

SUB-BOTTOM FEATURES AND PHYSICAL PROPERTIES OF WATER OF THE TANGALLE BAY, SRI LANKA

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ABSTRACT

Monitoring of physical properties of water and local coastal geomorphological features are vital proxies to sustainable coastal management activities. In this study, sub-bottom features and water quality parameters were investigated in the Tangalle Bay during the northeast monsoon. Systematic sampling was carried out for covering three cross-shore and six longshore survey lines. Temperature variations displayed a thin epilimnion layer (i.e., about 3 m warm water) up to 4 km distance from the shoreline. The variation of temperature also suggested that the deeper and distance area was characterized by extremely well-mixing nature. Similarly, high dissolved oxygen values (range from 7.5-8.0 ppm) suggested well mixing/circulation pattern of marine water. These observations were further supported by sand-rich, well oxidized and organic matter poor surface sediment of the study area. Salinity values (range from 33.4 to 33.8 ppt, average = 33.6 ± 0.14) are relatively low due to the supply of a significant amount of freshwater. Sub-bottom survey indicated that the attached coral reef to the bedrocks can generate two different depositional environments. It was followed by deposition of unconsolidated and homogenous sediments separately, possibly from two different sources.

Key words: *Tangalle Bay, Physical properties of water, Sri Lanka Sub-bottom morphology,*

INTRODUCTION

Global climate is forcefully influenced by coastal geomorphological changes in the tropical region. This is greatly relevant to the issues during the Anthropocene that experience rising of CO₂ and temperature (Kirwan and Megonigal, 2013; Nicholls and Cazenave, 2010). Sediment transport, shoreline migration, seawater intrusion and water chemistry variations are dynamic processes in coastal aquatic

systems related to geomorphological changes (Van Rijn, 2011; Jayawardana *et al.*, 2012; Zhou *et al.*, 2014; Dubois *et al.*, 2018). These processes interact with existing coastal aquatic system over a variety of time and spatial scales. Therefore, understanding of physicochemical and morphological changes in coastal systems is important to monitor biological processes and to understand geological changes (Jayawardana *et al.*, 2012; Ratnayake *et al.*, 2017b, 2018a). In fact, the case

studies of reef topography, bathymetric data, suspended sediments in coastal waters and shoreline changes are also remarkably important to construct hard engineering structures such as seawalls, wave breakers, groyne and harbors (Ratnayake *et al.*, 2018b). Coastal deterioration such as erosion negatively affects tourism-based economy of Sri Lanka due to limits public beach access, and damages homes/infrastructure and ecology. So far, few studies have been carried out in Sri Lanka for identifying physicochemical changes and sub-bottom profiles in coastal zones (e.g., Ratnayake *et al.*, 2013). In addition, our present understandings of coastal processes are limited by the instrumental records, especially in the south coast of Sri Lanka. The island of Sri Lanka belongs nearly 1550 km of coastal line stretch with a variety of geomorphological features such as bays, lagoons, headlands, etc. The continental shelf is particularly narrow to the west to south coasts, widening to the northwest to north coasts (Cooray, 1984). Many of the coastal lines are seasonally dominated by the high wave energy in the southwest and northeast monsoons. It can follow the changes of physicochemical parameters and coastal geomorphology (Van Rijn, 2011; Jayawardana *et al.*, 2012; Zhou *et al.*, 2014). The objective of this case study is to identify the variability of the physical properties of water (i.e., dissolved oxygen, salinity, temperature and density) in the Tangalle Bay, as a monitoring program. The authors also investigate shallow depth sub-bottom conditions of the Tangalle Bay using geophysical investigations.

STUDY AREA

The Tangalle Bay is located at the most southern part of Sri Lanka (Figure 1). The Rekawa Lagoon is also

located adjacent to the Tangalle Bay. Tangalle is one of the famous tourist destinations for watching sea turtle and corals in the southern coast of Sri Lanka. However, the literature studies suggested that corals in the Tangalle Bay are partially degraded due to sedimentation and anthropogenic activities (Rajasuriya and White, 1995). Coastal tourism plays an important role presently around the study area as employment and income for locals. In addition, another important economic activity of the study area is catching of live fish species existing around corals for ornamental purposes and trading. Several tourist hotels are located along the beach of the Tangalle Bay causing environmental changes to the naturally existing ecosystems. The study area experiences the dominant ocean waves during the southwest monsoon (Figure 1). Therefore, seasonal sand deposition and erosion at the estuary mouth can significantly control variation of physicochemical parameters such as salinity in the Rekawa Lagoon. Two branches of Kirima Oya stream fall into the bay and feed by sediments. Several breakwaters and groins are constructed in the Tangalle Bay to prevent the coastal erosion.

