practicable taxonomic level, generally to genus, based on standard marine plankton identification references (Newell & Newell, 1965; Sumich, 1999; IOC/WESTPAC, 2001). For each sample, the mean number of individuals per field of view (n) was used to estimate abundance per unit volume following Baird & Bridgewater (2017):

$$\mathrm{N} = n \times \frac{A}{B} \times \frac{C}{D} \times \frac{1}{E}$$

N = total plankton (ind L^{-1} or cells L^{-1});

n = mean count per field of view;

A = area of the cover glass (mm^2);

B = area of one field of view (mm^2);

C = volume filtered to the SRC (mL);

D = volume of one drop under the cover glass (mL);

E = volume of water filtered (L).

Community indices were calculated as in (Alam et al., 2019; Shabrina at al., 2021)

$$\mathrm{H}' = -\sum_{n=f}^{s} pi \ln pi$$

Because each station-week was represented by a single composite sample, analyses were limited to descriptive summaries of abundance and community indices. Spatial and temporal differences were interpreted qualitatively rather than through formal statistical inference.

Shannon–Wiener diversity with interpretation: $H' > 3$ high; $1 < H' \leq 3$ moderate; $H' < 1$ low.

$$D = \sum_{n=1}^{n} pi^2$$

Simpson dominance, where is the proportion of individuals belonging to the *i*-th taxon relative to the total number of individuals in the sample. In this formulation, D ranges from 0 to 1, and higher values indicate greater dominance (i.e., lower diversity).

$$\mathrm{E} = \left(\frac{H'}{H\ Max} \right)$$

Pielou evenness with interpretation: $0 < E \leq 0.4$ low (community stressed); $0.4 < E \leq 0.6$ moderate (community unstable/perturbed); $0.6 < E \leq 1$ high (community stable/good condition).

Here, $p_i = n_i/N$, n_i is the abundance of taxon i, N is total abundance, S is richness, and $H_{max} = \ln S$.

For each station and week, we summarised total phytoplankton and zooplankton abundance, taxonomic richness (S), Shannon–Wiener diversity (H′), Simpson dominance (D), and Pielou evenness (E). Temporal patterns were examined by comparing weekly values across the six-week series, and spatial patterns were examined by comparing among the three stations along the nearshore–farm–offshore transect.

Station coordinates were merged with weekly mean abundance values (ind L^{-1}) for each station in ArcGIS 10.8 to visualize the spatial variation of plankton abundance. Abundance values were reported as standardized densities (ind L^{-1}) enabling direct comparisons between stations and sampling weeks. Instead of using cumulative abundance totals, these values were used to better reflect weekly plankton dynamics and to avoid potential bias associated with pooling observations from different sampling periods. For each sampling week, Inverse Distance Weighted (IDW) interpolation was used to generate continuous surfaces of estimated plankton abundance across the study area. The IDW gives more weight to observations that are closer to the prediction location, so it is well suited to represent local-scale spatial patterns. Due to the small number of sampling stations (n = 3) the maps obtained should be regarded as qualitative descriptions of spatial variation rather than exact predictions. The resulting maps reveal changes in plankton abundance along the nearshore-farm-offshore gradient over time.

RESULTS

Across the six-week sampling period, the plankton assemblage comprised 10 phytoplankton taxa and 5 zooplankton taxa (Table 1). Table 1 summarizes the cumulative abundance (ind L^{-1}) of plankton taxa pooled across all stations and the six-week sampling period, providing a general overview of community composition and taxonomic dominance rather than spatial or temporal variation. Among phytoplankton, *Chaetoceros* sp. dominated (70,470 ind L^{-1}), followed by *Leptocylindrus* sp. (38,880 ind L^{-1}) and *Paralia* sp. (25,380 ind L^{-1}). Other abundant taxa included *Protoperidinium* sp. (25,110 ind L^{-1}), *Biddulphia* sp. (19,980 ind L^{-1}), and *Ceratium furca* (18,630 ind L^{-1}). *Rhizosolenia* sp., *Euchampia* sp., and

Pleurosigma sp. contributed 16,470, 11,340, and 8,100 ind L^{-1}, respectively, while *Peridinium* sp. had the lowest phytoplankton abundance (4,590 ind L^{-1}).

