 DOI: 10.11598/btb.2018.25.3.1001

WATER POLLUTION LEVELS IN THE SUWUNG ESTUARY, BALI, BASED ON BIOLOGICAL OXYGEN DEMAND**

NI LUH GEDE RAI AYU SARASWATI[1*], I WAYAN ARTHANA[1], I GEDE SURYA RISUANA[2] AND I GEDE HENDRAWAN[2]

[1]*Department of Aquatic Management Resources, Faculty of Marine Sciences and Fisheries, Universitas Udayana, Bukit Jimbaran, Bali 80361, Indonesia*
[2]*Department of Marine Science, Faculty of Marine Sciences and Fisheries, Universitas Udayana, Bukit Jimbaran, Bali 80361, Indonesia*

Received 07 February 2018 / Accepted 11 May 2018

ABSTRACT

Biological Oxygen Demand (BOD) is generally used for determining water pollution levels in bodies of water. Estuary is a semi-enclosed body of water that can be polluted via land areas or rivers. This study was conducted to determine the spatial distribution of water pollution levels in the Suwung Estuary in Bali based on BOD_5 analyses conducted in January and February 2016. Samples were taken in 20 points (19 points in the Suwung Estuary and 1 outside the Suwung Estuary as control). BOD_5 samples were then analysed in the laboratory. Our BOD_5 analyses used the amperometric method based on the National Field Manual for the Collection of Data Water-Quality, Chapter A7. BOD_5 samples were taken at all tide cycles, during low to high tide and high to low tide. BOD_5 values ranged from 0.84 mg/L–9.47 mg/L during low to high tide and 0.96 mg/L–8.75 mg/L during high to low tide. The BOD_5 concentration in Suwung Estuary showed slight contamination during both tidal conditions. The spatial distribution of BOD_5 concentration was higher around cage aquacultures, rivers, the Suwung Landfill, and around the Benoa Harbour.

Keywords: BOD_5, spatial distribution, Suwung Estuary, water pollution level

INTRODUCTION

Suwung Estuary is a transitional area located in the sub-district of South Denpasar, Bali. This estuary is a habitat for mangrove vegetation around 734.5 ha in size (Sari 2002). In addition, Suwung Estuary is the location for several activities, namely cage aquaculture in the north eastern part of the estuary, landfill (Suwung Landfill), and the Benoa Harbour in the southern part of the estuary. These activities may have been contributing pollutants in the form of feeding residue and metabolic products of fish in cage aquaculture areas, leachate leakage from the landfill area, and oil spills from harbour activities—all of which are likely to affect Suwung Estuary's water quality. Pollution pressure can affect water quality, especially the water's dissolved oxygen (DO). According to Hendrawan and Asai (2014), tides around the Suwung Estuary have low flushing rates, with only 30% of particles transported directly into the sea. This condition has the potential to reduce the quality of water around Suwung Estuary.

Oxygen concentrations are among the indicators of an estuary's health in supporting the life of aquatic organisms (NOAA 2007; Ohrel & Register 2006). All living organisms need oxygen to breathe and metabolize. In addition, oxygen plays an important role in the processes of oxidation and reduction of organic and inorganic compounds into simpler non-toxic substances (NOAA 2007; Salmin 2005). The oxidation process of organic materials by the organism is related to biological oxygen demand (BOD).

BOD is defined as the amount of oxygen required by organisms to break down organic matter in aerobic conditions through biological and chemical processes (Ohrel & Register 2006; Henze & Yves 2008). BOD is also one of the

*Corresponding author: raiayu35@gmail.com
**This paper was presented at the 1st International Conference on Marine Biodiversity (CoMBI2016), 31 October–01 November 2016, Denpasar, Bali, Indonesia.

indicators for determining water pollution levels in water bodies and is an early warning for water quality degradation (Sheldon & Alber 2011). Because water is dynamic in nature, the distribution of pollutants in estuarine waters is much affected by tides. The fluid movement of tides affects distribution patterns and organic materials carried from the river. This study was performed to determine water contamination levels in Suwung Estuary, based on the estuary's BOD_5 analysis as well as in terms of the pollution's spatial distribution.