MATERIALS AND METHODS

Field excursion of the Tangalle Bay was carried out using the *Samudrika* vessel (belongs to the Ocean University of Sri Lanka) in February, 2017. In this period, the study area is relatively calm due to weak northeastern monsoon influence along the southern coast of Sri Lanka. Systematic sampling ($n = 18$) was carried out to measure water quality parameters using Valeport Midas CTD instrument. It incorporates the physical properties of water such as temperature, depth, salinity, dissolved

oxygen, and water density. Dissolved oxygen level was calculated using the oxygen saturation scale of 100-108 % at 30 °C (Mortimer, 1956). The recorded data of CTD instrument was extracted and used to draw water

quality parameter profiles along the survey lines. In contrast, surface sediments samples were collected from same sampling locations using an Ekman-Berge type grab sampler.

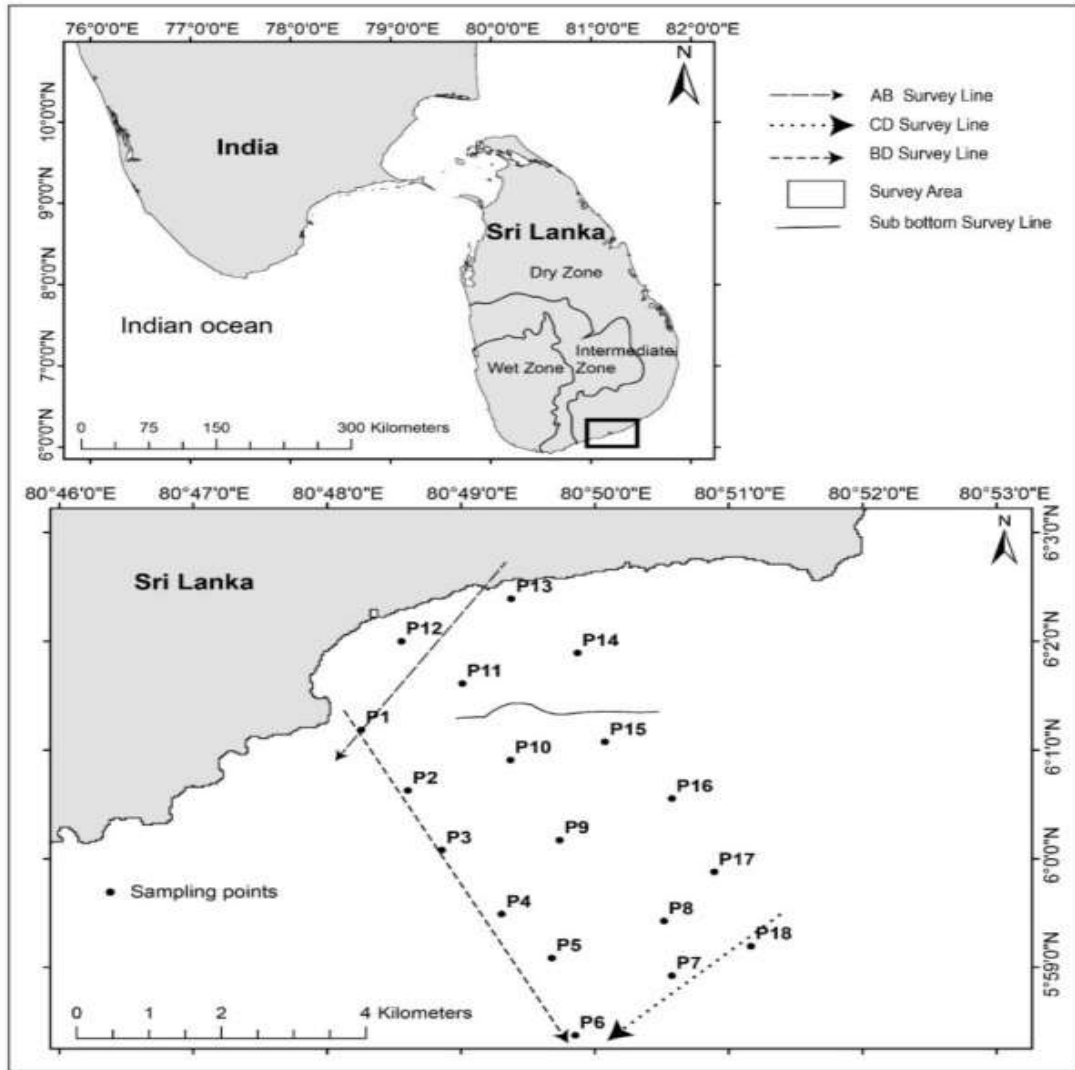


Fig. 1 Map of Sri Lanka showing the Tangalle bay and sampling point.

All sampling sites were plotted on a digital map and Global Position System (GPS) was used to select desired locations during the field works. Sampling area was covered about 7 km maximum distance from the shoreline and about 4 km width of the Tangalle Bay. In addition, it included three cross-shore and longshore survey lines.

GPS coupled Bathy 2010PCTM CHIRP sub-bottom profiler (frequency 3.5 kHz) and bathymetric echo sounders (frequency 210 kHz) were used to understand sub-bottom conditions and bathymetry, respectively. The details of the instrumental handling procedures were described by Ratnayake *et al.* (2017a).

RESULTS AND DISCUSSION

BATHYMETRY AND SUB-BOTTOM CONDITION

Figure 2 shows the bathymetry map of the Tangalle Bay. The water depths of the study area range from 6 m to 37 m. The authors calculated slope angle considering depth and distance along cross-shore survey lines. The average shelf slope angle is approximately 0.3° degrees (i.e., 6 m depth range per 1 km of distance).

Surface samples mainly consist of sand particles with coral fragments and shells. Organic matter preservation is poor in surface sediment may be due to a well-oxidized bottom condition (Müller and Suess, 1979; Hedges and Keil, 1995; Sampei *et al.*, 1997). Several isolated coral reef patches can be identified during the collection of surface sediment samples, as discussed under sub-bottom profile data.