Within zooplankton, "unidentified crustacea" was most abundant (39,150 ind L^{-1}), followed by *Tintinnopsis* sp. (26,730 ind L^{-1}) and *Balanus* larvae (19,980 ind L^{-1}). "Unidentified bivalve larvae" and "unidentified polychaete larvae" reached 12,690 and 7,020 ind L^{-1}, respectively (Table 1; Fig. 2).

Weekly totals by station indicated phytoplankton abundances roughly twice those of zooplankton at all sites. At Station A, phytoplankton ranged 10,800–16,470 ind L^{-1} and zooplankton 4,860–7,290 ind L^{-1}, yielding totals of 15,660–23,760 ind L^{-1}; Station B showed a similar pattern (phytoplankton 10,800–16,470 ind L^{-1}; zooplankton 4,590–6,480 ind L^{-1}; totals 15,660–22,950 ind L^{-1}), while Station C exhibited slightly higher phytoplankton

Table 1. Cumulative abundance (ind L^{-1}) of plankton taxa pooled across all sampling stations over the six-week study period in Aeng Batu-Batu Village, North Galesong District, Takalar Regency, South Sulawesi

Taxa	Abundance (ind./L) Week 1 - Week 6
Phytoplankton	
Chaetoceros sp.	70470
Leptocylindrus sp.	38880
Paralia sp.	25380
Protoperidinium sp.	25110
Biddulphia sp.	19980
Ceratium furca	18630
Rhizosolenia sp.	16470
Euchampia sp.	11340
Pleurosigma sp.	8100
Peridinium sp.	4590
Zooplankton	
Tintinnopsis sp.	26730
Larva balanus	19980
Unidentified crustacea	39150
Unidentified larva bivalvia	12690
Unidentified larva polychaeta	7020

Figure 2. Temporal variation in plankton abundance (ind L^{-1}) and number of taxa in Aeng Batu-Batu Village, North Galesong District, Takalar Regency, South Sulawesi. The left y-axis represents plankton abundance (ind L^{-1}), while the right y-axis indicates the number of taxa.

(10,800–17,010 ind L^{-1}) and totals peaking at Week 3 (23,760 ind L^{-1}). Taxonomic richness remained stable at 10–11 taxa per station per week, with phytoplankton contributing 7–8 taxa and zooplankton three taxa. Despite week-to-week fluctuations in abundance, the near-constant richness indicates limited shifts in overall community structure, and suggests that temporal variability in totals was driven primarily by phytoplankton dynamics (Fig. 3).

Diversity metrics corroborate these patterns and provide further insight into dominance and evenness among taxa.Shannon–Wiener diversity index (H′) for phytoplankton varied from 1.67–1.99 among all stations, indicating moderate diversity typical of coastal systems. Station B generally showed slightly higher and more stable values, especially during Weeks 3–6 (H′ > 1.90), than Stations A and C.

Simpson's dominance index (D) where higher values indicate greater dominance of the community. Although *Chaetoceros* sp. numerically dominated, the high evenness values (E = 0.86–0.97) indicate that several taxa contributed significantly to total abundance rather than dominance by a single taxon.

In contrast, zooplankton diversity was lower, with H′ values ranging from 1.02 to 1.09 and dominance values (D = 0.62-0.66) indicating a more balanced distribution among fewer taxa. The evenness was good (E = 0.93-0.99) suggesting the leading zooplankton groups were relatively similar in proportion. Regarding time, zooplankton indices were largely steady in all

the sites, but phytoplankton showed more variability suggesting that short-term environmental variations could have affected phytoplankton dynamics to a larger extent.

