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Physicochemical Water Characteristics and Massive Coral Cover in the Waters of Saonek Village, Raja Ampat Regency

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ABSTRACT

The waters of Saonek Village, South Waigeo District, Raja Ampat Regency, lie within the coral triangle and are subject to anthropogenic pressures from port operations, tourism, and residential activities. This study aimed to analyze physicochemical water characteristics and the cover of live hard corals and massive corals in these waters. Surveys were conducted at four stations: Gurara, D'Coral, Pandawa, and Pelabuhan. Environmental parameters included pH, salinity, temperature, current velocity, water transparency, depth, and substrate type. Coral cover was assessed using the underwater photo transect (UPT) method. Water pH ranged from 6.16 to 7.79, salinity from 30.3 to 32.7‰, temperature from 30.0 to 31.9 °C, and current velocity from 0.033 to 0.050 m s^{-1}. Water transparency was 100%, and depth ranged from 2 to 11 m. Live hard coral cover ranged from 15.53 to 49.80% (mean: 29.99%), corresponding to poor to fair reef condition, whereas massive coral cover ranged from 4.63 to 16.47% (mean: 10.82%). The highest proportions of massive corals within live hard coral cover were recorded at Pelabuhan and Gurara stations (71.6% and 49.3%, respectively), where pH was below the quality standard range. These findings suggest that massive growth forms are more tolerant of environmental stress and therefore tend to dominate coral communities in disturbed waters.

INTRODUCTION

Coral reefs are among the most productive and biologically diverse coastal ecosystems in the tropics. They provide habitats, spawning grounds, and food resources for a wide range of marine organisms and protect coastlines from wave action and erosion (Nybakken, 1992; Supriharyono, 2007). Indonesia lies at the center of the Coral Triangle, which supports the highest diversity of reef-building coral species worldwide (Veron et al., 2009). Within this region, Raja Ampat Regency is recognized as a hotspot of coral reef fish diversity and endemism in the Indo-Pacific (Allen, 2008).

Despite their considerable ecological and economic value, coral reefs in Southeast Asia face increasing threats from human activities and climate change (Burke et al., 2011). Rising sea surface temperatures have triggered recurrent mass coral bleaching across multiple regions (Hoegh-Guldberg, 1999; Hughes et al., 2017). At the local scale, terrestrial inputs of sediment and organic matter can degrade water quality and inhibit coral growth (Rogers, 1990;

Fabricius, 2005). In addition, declining seawater pH reduces the availability of carbonate ions required for coral calcification (Doney et al., 2009).

Coral growth and distribution are governed by physicochemical factors, including temperature, salinity, pH, light intensity, currents, and substrate type (Kleypas et al., 1999). Responses to changes in these factors vary among coral growth forms. Massive corals, including members of the genus Porites, have thick tissues and slow growth rates and are therefore more tolerant of sedimentation and elevated temperatures than branching corals (Loya et al., 2001; Darling et al., 2012). Consequently, the dominance of massive corals within a community may indicate environmental stress.

Saonek Village is located in South Waigeo District, near Waisai, the administrative capital of Raja Ampat Regency. Its coastal waters support port operations, vessel traffic, marine tourism, and residential activities, all of which may affect water quality and coral reef condition. However, information on the relationship between water characteristics and massive coral cover at this location remains limited. This study aimed to analyze physicochemical water characteristics and the cover of live hard corals and massive corals in the waters of Saonek Village, Raja Ampat Regency. The findings are expected to provide baseline information for coral reef ecosystem management in the area.

METHOD

Study period and location

The study was conducted from May to August 2026 in the waters of Saonek Village, South Waigeo District, Raja Ampat Regency, Southwest Papua Province, Indonesia. Data were collected at four stations: Gurara (00°26′34.24″ S, 130°47′20.41″ E), D'Coral (00°26′19.82″ S, 130°46′52.92″ E), Pandawa (00°26′28.49″ S, 130°46′12.77″ E), and Pelabuhan (00°26′08.58″ S, 130°48′04.05″ E). Stations were selected purposively based on the presence of coral reef ecosystems and differences in the intensity of nearby human activities. Station coordinates were recorded using a global positioning system (GPS).

Measurement of physicochemical water parameters

Physicochemical water parameters were measured *in situ* at each station. Water pH was measured using a pH meter, salinity using a refractometer, and temperature using a thermometer. Current velocity was determined using the floating drogue method by dividing the distance traveled by the float by the elapsed time and expressed in m s^{-1}. Water transparency was assessed using a Secchi disk. The disk remained visible down to the seabed at each station; therefore, water transparency relative to water depth was recorded as 100%. Water depth was measured using a depth gauge. Substrate types were identified visually along the survey transects.

Assessment of coral reef condition

Coral reef condition was assessed using the underwater photo transect (UPT) method following Giyanto et al. (2010) and Giyanto (2012a,b). At each station, divers deployed a 50 m transect tape parallel to the shoreline at a depth of approximately 5 m. Photographs were taken at 1 m intervals with the camera oriented perpendicular to the seabed. A 58 × 44 cm frame was used to standardize the photographed area to 2,552 cm^2. Images that met the criteria for sharpness and substrate visibility were grouped by station and transect and analyzed using Coral Point Count with Excel extensions (CPCe), with 30 random points overlaid on each image (Kohler & Gill, 2006).