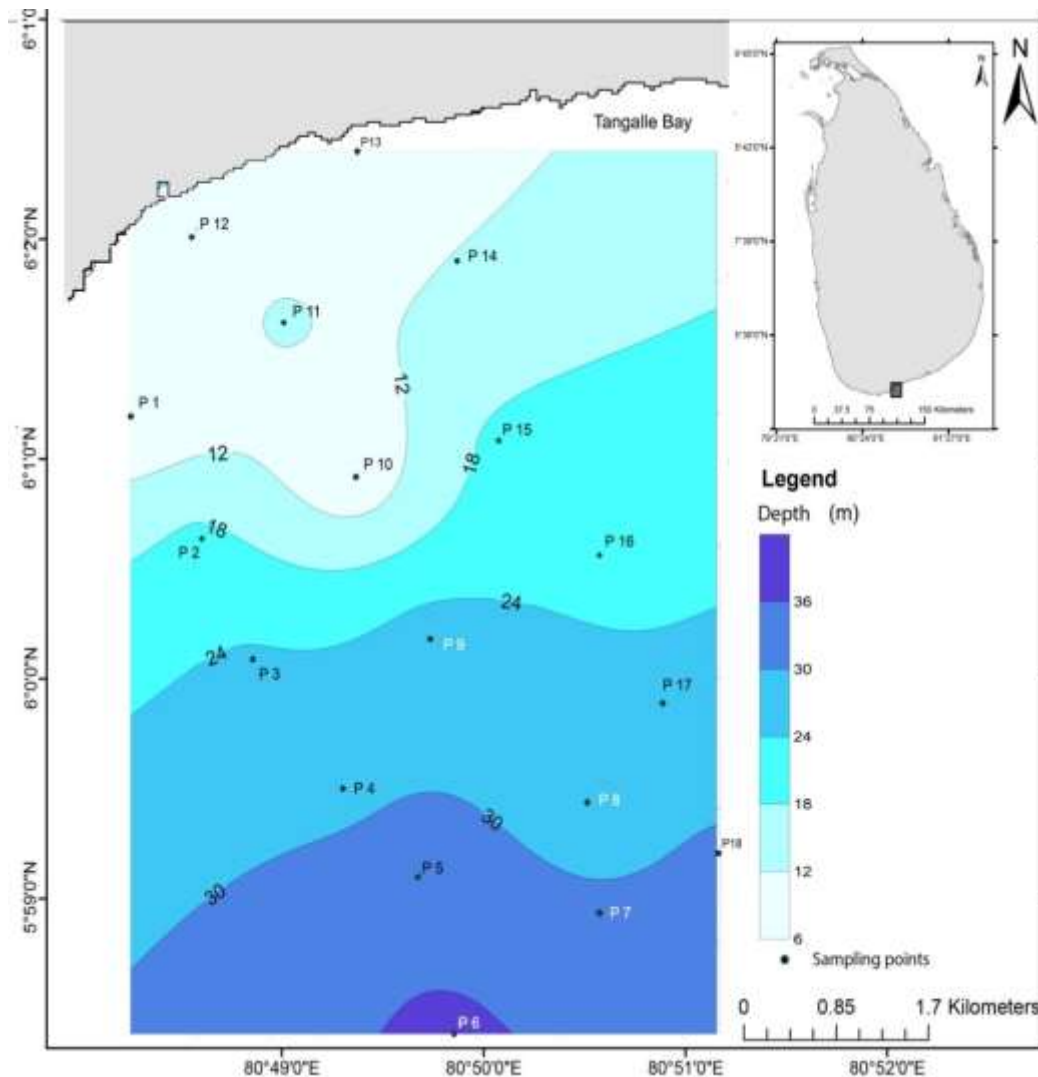


Fig. 2. The simplified bathymetry map of the study area.

Figure 3 indicates sub-bottom features along the representative survey line of the Tangalle Bay. It provides high-resolution penetration images up to ~20 m in depth.

In this study, sub-bottom profiler data clearly indicate the attached coral reef on the bedrock of the oceanic bottom (Figure 3). The echogram shows that the attached coral reef creates two depositional environments along this survey line. One side of the reef consists of layered sedimentary structures. However, the opposite side is characterized by the distribution of homogeneous sediments (Figure 3). In addition, it can indicate two different sources such as marine and terrestrial