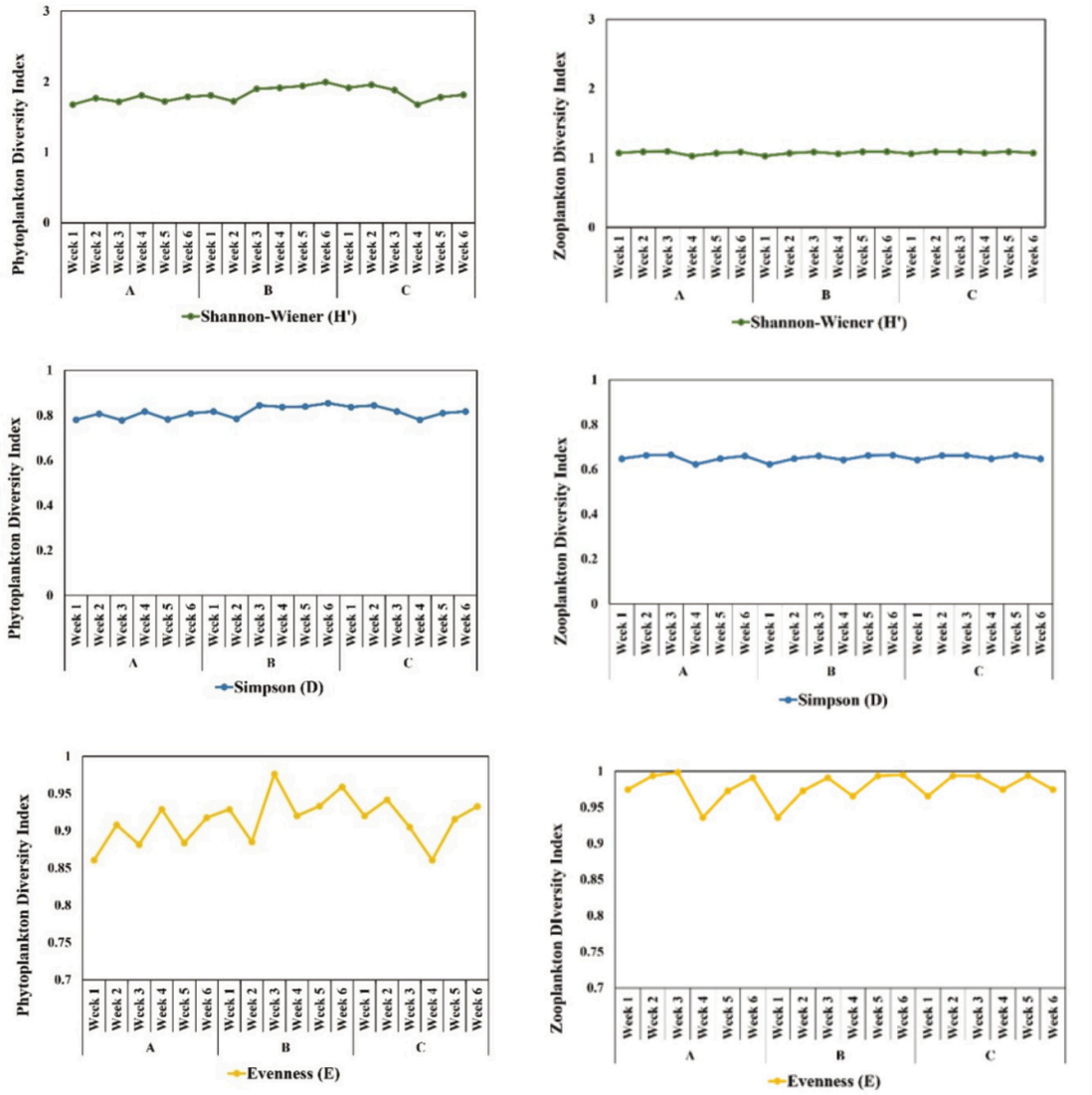

Figure 3. Temporal variation of phytoplankton (left) and zooplankton (right) diversity indices across stations A, B, and C during Weeks 1–6: Shannon diversity (H′), Simpson index (D), and Evenness (E).

The IDW spatial interpolation gives an idea about the movement of the center of plankton abundance through time and space (Fig. 4). During Weeks 1–3, the highest totals were consistently offshore at Station C (21,330; 20,250; peak 23,760 ind L^{-1}), while Stations A and B remained lower and comparatively stable, indicating an early offshore concentration of biomass. In Week 4, the center of abundance shifted shoreward, with Station A leading (21,330 ind L^{-1}), coincident with a decline at Station C (15,930 ind L^{-1}) and a minimum at Station B (15,660 ind L^{-1}). Week 5 showed a redistribution favoring Stations A (19,440 ind L^{-1}) and B (18,360 ind L^{-1}) relative to C (17,820 ind L^{-1}), and by Week 6 Station A exhibited the study's overall maximum (23,760 ind L^{-1}), followed closely by Station B (22,950 ind L^{-1}), while

Station C decreased to 16,200 ind L^{-1}. Taken together, these maps suggest a progression from an offshore-focused assemblage early in the series to a nearshore- and farm-focused assemblage later, with the highest terminal values occurring nearshore. Although mechanistic causes were not directly quantified in this study, the pattern found reflects a temporal shift in the spatial distribution of plankton abundance along the nearshore-farm-offshore gradient. However, this interpretation should be taken with caution as the interpolation is based on mean standardized abundance values from a limited number of sampling stations (n = 3) and is thus a qualitative depiction of spatial trends, rather than an accurate portrayal of spatial processes. Given that the interpolation was performed on mean standardized abundance values of only three sampling sites, the respective geographical patterns have to be evaluated with caution and viewed as qualitative representations rather than actual ecological forecasts. In real terms, stability of richness and evenness metrics, and shifting spatial peaks can indicate a reasonably robust community, responding rapidly in abundance, without much change in taxonomic diversity.