MATERIALS AND METHODS

The water samples for BOD_5 analysis were collected in the Suwung Estuary area in January and February 2016. There were 20 sample points, 19 points in the Suwung Estuary area and 1 point outside the estuary as control (Fig. 1). The control sample was an area with no activity and input from rivers, and with a high flushing rate. Water samples were taken from the surface in both low to high tide and high to low tide conditions during the day. While taking BOD_5 water samples, we ensured that there were no bubbles in each sample bottle, which meant water sampling was taken below the water's surface. All samples were kept in a box at a temperature of 4°C to minimize bacterial activity.

Our BOD_5 analysis was performed using the amperometric method, referring to the standard method contained in the National Field Manual for the Collection of Data Water-Quality, Chapter A7, by Delzer and McKenzie (2003). Analyses were done in the laboratory of the Faculty of Marine Sciences and Fisheries, Udayana University. Nutrient solution ($CaCL_2$, $FeCl_3$, $MgSO_4$ and phosphate buffer) and dilution water were prepared before they were mixed with BOD_5 samples. These solutions had to be prepared three to five days before starting the test. It was necessary to mix these solutions with the BOD_5 samples when the BOD_5 range was larger than 7 mg/L. The anticipated BOD_5 range in this study was 6–21 mg/L, which meant a 200-ml nutrient solution was needed for 100-ml BOD_5 samples. The DO meter was calibrated before measuring the initial DO (D1) and final DO (D2). After all BOD_5 samples were treated with a nutrient solution and measured using the DO meter, they were stored in an incubator with a constant temperature of 20±1°C for five days. During incubation, all samples was kept in dark bottles to prevent photosynthetic microorganisms from reacting to the sun, possibly adding oxygen concentrations to the samples. The general BOD_5 equation from the initial DO (D1) and final DO (D2) was:

$$BOD_5\ (mg/L) = \frac{D1 - D2}{P}$$

Where D_1 = initial DO of the sample,
D_2 = final DO of the sample after 5 days, and
P = decimal volumetric fraction of sample used.

The BOD_5 results were then compared to water pollution levels, as categorized by Wirosarjono (1974) *in* Salmin (2005) (Table 1).

Table 1 Water pollution levels based on BOD values

Range of BOD value (mg/L)	Pollution Level
0-10	Low
10-20	Moderate
25	High

Spatial distribution of the BOD_5 values in the coastal waters of the Suwung Estuary was displayed under three conditions, namely the conditions of low to high tide, high to low tide and the average of both tides. Spatial distribution was mapped using the Inverse Distance Weighted (IDW) method processed using the QGIS software (version 2.4.0). Suwung Estuary area is divided into two parts: Southern (station 1-11) and Northeastern (point 12-19). There are two gulf mouths in Benoa Bay as part of the estuary: mouth of Gulf I (in the Northeastern part of the estuary) and mouth of Gulf II (in the Southern part of the estuary). The distribution of BOD_5 values was indicated by the difference in color thickness, with thicker colors corresponding to higher BOD_5 values. Color levels were determined based on the range of BOD_5 values obtained. Based on the BOD_5 values, the following categories were made for this study, from the lowest extensions to the highest: very low (0-1 mg/L), low (>1-4 mg/L), moderate (>4-6 mg/L), high (>6-8 mg/L) and very high (>8-10 mg/L).

Point	Longitude	Latitude
1	115.213873	-8.744991
2	115.217039	-8.744525
3	115.214631	-8.741668
4	115.218075	-8.74088
5	115.215427	-8.737275
6	115.21883	-8.73645
7	115.215759	-8.732862
8	115.220196	-8.73292
9	115.215747	-8.728299
10	115.219176	-8.728571
11	115.222675	-8.727605
12	115.228181	-8.724523
13	115.227038	-8.722199
14	115.23042	-8.721906
15	115.233072	-8.72066
16	115.23685	-8.719873
17	115.239646	-8.71835
18	115.242096	-8.717234
19	115.241303	-8.720366
20	115.247311	-8.741177