(Seibold and Berger, 1996). Therefore, sediment distribution of the study area can be controlled by isolated patches of coral reef.

PHYSICAL PROPERTIES OF WATER

The longshore water column profiles along the shallow depth (AB, including sampling sites P1, P12 and P13) and high depth (CD, including sampling sites P5, P8 and P17) survey lines are shown in Figure 4 and 5, respectively. The cross-shore water column profile (including sampling sites from P1 to P6) is shown in Figure 6. Table 1 shows the summary of physical parameter data of each survey lines.

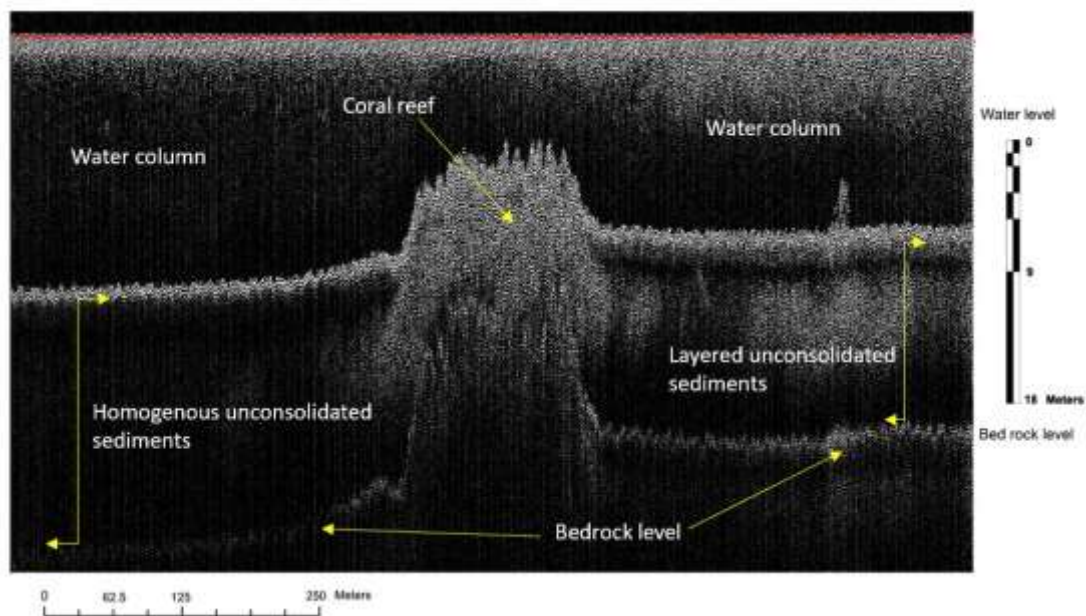


Fig. 3. The echogram shows sub-bottom condition along the survey line.

