Water quality evaluation of some mangrove ecosystems with variations of time restoration in South Malang, East Java, Indonesia

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Abstract. The area of the mangrove ecosystem in the South Malang, East Java region of Indonesia has dropped from 2000 due to land conversion and human activities. The society and the government have sought to preserve mangrove plants. The goal of this study was to assess the quality of the mangrove ecosystem, particularly its results by observing water quality and analyzing the connection between human activities around the mangrove ecosystem and water quality. The research method was Ex Post Facto. Monitoring was carried out on five selected mangrove ecosystems in South Malang including Clungup Mangrove Conservation (CMC), Bajulmati, Kondang Buntung, Sendiki and Tamban. Sampling at each site is performed at many stations based on variations in the timing of the revegetation activities. Sampling for each station was carried out at three places as replications. The total number of samples is 30 samples. Water quality parameters of mangrove ecosystem was measured in this study including dissolved oxygen (DO), salinity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate, and orthophosphate. We also observed the human activities in the each sampling location using Hemeroby index. The results of study showed that the water quality in several mangrove ecosystems in southern Malang varied. In general, the salinity (0.0-26.3% o) and BOD (2.1-9.6 mg / L) have met the standard values for seawater quality for the benefit of marine life. DO levels that have met the quality standard value were only in the mangrove ecosystems of Kondang Buntung, Sendiki and Tamban (5.3-6.3 mg / L). Nutritional content in the waters of all mangrove ecosystems is high with Nitrate levels exceeding the government quality standards (0.17-1.96 mg / L). COD levels have a positive correlation with water salinity levels. The water quality was degraded by the mangrove environment with higher human activities. CMC and Bajulmati conservation practices have influenced the enhancement of water quality in the ecosystem of the mangroves.

1. Introduction
Mangrove ecosystems are often found in coastal areas which are always or regularly inundated by sea water and are affected by tides but are not affected by climate. This ecosystem can be found only in the tropics and is dominated by several species of trees that have the ability to grow in salty waters or high salinity, high temperatures, high sedimentation and low oxygen levels [1]. The mangrove
ecosystem has many functions including ecological functions, conservation functions, and as a sediment trap. Mangrove vegetation also acts as riparian vegetation which plays a role in the phytoremediation process to maintain and improve water quality [2].

However, human activities have caused damage to the mangrove ecosystem. This is also the case in the southern Malang mangrove ecosystem. The area of mangrove forests in southern Malang has fallen as a result of land conversions and logging. In Malang Regency, the mangrove forest area in 2015 was approximately 64.7 ha [3]. The area of the mangrove forest is greatly reduced compared to 2007, which was around 340 ha [4]. However, several coastal areas in Malang Regency have carried out restoration through mangrove planting or revegetation. This activity is mainly pioneered by non-governmental organizations (NGOs) and academics, for example at Tiga Warna Beach known as Clungup Mangrove Conservation (CMC) which has carried out restoration in stages starting in 2005, 2013 and 2014. In addition to that in certain areas, the District Government Malang is also carrying out rehabilitation of mangrove forests.

The success of restoration activities can be carried out after planting for minimum 5-10 years [5] [6]. However, early monitoring is very important to evaluate the extent of plant growth, identify growth disturbing factors such as invasive species, and other environmental conditions [7] [8]. This monitoring is important in the framework of further management and also to minimize the risk of failure in the restoration / revegetation program that has been carried out [9] [10].

The success of restoration activities can be monitored by measuring water quality. This water quality evaluation is necessary to know the effect on the mangrove environment of human activities. Human behaviors can be detected using the Hemerobry Index in certain habitats. Based on the above, the purposes of this study were to evaluate the quality of the mangrove ecosystem, especially the results of restoration that have been carried out by both the private sector and the government through water quality observations and analyzing the relationship between surrounding human activities with water quality in mangrove ecosystem. The data then can be used as the basis for the strategic management of degraded water quality in the mangrove ecosystem.

2. Research Methods
The research was conducted in selected mangrove ecosystems located in Malang Regency, East Java Province, Indonesia. The measurement of several water quality parameters was carried out in the Laboratory of Ecology and Animal Diversity, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya Malang.