The object beneath each point was identified according to benthic cover categories, including live hard corals, massive corals, other biota, and substrate. Massive corals were recorded as a subset of live hard corals. Percentage cover for each category was calculated by dividing the number of points assigned to that category by the total number of analyzed points and multiplying by 100%. Thus, coral cover was estimated from the proportion of points on photographs rather than the length of coral intersecting the transect line.

Data analysis

Data were analyzed using a descriptive comparative approach and presented in tables and figures. Physicochemical water parameters were compared with the seawater quality standards for marine biota (corals) specified in Decree of the State Minister of the Environment No. 51 of 2004. Live hard coral cover was classified following Gomez and Yap (1988) and Decree of the State Minister of the Environment No. 4 of 2001 as poor (0–24.9%), fair (25–49.9%), good (50–74.9%), or excellent (75–100%).

RESULT AND DISCUSSION

Physicochemical water characteristics

The physicochemical water parameters measured at the four stations are presented in Table 1. Water pH ranged from 6.16 to 7.79, with the lowest value recorded at Gurara station and the highest at D'Coral station. Salinity ranged from 30.3 to 32.7‰, and temperature ranged from 30.0 to 31.9 °C. Currents were weak at all stations (0.033–0.050 m s^{-1}), whereas water transparency reached 100% over a depth range of 2–11 m. The seabed substrate at all stations comprised live corals, dead corals, coral rubble, and sand, with mud also present at D'Coral station.

Table 1. Physicochemical water parameters in the waters of Saonek Village, Raja Ampat Regency

Station	pH	Salinity (‰)	Temperature (°C)	Current velocity (m s^{-1})	Water transparency (%)	Depth (m)	Substrate
Gurara	6.16	30.3	31.9	0.039	100	5–10	LC, DC, R, S
D'Coral	7.79	30.8	30.6	0.035	100	3–11	LC, DC, R, S, M
Pandawa	7.50	30.7	30.0	0.033	100	2–10	LC, DC, R, S
Pelabuhan	6.30	32.7	30.3	0.050	100	4–9	LC, DC, R, S
Quality standard[a]	7–8.5	33–34	28–30	–		–	–

Notes: LC = live coral; DC = dead coral; R = coral rubble; S = sand; M = mud. [a] Seawater quality standards for marine biota (corals) under Decree of the State Minister of the Environment No. 51 of 2004.

Live hard coral cover and massive coral cover

Live hard coral cover in the waters of Saonek Village ranged from 15.53 to 49.80%, with a mean of 29.99% (Figure 1). The highest cover was recorded at Pandawa station (49.80%), followed by Gurara station (31.63%), Pelabuhan station (23.00%), and D'Coral station (15.53%). Based on the criteria of Gomez and Yap (1988), coral reef condition was classified as fair at Pandawa and Gurara stations and poor at Pelabuhan and D'Coral stations.

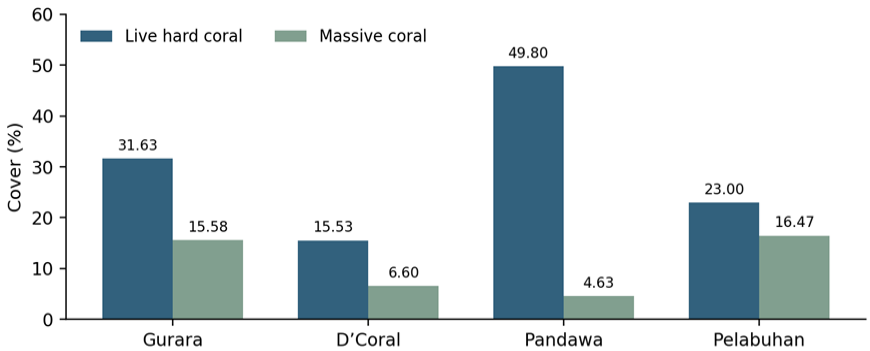


Figure 1. Live hard coral cover and massive coral cover at each station

Massive coral cover ranged from 4.63 to 16.47%, with a mean of 10.82%. The highest cover was recorded at Pelabuhan and Gurara stations (16.47% and 15.58%, respectively),

while lower values were recorded at D'Coral and Pandawa stations (6.60% and 4.63%, respectively). The proportion of massive corals within live hard coral cover showed a different pattern from total live hard coral cover: 71.6%, 49.3%, 42.5%, and only 9.3% at Pelabuhan, Gurara, D'Coral, and Pandawa stations, respectively. Based on observations of the UPT, *Porites* was the most prominent genus among massive corals at all four sampling stations.