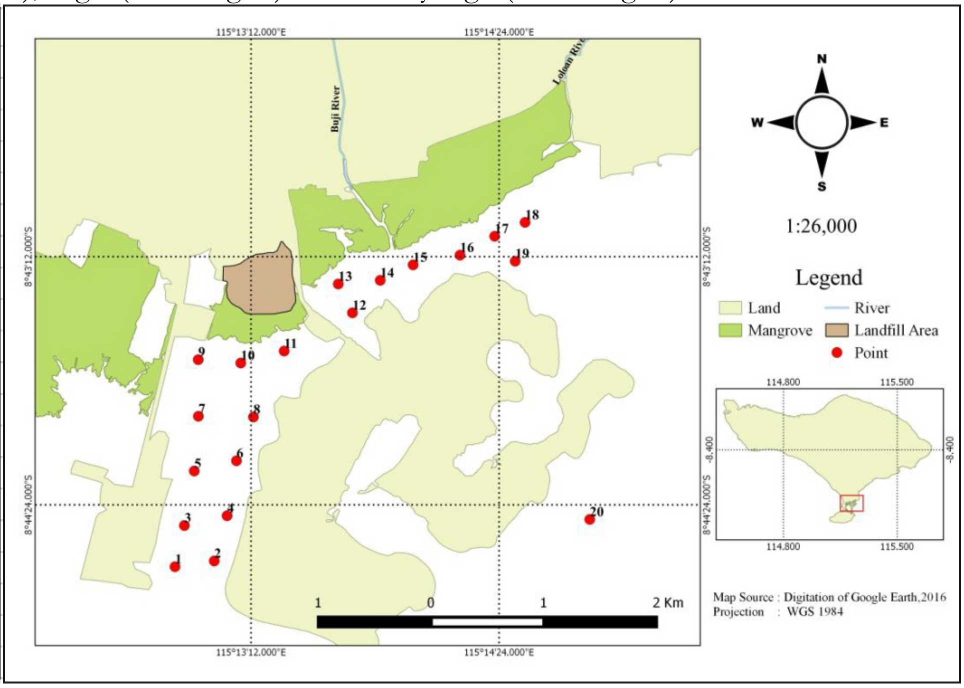


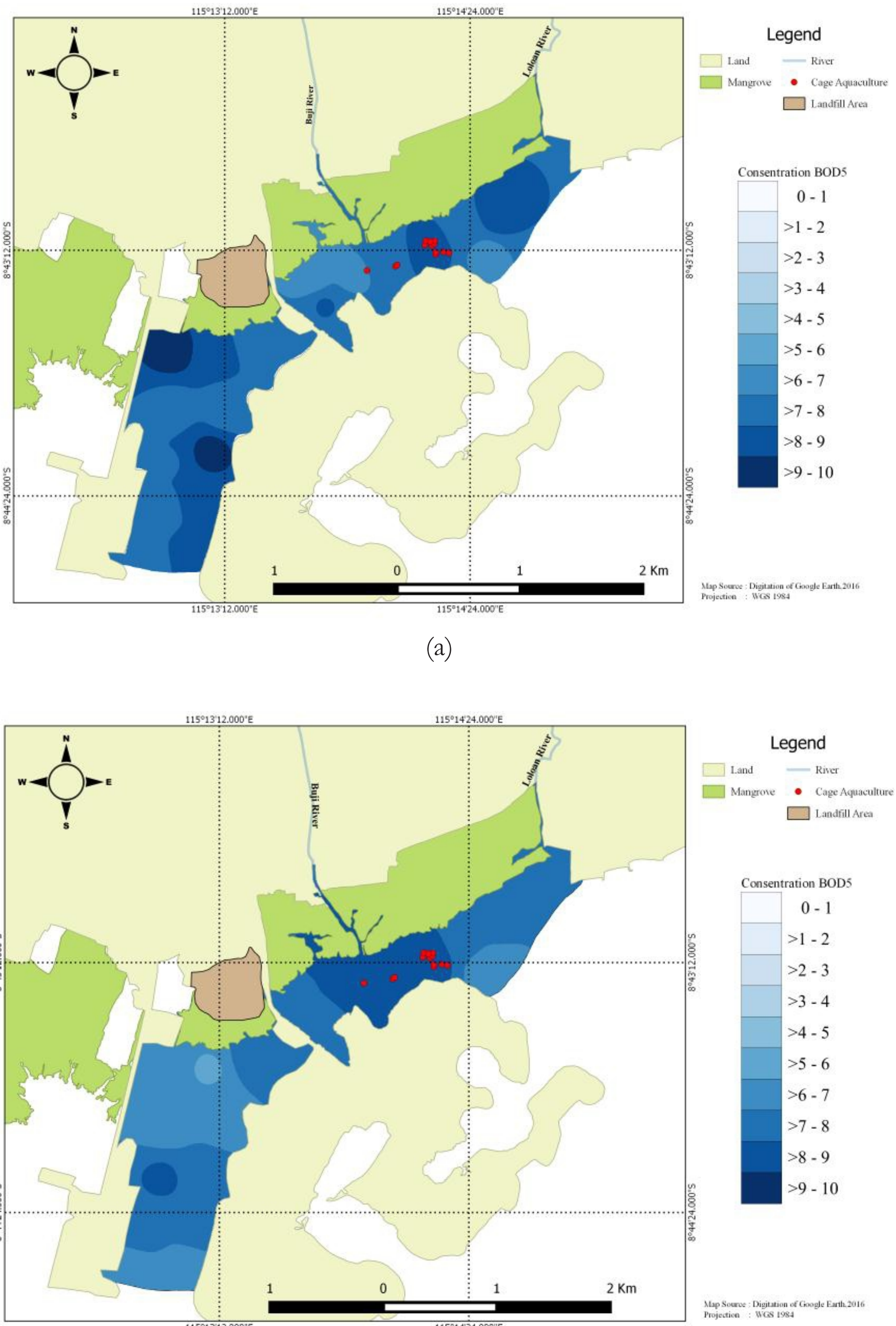
Figure 1 Distribution of the 20 sample stations in Suwung Estuary (19 stations inside the estuary and 1 outside)