TEMPERATURE

Temperature values generally range between 27°C to 30°C. Temperature is measured digitally as a function of pressure. Figure 4 and 5 indicate that relatively high temperature on the surface and a little decrease in the depth along cross-shore survey lines. It can indicate a reduction of sunlight

penetration on the surface of the sea water. However, in this study, the strong thermal stratification cannot be observed due to well-mixing and well-circulation nature under the tropical condition. On the other hand, ocean waves and wind actions can cause turbulent mixing of the top layer and bring temperature equal value. According to longshore survey lines,

the epilimnion (i.e., warm layer) is limited to 2-3 m in depth. In contrast, the cross-shore survey lines show that the epilimnion (the maximum depth < 4 m) is limited to shallow water, up to 4 km distance from the shoreline (Figure 6). Consequently, the oceanic mixed layer depth of the study area is

very shallow. The oceanic mixed layer makes a connection between atmosphere and ocean. In addition, it holds high heat capacity compared to the atmosphere above. The mixed layer thus plays a significant role in climate variability (Carton and Giese, 2008).

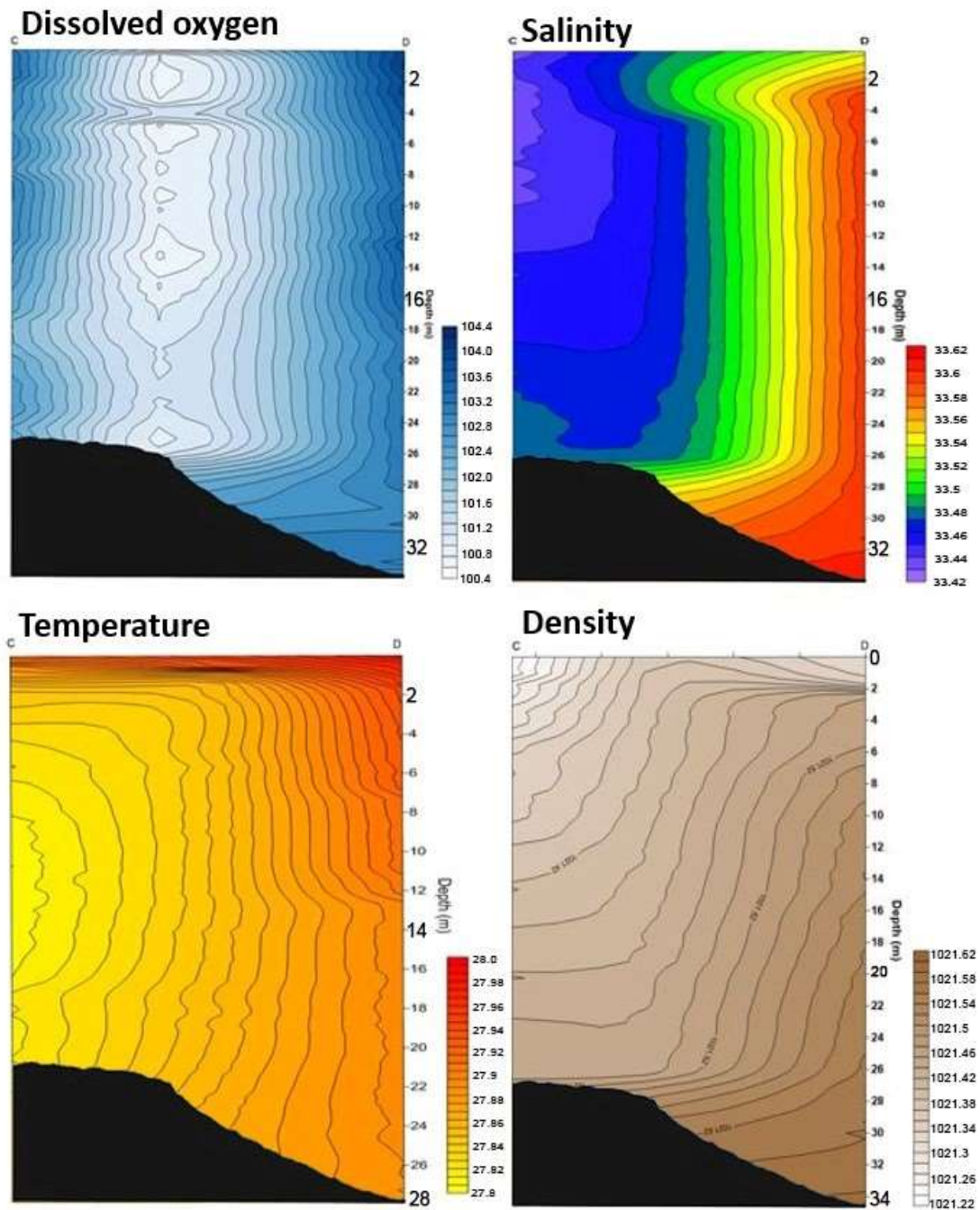


Fig. 4. The longshore survey profile along the shallow depth (AB, including sampling sites P1, P12, and P13) shows physicochemical variations.