(a) (b) (c)

Figure 2. Massive corals of the genus *Porites*; a. *Porites* sp.*, b. Porites solida, and c. Porites lutea*

Physicochemical water conditions

Water pH at D'Coral and Pandawa stations (7.79 and 7.50, respectively) was within the quality standard range, whereas values at Gurara and Pelabuhan stations (6.16 and 6.30, respectively) were below the specified range of 7–8.5. Seawater pH is generally relatively stable at approximately 7.8–8.3 because of the carbonate buffering system; values below 6.5 are therefore unusual in open marine waters. The low pH at these two stations may be associated with freshwater and terrestrial organic matter inputs, as well as port activities, although measurement error must also be considered. Declining pH can inhibit coral calcification by reducing carbonate ion availability (Doney et al., 2009).

Salinity at all stations (30.3–32.7‰) was slightly below the optimum range of 33–34‰ but remained within coral tolerance limits. Kleypas et al. (1999) reported that coral reefs can develop over a wider salinity range, while Supriharyono (2007) noted that reduced salinity generally results from terrestrial freshwater inputs. The highest salinity, recorded at Pelabuhan station, may reflect its more exposed location and greater influence of marine water masses.

Water temperatures at Gurara, D'Coral, and Pelabuhan stations (30.3–31.9 °C) slightly exceeded the upper quality standard limit of 30 °C, whereas the temperature at Pandawa station was exactly at this limit. Temperatures sustained at 1–2 °C above the mean seasonal maximum can trigger coral bleaching (Hoegh-Guldberg, 1999). Accordingly, the temperature of 31.9 °C recorded at Gurara station could cause thermal stress if sustained for an extended period.

Weak currents at all stations (0.033–0.050 m s^{-1}) indicate relatively calm conditions in the waters of Saonek Village. Currents supply nutrients and oxygen and remove sediment from coral colony surfaces (Nybakken, 1992). Weak currents may promote particle deposition, particularly at stations with muddy substrates, such as D'Coral station. Meanwhile, 100% water transparency at depths of 2–11 m indicates that light penetrated to the seabed, supporting zooxanthellae photosynthesis.

Live hard coral cover and massive coral dominance

The mean live hard coral cover of 29.99% indicates that coral reef condition in the waters of Saonek Village was generally fair. Pandawa station had the highest hard coral cover but the lowest proportion of massive corals (9.3%). This indicates that its coral community was dominated by non-massive growth forms, which are generally more sensitive to environmental stress. This pattern coincided with the lowest temperature (30.0 °C), pH within the quality standard range, and the weakest currents at Pandawa station.

By contrast, massive corals dominated the hard coral community at Pelabuhan station (71.6%) and accounted for a substantial proportion at Gurara station (49.3%), the two stations

with the lowest pH. *Porites* was prominent among massive corals in the UPT at all four sampling stations. The reported percentages refer to the entire massive coral category. For example, *Porites lutea* can form dome-shaped, hemispherical colonies exceeding 4 m in diameter. Distinguishing species with similar colony forms, such as *P. lutea* and *P. lobata*, requires examination of corallite structure. Accordingly, the Saonek transect observations are discussed at the genus level. Gurara station also had the highest temperature, whereas Pelabuhan station had the highest current velocity and was exposed to vessel activity. Massive corals have thick tissues, slow growth rates, and a greater capacity to remove sediment, making them more resistant to thermal stress and sedimentation (Loya et al., 2001). Darling et al. (2012) classified corals with massive morphologies as stress-tolerant. The high proportion of massive corals at Pelabuhan and Gurara stations therefore suggests greater environmental stress at these stations than at the other stations.

D'Coral station had the lowest hard coral cover (15.53%) despite having the highest pH. This may be associated with its muddy substrate, which suggests elevated sedimentation. Sedimentation can cover coral surfaces, reduce light penetration, and inhibit coral larval settlement and survival (Rogers, 1990; Fabricius, 2005).

Overall, the findings suggest that coral cover is influenced by a combination of physical, chemical, and substrate-related factors rather than a single parameter. Given the limited number of observation stations, these relationships are indicative and require confirmation through studies with more stations and repeated sampling over time.

CONCLUSION

Water conditions in the waters of Saonek Village, Raja Ampat Regency, including salinity (30.3–32.7‰), current velocity (0.033–0.050 m s^{-1}), water transparency (100%), and depth (2–11 m), were generally conducive to coral survival. However, pH at Gurara and Pelabuhan stations (6.16 and 6.30, respectively) was below the quality standard range, and temperatures at three stations slightly exceeded the upper quality standard limit. Live hard coral cover ranged from 15.53 to 49.80% (mean: 29.99%), corresponding to poor to fair reef condition, while massive coral cover ranged from 4.63 to 16.47% (mean: 10.82%). The high proportions of massive corals at Pelabuhan and Gurara stations (71.6% and 49.3%, respectively) suggest greater environmental stress at these two stations. The genus *Porites* was prominent among the massive corals observed in transect photographs from all four sampling stations.

Further research should repeat pH measurements using calibrated instruments across multiple sampling periods and include sedimentation rate, nutrient concentrations (nitrate and phosphate), and dissolved oxygen. Regular monitoring of coral reef condition, together with management of port activities and residential wastewater, is needed to conserve coral reef ecosystems in the waters of Saonek Village.

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