RESULTS AND DISCUSSION

During sampling in January 2016, the weather was sunny in all of the tide conditions. In February 2016, it was rainy and cloudy during almost all tide conditions. BOD_5 values in the Suwung Estuary in these two months showed that the estuary was classified as slightly polluted. Contaminant input to the Suwung Estuary tended to be low in concentration.

BOD_5 distribution in January and February was relatively high in the cage aquaculture area, river mouth area, Suwung Landfill area and the Benoa Harbour. The relatively high BOD_5 was not concentrated in one area, but rather shifted with the succession of tides. The range of BOD_5 during the two months were 3.13 to 9.47 during low to high tide and 2.73 to 8,86 mg/L during high to low tide. Meanwhile, in the control point, there were high BOD_5 concentrations during low to high tide in both months. However, these concentrations were still lower than BOD_5 levels inside the Suwung Estuary. Higher BOD_5 concentrations inside the estuary may have been caused by the input of organic material from land and rivers around the estuary. Most organic materials are donated through input from rivers, and their concentrations were high during the low tide.

In average, the spatial distribution of BOD_5 values in January 2016 in the Suwung Estuary tended to be high. These results different from average BOD_5 value in February 2016, when the distribution of BOD_5 values was moderate in the North eastern and Southern part of the estuary. Moderate values were also seen around the mouth of the river, cage aquaculture, Suwung Landfill and Benoa harbour. According to Lihawa (2014), the movement of sea water causes the dilution that may be reducing the distribution and concentration of pollutants.



(a)

(b)

Figure 2 Spatial distribution in January 2016: (a) low to high tide and (b) high to low tide conditions