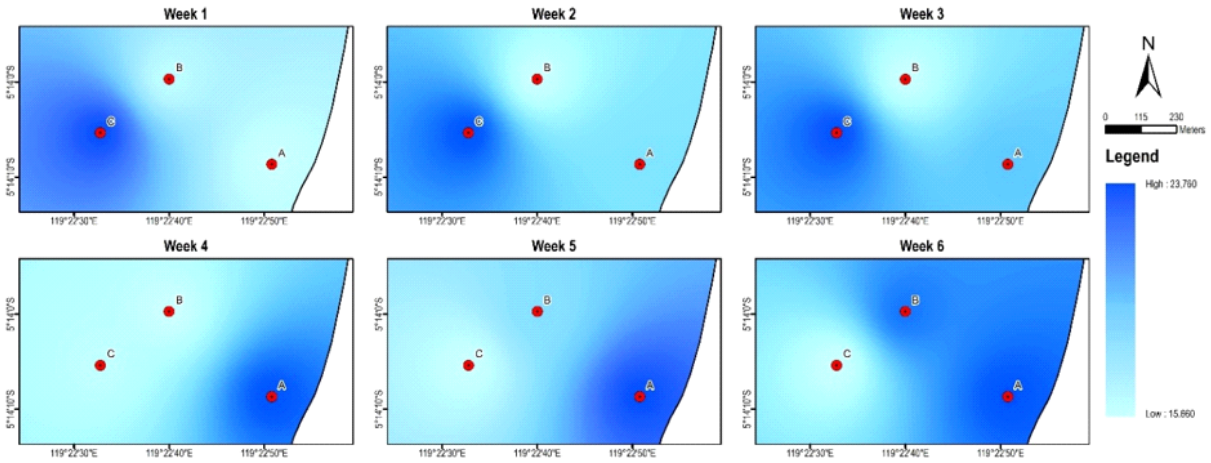

Figure 4. IDW-based interpolation maps illustrating weekly spatial variation in total plankton abundance (ind L^{-1}) across three sampling stations in Aeng Batu-Batu Village, North Galesong District, Takalar Regency, South Sulawesi. The maps are based on total abundance values and should be interpreted as qualitative visualizations of spatial patterns rather than precise representations of hydrodynamic processes, given the limited number of sampling stations (n = 3).

DISCUSSION

This study provides a short-term descriptive baseline of phytoplankton and zooplankton assemblages along a nearshore–seaweed farm–offshore gradient in Galesong, South Sulawesi. The net-retained phytoplankton assemblage was dominated by diatoms, particularly *Chaetoceros* sp. and *Leptocylindrus* sp., whereas the zooplankton assemblage comprised a smaller number of recurring taxa, including unidentified crustaceans, *Tintinnopsis* sp., *Balanus*

larvae, and bivalve and polychaete larvae. The station with the highest observed abundance changed over the six-week sampling period, with the offshore station recording the highest values during Weeks 1–3 and the nearshore station during Weeks 4–6. These observations demonstrate short-term variation in abundance among the three station positions, but the underlying environmental mechanisms cannot be determined from the present dataset.

The dominance of diatoms in the phytoplankton assemblage is consistent with findings from coastal systems where nutrient supply and hydrodynamic conditions favour fast-growing, silica-requiring taxa (McNair et al., 2018). Genera such as *Chaetoceros* and *Leptocylindrus* are commonly associated with nutrient-enriched and well-mixed coastal environments, where turbulence and recurrent nutrient inputs can promote rapid cell division and high population turnover (Bilbao et al., 2023; Arin et al. 2026). Their prevalence in Galesong may therefore indicate environmental conditions that favour active nutrient cycling, rapid phytoplankton growth, and sustained coastal productivity.