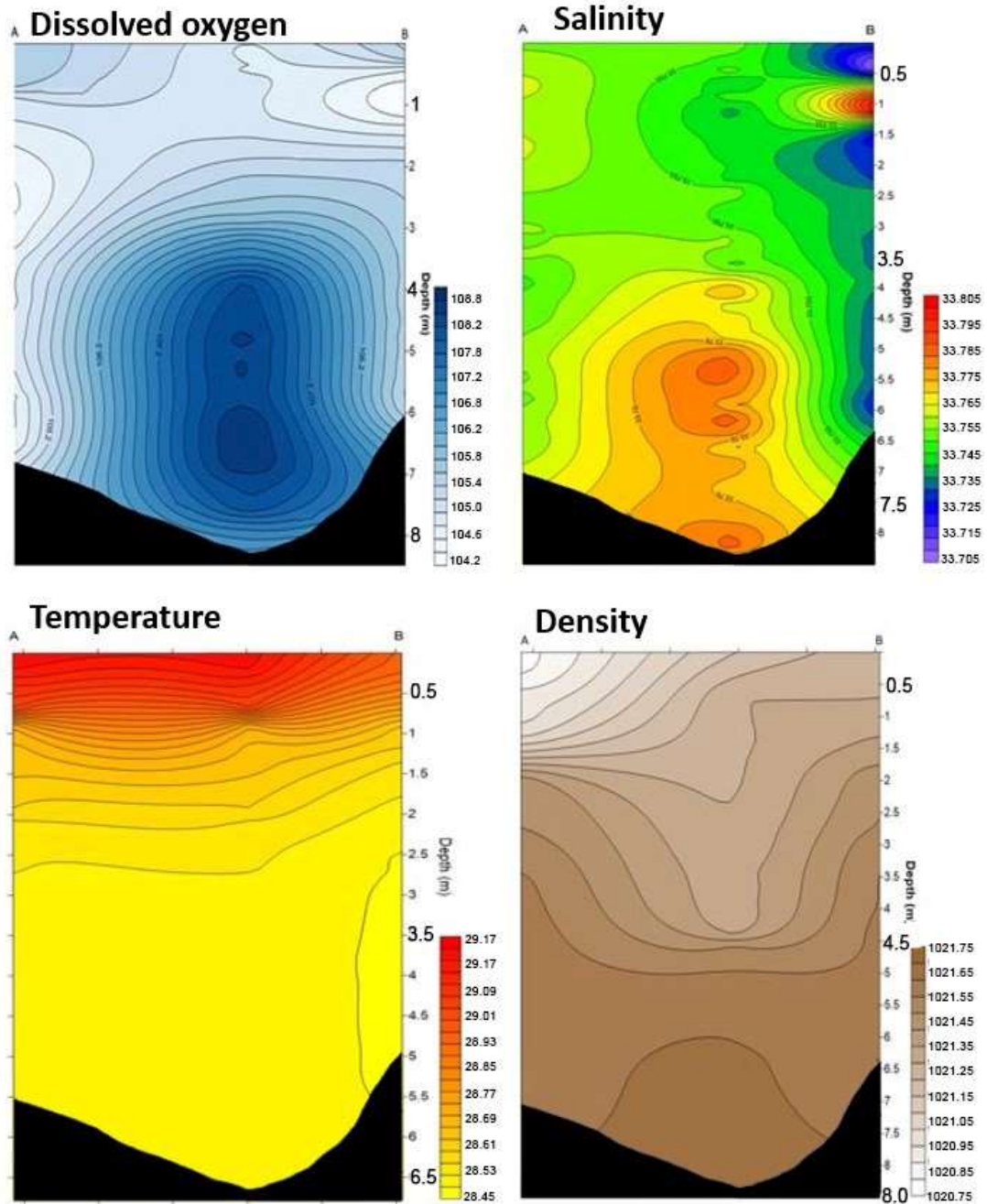


Fig. 5. The longshore survey profile along the deeper depth (CD, including sampling sites P5, P8, and P17) shows physicochemical variations.

SALINITY

Salinity is usually measured as the total amount of dissolved salt in water. No clear salinity variations can be observed along the cross-shore survey line (Figure 6). However, salinity values gradually increase with depth along the shallow depth longshore survey line (Figure 4). Figure 5 shows that salinity values gradually increase

towards southwest direction (from sampling site P17 to P5). The average salinity value of the study area is about 33 ppt. The salinity of the Tangalle Bay is just lower compared to the global average value of 35 ppt (e.g., Huber *et al.*, 2000). It is followed by heavy rainfall and relatively high humidity, and a significant contribution of freshwater to equatorial seawater.