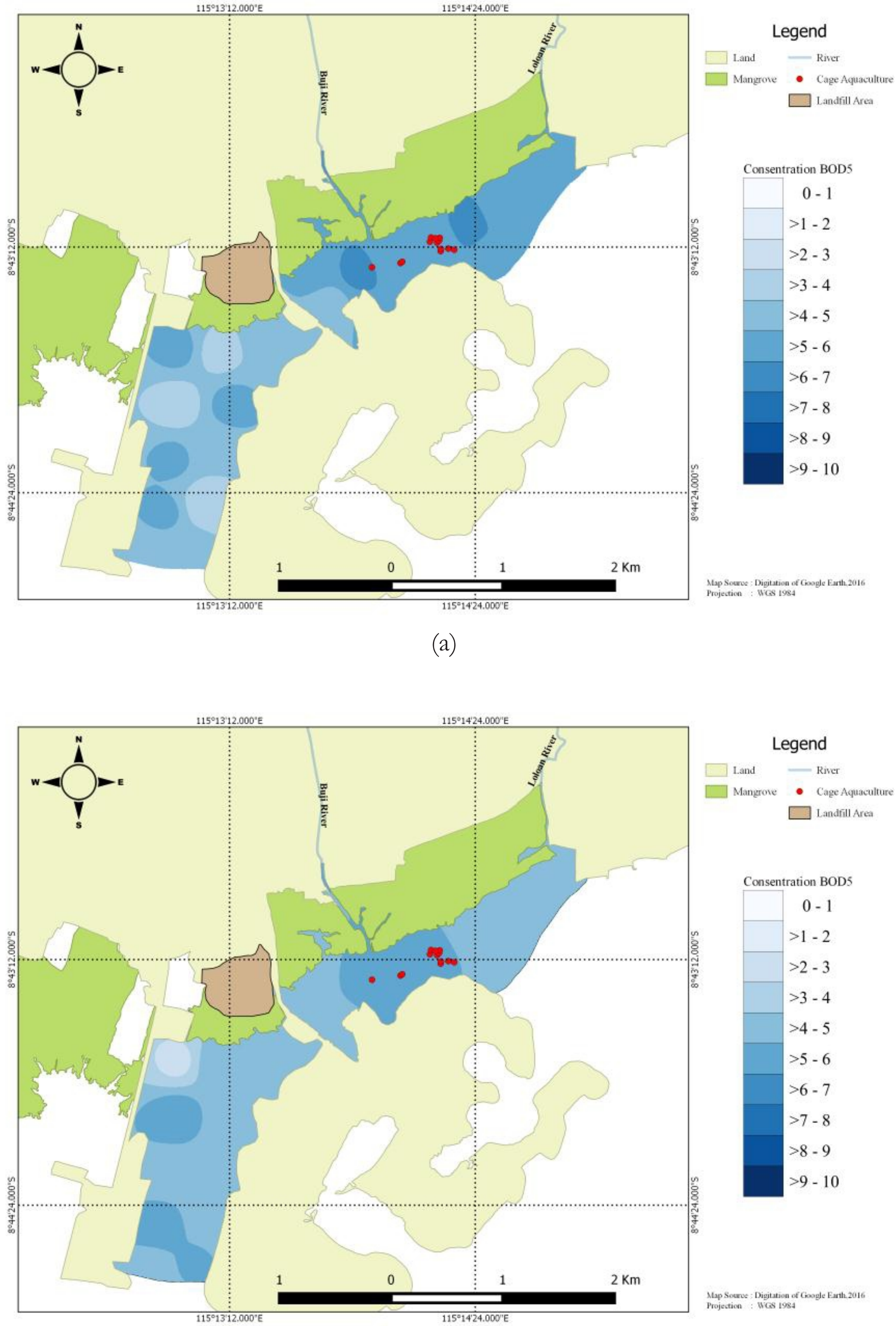


Figure 3 Spatial distribution in February 2016: (a) low to high tide and (b) high to low tide conditions