Diatoms can respond rapidly to nitrate and silicate inputs and may form short-lived blooms under favourable light, nutrient, and mixing conditions. The prominence of *Chaetoceros* and *Leptocylindrus* may also reflect an early or intermediate successional stage, during which opportunistic, rapidly growing taxa exploit available resources before being replaced as environmental conditions change (Lee et al., 2025; Raut et al., 2026). Their numerical importance may have further ecological relevance because diatoms provide food for microzooplankton and larger zooplankton and can contribute to energy transfer within coastal food webs. The moderate Shannon diversity ($H' \approx 1.7–2.0$) and high evenness indicate that, despite the prominence of these two genera, several other phytoplankton taxa also contributed substantially to the assemblage. This combination of diatom dominance and relatively even taxonomic representation is consistent with assemblages reported from productive coastal waters that are not overwhelmingly dominated by a single taxon (Soetignya et al., 2021; Liya et al., 2025). However, because chlorophyll-*a*, hydrodynamic conditions, grazing, and primary productivity were not measured, the proposed successional, bloom, and trophic interpretations remain plausible explanations rather than confirmed mechanisms.

Phytoplankton abundance also varied among weeks and stations. Higher values were recorded at the offshore station during Weeks 1–3, followed by an increase at the nearshore station toward the end of the sampling period. Temperature and water-column stratification can influence the timing and magnitude of coastal phytoplankton blooms by altering light conditions, nutrient availability, and vertical mixing (Trombetta et al., 2019; Dai et al., 2023). The fluctuations observed in Galesong are therefore consistent with short-term variability in

hydrodynamics and nutrient transport reported from other tropical and subtropical coastal environments, although these processes were not measured directly in this study (Hilaluddin et al., 2020; Jung et al., 2025).

Compared with phytoplankton, zooplankton diversity was lower, reflecting the smaller number of taxa observed, while evenness remained consistently high. The main groups crustacean larvae, *Tintinnopsis* sp., and bivalve and barnacle larvae occurred in relatively similar proportions each week at all stations. Together with the narrow temporal range of the zooplankton indices, this pattern indicates that the numerical structure of the recorded zooplankton assemblage varied less markedly than phytoplankton abundance during the study period.

The consistent presence of *Tintinnopsis* sp. was ecologically noteworthy. Tintinnid ciliates commonly occur in productive, nutrient-influenced, and physically dynamic coastal waters, where they function as microzooplankton grazers and contribute to the transfer of phytoplankton production to larger consumers. As important components of the microbial food web, tintinnids consume pico- and nanophytoplankton as well as small diatoms and flagellates, thereby linking microbial production to mesozooplankton and higher trophic levels (Santoferrara & Alder, 2012; Dolan et al., 2013). Their recurrent occurrence across stations and weeks may therefore reflect relatively sustained food availability during the observation period. This interpretation is consistent with studies showing that tintinnid ciliates can track variations in small phytoplankton and chlorophyll-*a* in tropical estuarine and coastal environments (Sathish et al., 2024). In productive coastal waters, tintinnid abundance has frequently been associated with elevated phytoplankton biomass and stable nutrient supply, suggesting that these ciliates can serve as indicators of active microbial and planktonic food-web processes (Dolan et al., 2016).

The co-occurrence of *Tintinnopsis* sp. and crustacean larvae with a diatom-dominated phytoplankton assemblage consequently suggests a potential trophic connection between primary producers and zooplankton consumers. Sustained dominance of diatoms phytoplankton taxa may therefore have provided a relatively continuous food source that supported the persistence of tintinnids and larval crustaceans throughout the sampling period. Similar associations between diatom-rich phytoplankton communities and stable microzooplankton assemblages have been reported in coastal ecosystems where primary production is efficiently transferred through microbial and mesozooplankton pathways (Calbet & Landry, 2004; Tames-Espinosa et al., 2020). The repeated occurrence of crustacean larvae

may further indicate that local conditions remained suitable for larval survival and development, potentially reflecting a combination of adequate food availability and relatively stable environmental conditions.

The comparatively narrow variation in zooplankton indices may also reflect the tendency of zooplankton assemblages to integrate changes in food availability and physical conditions over longer timescales than phytoplankton, which may respond more rapidly to short-term environmental variability (Wei et al., 2022). From an ecosystem point of view, the presence of *Tintinnopsis* sp. and crustacean larvae at all stations may be indicative of some degree of trophic stability in the coastal plankton community, as this suggests that any changes in phytoplankton abundance did not induce any important changes in the dominant zooplankton groups during the study period. This stability may be a result of sustained primary productivity, efficient trophic coupling between phytoplankton and grazers, or relatively constant environmental conditions across the nearshore–offshore gradient. However, the presence of direct trophic coupling cannot be confirmed due to the lack of measurements of grazing rates, chlorophyll-*a*, prey availability and zooplankton feeding. As such, these interpretations should be regarded as plausible ecological explanations that warrant further investigation through the combination of measurements of phytoplankton biomass, microzooplankton grazing and environmental variability.