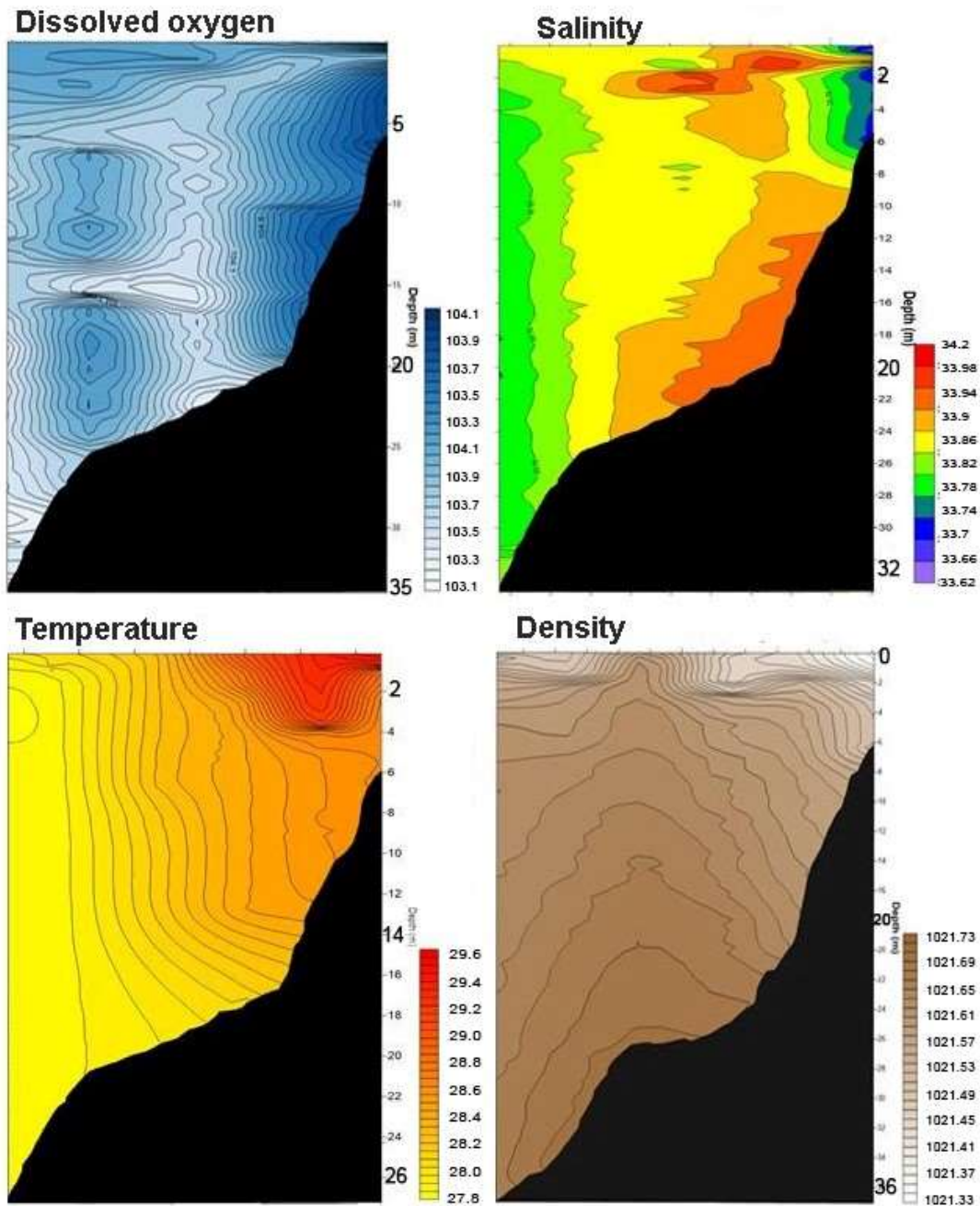


Fig. 6: The cross-shore survey profile (sampling sites from P1 to P6) shows physicochemical variations.

DISSOLVED OXYGEN

The oxygen exchanging process between the air-sea interfaces can be considered as one of the main physical factor to control the dissolved oxygen content in surface water (Liss, 1973; Broecker and Peng, 1974). In addition, oxygen enters the water column when entrained in bubbles from breaking

waves. This process is independent of dissolved oxygen content (Broecker and Peng, 1982). In this study, dissolved oxygen values vary from 7.5 – 8.0 ppm, according to saturation level 100-108% at 30 °C. Dissolved oxygen values are relatively high along the shallow depth longshore survey line (Figure 4). Figure 5 shows that dissolved oxygen values are quite high

towards southwest direction (from sampling site P17 to P5). In addition, no systematic dissolved oxygen variations can be observed along the cross-shore survey line (Figure 6). However, the measured dissolved oxygen values are quite high for the equatorial marine condition. Dissolved oxygen content can be used to

understand the quality of aquatic life, as it is a byproduct of photosynthesis and required a component of the respiration. Therefore, biological activities are controlled by dissolved oxygen level in the marine water (Redfield, 1958; Luz and Barkan, 2000).

Table 1. Summary of the maximum and minimum values of physical parameters of water in survey lines

Physical Parameters	Survey Lines					
	AB		CD		BD	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Dissolved oxygen (ppm)	8.5	8.8	7.8	8.0	7.8	8.1
Salinity (ppt)	33.71	33.81	33.42	33.62	33.62	34.40