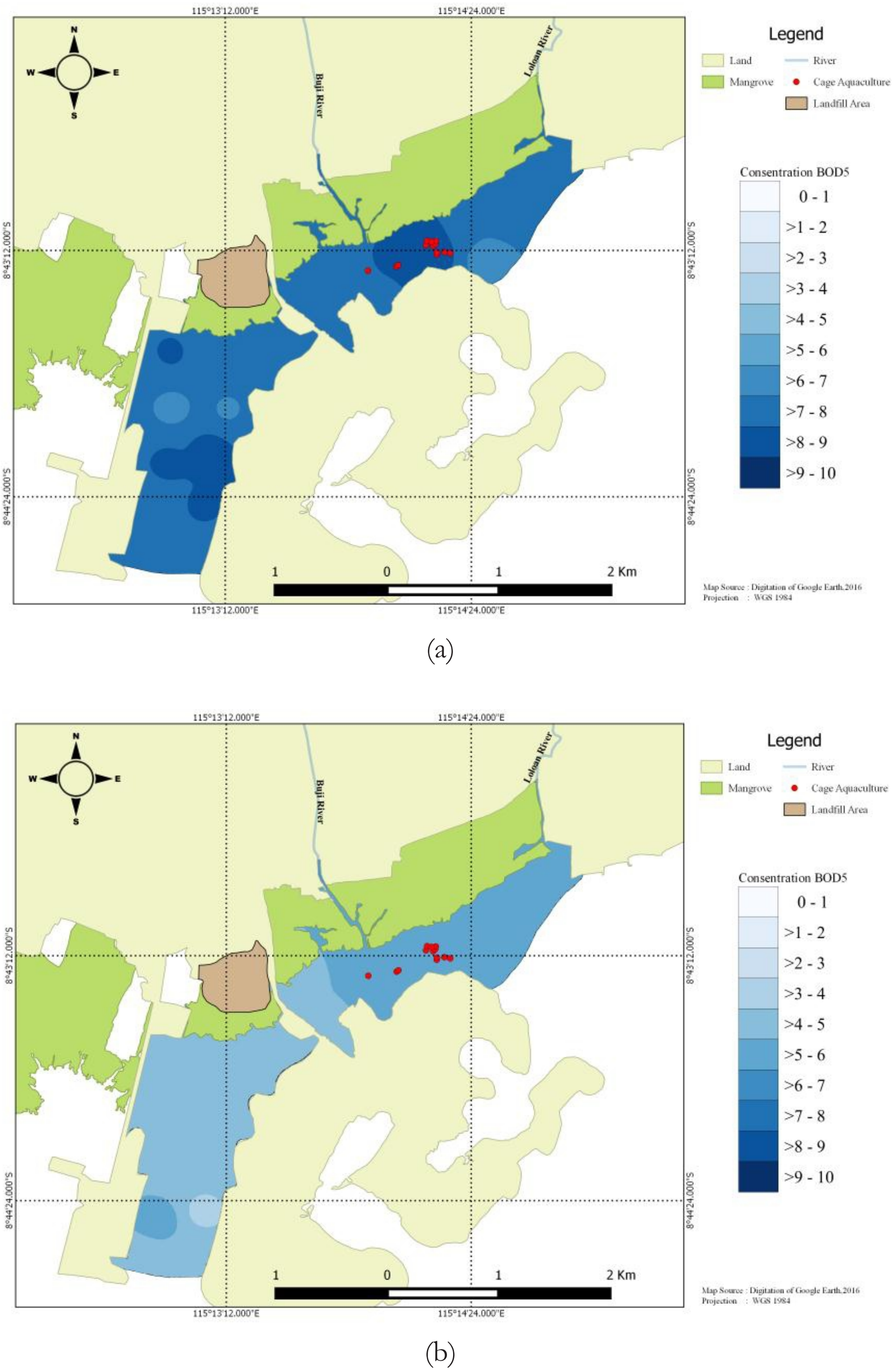
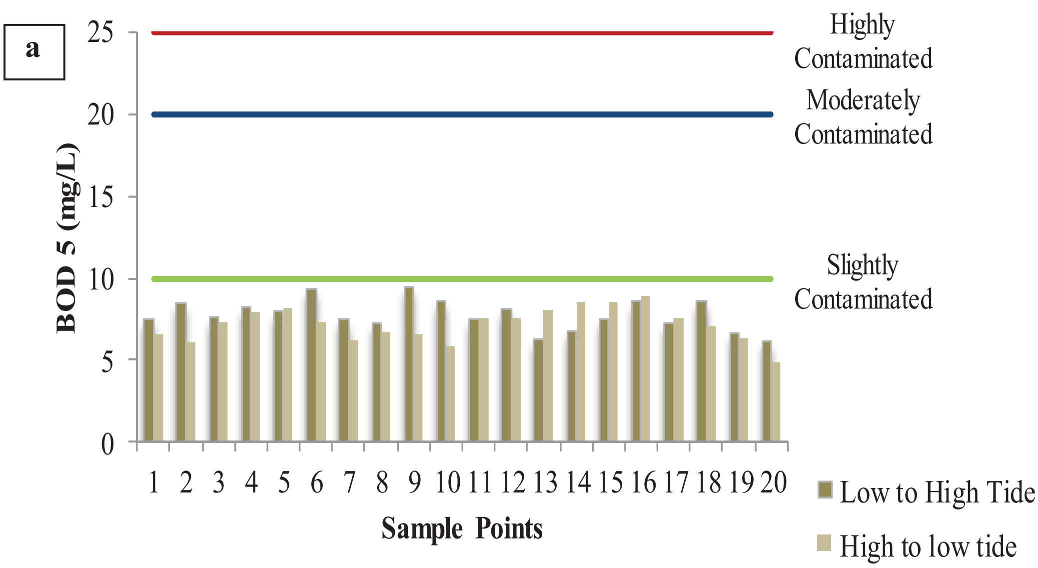