The IDW-based maps highlight a shift in the centre of total plankton abundance from offshore (Station C) in Weeks 1–3 to nearshore and farm stations (A and B) in Weeks 4–6. Similar spatial–temporal reorganisation of plankton has been documented in other coastal systems, where circulation patterns, mixing, and land–sea gradients in nutrient inputs shape plankton distributions at scales of kilometres and days to weeks (Zhou et al., 2024). In Galesong, the offshore maxima early in the series may reflect conditions in more open coastal waters, while later increases at the nearshore and farm stations are consistent with a growing influence of processes acting closer to shore, such as nearshore mixing, resuspension, or land-derived inputs.

Because only three fixed stations were sampled and environmental variables were not measured, the interpolated surfaces should be interpreted as qualitative visualisations rather than precise predictions. Nonetheless, the combination of relatively stable taxonomic richness and high evenness with shifting spatial peaks in abundance suggests that, over the six-week period, the same set of taxa persisted while total biomass was redistributed along the transect. This pattern may be influenced by short-term environmental variability, although the underlying mechanism were not directly examined in this study.

The study area is embedded within an active *Kappaphycus alvarezii* farming landscape and a coastline subject to sediment transport, and multiple human uses (Rahadiati et al., 2017; Umar et al., 2023; Tang et al., 2024). Seaweed cultivation can influence local water quality and plankton through nutrient uptake, organic exudation, and habitat provision, while also delivering socio-economic benefits (Rimmer et al., 2021; Hardiana et al., 2024; Pessarrodona et al., 2024). In the present study, however, the farm station (Station B) did not show a consistent abundance or diversity pattern that clearly distinguished it from the nearshore and offshore stations. The observed patterns therefore do not provide direct evidence that seaweed cultivation increased or decreased phytoplankton or zooplankton abundance.

Several limitations should be considered when interpreting these findings. Each station-week was represented by one composite sample, each position along the gradient was represented by one fixed station, and sampling covered only six weeks. In addition, environmental variables, hydrodynamic conditions, seaweed biomass, nutrient uptake, and farm intensity were not measured, while the 64-µm plankton net may have underrepresented smaller phytoplankton and microzooplankton. The analysis should therefore be regarded as descriptive and as an initial ecological baseline rather than a definitive assessment of seaweed-farm effects.

Future studies should include replicated farm and non-farm stations, increase sampling across seasons, and measure nutrient concentrations, temperature, salinity, pH, dissolved oxygen, turbidity, chlorophyll-*a*, hydrodynamic conditions and seaweed biomass. The combination of plankton observations with farm characteristics and environmental measurements could help to identify potential farming influences from natural coastal variability and to elucidate mechanisms behind observed spatial and temporal patterns.

Despite its limitations, this study provides an initial record of phytoplankton and zooplankton assemblages across nearshore, seaweed-farm, and offshore positions in North Galesong. The findings identify numerically prominent taxa and document short-term variation in abundance and diversity metrics. Continued monitoring could help detect changes associated with eutrophication, harmful algal blooms, water-quality deterioration, farm expansion, or coastal development. Combining plankton indicators with hydrodynamic information, land-based inputs, and farm operations would provide a stronger basis for ecosystem-based management, spatial planning, and assessment of aquaculture carrying capacity along the Galesong coast.

CONCLUSION

This study shows that the plankton community in Galesong waters is stable in composition but dynamic in spatial distribution, thus achieving the research objective of understanding its structure and variation. The dominance of diatoms with high uniformity values reflects a balanced community without strong ecological pressure. The shift in the center of abundance from offshore waters at the beginning of the observation to coastal and cultivation areas in the final week shows that biomass redistribution is more influenced by physical dynamics of the waters than by changes in community structure. These findings provide an initial baseline for the ecological conditions of the Kappaphycus alvarezii cultivation area and confirm the potential of plankton as an environmental indicator. Long-term monitoring with the integration of oceanographic parameters is needed to strengthen the application of ecosystem-based management in the Galesong region.

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