Temperature ($^{\circ}$ C)	28.45	29.17	27.80	28.00	27.80	29.60
Density (kg/m^3)	1,020.75	1,021.75	1,021.22	1,021.62	1,021.33	1,021.73

DENSITY

Water density is controlled by temperature, salinity, and pressure (Millero, 2000; Smith, 2004). CTD instrument calculates water density using above mentioned controlling parameters. The calculated water density values of the Tangalle Bay range from 1020.7 – 1021.5 kg/m^3 . The cross-shore and longshore survey lines indicate that the calculated water density of the Tangalle Bay is slightly increased with depth within a narrow range (Figures 4, 5 and 6). In contrast, the upwelling can be recognized as one of the major nutrient/density mixing and distribution processes in the marine environment (Macdonald *et al.*, 1987). However, additional field excursions are required to identify seasonal changes of water quality

parameters in the study area.

CONCLUSION

The echogram of the sub-bottom profiler data can be used to understand local geomorphological changes such as recorded in coral reef barriers and sediment dynamics/transportation patterns of the particular area. Such knowledge can be productively applied to design sustainable coastal engineering structures and monitor coastal environmental changes.

Physical properties of water in the study area show homogenous distributions with the little changes. Therefore, it is an indicator of well-mixed nature. In addition, water quality parameters show health aquatic system. The recorded water quality

parameters can be used as baseline data for the future monitoring programs and pollution risk evaluations of the Tangalle Bay.

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