Figure 4 Average spatial distribution in (a) January 2016 and (b) February 2016

BOD_5 value can be used to determine the level of contamination in a body of water (Cahyaningsih & Harsoyo 2010; Salmin 2005). A high BOD_5 concentration can cause an anaerobic condition, which can in turn impact the life of fish and other organisms (Mocuba 2010). Water pollution levels were categorized in slight or low pollution (0-10 mg/L), medium pollution (>10-20 mg/L) and high pollution (>20 - 25 mg/L) (Wirosarjono 1974 *in* Salmin 2005). Pollution levels in Suwung Estuary varied between tide conditions in each month (January and February 2016) during the research. BOD_5 values in these two months showed that the waters in Suwung Estuary were slightly polluted. January 2016 had the most numbers of points, with BOD_5 values of more than 5 mg/L in both tide conditions, compared to February 2016. These high values were due to the hot weather in January 2016, as hot weather increases the concentration of organic materials in an estuary (Islam *et al.* 2015). In addition, a high BOD_5 value trend in each month was more dominant during low to high tide conditions.

Tides and rain were suspected to dilute pollutants in the waters of the Suwung Estuary during this study. This could be observed during high to low tide, when BOD_5 values tended to decline. The decline may have been caused by the presence of the two mouths of the Benoa Gulf (mouths of Gulf I and Gulf II). The estuary's ability to cope with the pollution depends on its waterways, when the tides go in and out, and its open channels to the sea. Rain seems to be capable of diluting pollutant materials in the area of the estuary. The influence of tides and rain is very important to the dilution process, dispersion and self-purification in estuarine areas. BOD_5 values will be lower in the rainy season than the dry season (Maitera *et al.* 2010).

However, though Suwung Estuary's pollution level, based on BOD_5 values in January and February 2016, was still classified as slightly contaminated, it can potentially increase to medium or high pollution level due to activities around the estuary (cage aquaculture, landfill, harbour and river mouth, which brings contaminants from the mainland).



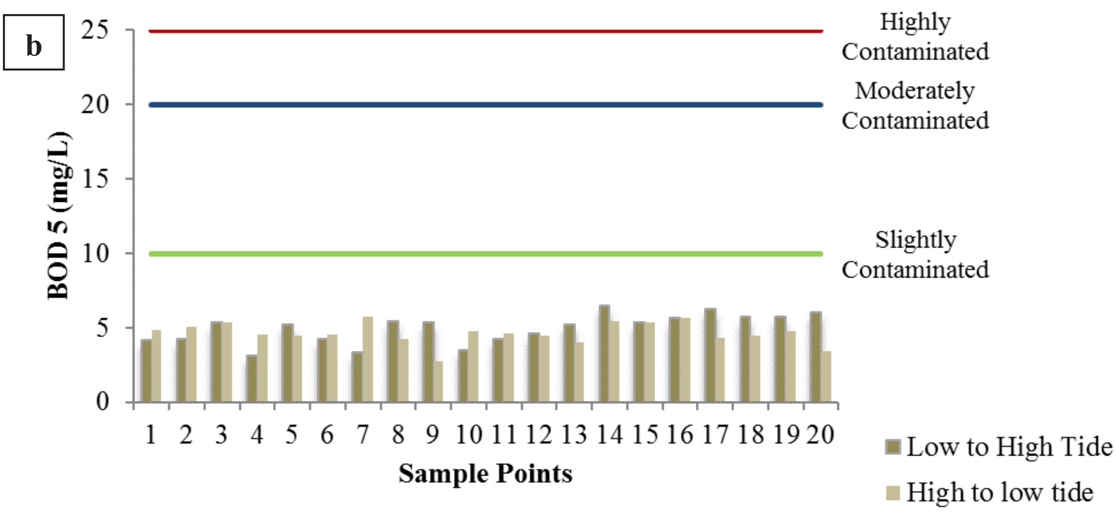


Figure 5 Water pollution levels in the Suwung Estuary in (a) January 2016 and (b) February 2016

CONCLUSION

Based on our BOD_5 analysis, pollution levels in the Suwung Estuary during the months of January and February 2016 were classified as slightly contaminated. BOD_5 was relatively high around the cage aquaculture area, river mouth, landfill and Benoa Harbour in both tide conditions. Rain was a discernible factor that contributed to the lowest BOD_5 values in February 2016, when the average BOD_5 value across all tide conditions was low.

ACKNOWLEDGEMENTS

The authors would like to thank the team immensely for their kind and valuable help during field sampling and analysis. We also thank the fisheries and computation laboratory of the Faculty of Marine Sciences and Fisheries, Udayana University, for supporting this research with its BOD analysis equipment and spatial distribution software.

REFERENCES

Cahyaningsih A, Harsoyo B. 2010. Distribusi spasial tingkat pencemaran air di DAS Citarum [Spatial distribution of water pollution levels in the Citarum watershed]. Jurnal Sains & Teknologi Modifikasi Cuaca 11(2):1-9.

Delzer GC, McKenzie SW. 2003. Five-day biochemical oxygen demand. In: Myers DN, Wilde FD, editors. National Field Manual for the Collection of Water-Quality Data Vol. 7.2, Techniques of Water-Resources Investigations Reports. Reston, VA (US): US Geological Survey. p. 1018-38.

Hendrawan IG, Asai K. 2014. Numerical study on tidal currents and seawater exchange in the Benoa, Bay, Bali-Indonesia. Acta Oceanol 33(3):1-11.

Henze M, Yves C. 2008. Part three: Wastewater characterization. In: Henze M, editor. Biological Wastewater Treatment: Principles Modelling and Design. London (UK): IWA Publishing. p. 33-52.

Islam MS, Uddin MK, Tareq SM, Shammi M, Kamal AKI, Sugano T, … Kuramitz H. 2015. Alteration of water pollution level with the seasonal changes in mean daily discharge in three main rivers around Dhaka city, Bangladesh. Environment 2:280-94.

Lihawa F. 2014. Pembuangan limbah cair PLTU Molotabu 2 x 12 MW ke laut oleh PT. Tenaga Listrik Gorontalo [Disposal of Molotabu 2x12 MW PLTU liquid waste into the sea by PT. Tenaga Listrik Gorontalo] [Report]. Retrieved from Universitas Gorontalo Repository.

Maitera ON, Ogugbuaja VO, Barminas JT. 2010. An assessment of the organic pollution indicator levels of River Benue in Adamawa State, Nigeria. J Environ Chem Ecotoxicol 2(7):110-6.

Mocuba JJ. 2010. Dissolved Oxygen and Biological Oxygen Demand in the water close to the quelimane sewage discharge [Thesis]. Retrieved from Geophysical Institute, University of Bergen, Repository.

National Oceanic and Atmospheric Administration (NOAA) [Internet]. 2007. Estuaries. [cited 2018 Jun 10]. Available from: https://oceanservice. noaa. gov/ducation/tutorial_estuaries/welcome. html.

Ohrel RL, Register KM. 2006. Volunteer estuary monitoring: A methods manual, 2nd edition. Washington DC (US): The Ocean Conservancy.

Salmin. 2005. Oksigen Terlarut (DO) dan Kebutuhan Oksigen Biologi (BOD) sebagai salah satu indikator untuk menentukan kualitas perairan [Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) as an indicator to determine water quality]. Oseana 30(3):21-6.

Sari NWV. 2002. Pengolaan sampah di kawasan hutan mangrove Suwung Teluk Benoa sebagai upaya kebersihan lingkungan dan pengembangan ekowisata mangrove [Waste management in the Suwung mangrove forest area of Bay Benoa as an effort to clean the environment and develop mangrove ecotourism] [Master Thesis]. Retrieved from Universitas Diponegoro Repository.

Sheldon JE, Alber M. 2011. Recommended indicators of estuarine water quality for Georgia. Proceedings of the 2011 Georgia Water Conference. Athens, GA (US): University of Georgia.