This research used Ex Post Facto method, which is a natural causal effect phenomenon in the mangrove ecosystem. Researchers do not need to give any more treatment but only see the effect on the dependent variable [11]. As dependent variables of this research were water physics chemical parameters, Hemerobry Index and independent variables were variations of human activities around the mangrove ecosystem.

Monitoring the quality of mangrove ecosystem was carried out in five mangrove ecosystems in southern Malang (Figure 1) including CMC, Bajulmati, Kondang Buntung, Sendiki and Tamban. The mangrove ecosystem in CMC was observed at the restoration results in 2013, 2015, natural location I which was dominated by Sonneratia alba, and natural location II with more diverse mangrove vegetation (Rhizophora mucronata, R. apiculata and Bruguiera sp.). The mangrove ecosystem in Bajulmati was observed at the location of restoration results in 2010, 2014 and 2016. Observations of mangrove ecosystems were also carried out in Kondang Buntung which is a natural location with a more diverse diversity of vegetation both coastal forests and mangroves, the mangrove ecosystem in the Sendiki estuary which is also a natural ecosystem where is the surrounding area has been degraded, and the mangrove ecosystem near Tamban beach which is the result of restoration in 2009-2014. Sampling for each station was carried out at three places as replications. The total number of samples is 30 samples.
Figure 1. Location of sampling in this research (Note: 1. CMC; 2. Bajulmati; 3. Kondang Buntung; 4. Sendiki; 5. Tamban)

Water quality parameters of mangrove ecosystem was measured in this study, as well as the measurement methods are presented in Table 1. The difference of each parameters between location was analyzed by Anova test and also we used descriptively analyzed by comparing the results obtained with the standard the quality of seawater for marine biota based on the Decree of the Minister of Environment of Indonesia No. 51 of 2004 concerning Sea Water Quality Standards, especially for marine life.

Table 1. Water physics chemical were measured in this research

| Parameters               | Unit     | Methods           |
|--------------------------|----------|-------------------|
| Dissolved Oxygen (DO)    | mg/L     | DO meter          |
| Salinity                 | ‰        | Refractometer     |
| BOD                      | mg/L     | Winkler           |
| Nitrate                  | mg/L     | Colorimetric      |
| Orthophosphate           | mg/L     | Colorimetric      |
| COD                      | mg/L     | Spectrophotometri |

We also observed the human activities in each sampling location directly using Hemeroby index. Some parameters we observed for the Hemeroby index were mechanical disturbance of the soil, direct mechanical disturbance of the vegetation and chemical disturbance into account [12]. The information obtained was then be used to determined the level of disturbance from human activity.

3. Result and Discussion

3.1. Quality of water physics chemical of several mangrove ecosystems in Southern Malang

The results of monitoring the physical and chemical quality of water in mangrove ecosystems in several locations in southern Malang can be seen in Table 2. Dissolved oxygen (DO) levels for marine biota are required to be a minimum of 5 mg / L. Thus, DO levels in the mangrove ecosystem waters in southern Malang that have met these requirements were only in Kondang Buntung, Sendiki and Tamban which have DO of 5.3-6.3 mg / L. Meanwhile, other locations have not yet fulfilled the DO values ranging from 4.1-4.6 mg / L. DO levels in waters will affect the respiratory activity of aquatic organisms. Each organism has a certain tolerance range for oxygen levels in the water. The
research results before, showed that macroalgae in coastal waters are more tolerant of low oxygen levels (2-4 mg/L) compared to Coral [13].

Table 2. Variations in the quality of physics and chemistry of water in several mangrove ecosystems in South Malang. Note: The same notation each parameter shows no significant difference based on the Anova test followed by Tukey HSD α 0.05.

| Location       | Time Restoration | DO (mg/L) | Salinity (%) | BOD (mg/L) | Nitrate (mg/L) | Orthophosphate (mg/L) | COD (mg/L) |
|----------------|------------------|-----------|--------------|------------|----------------|-----------------------|------------|
| CMC            | 2013             | 4.9±0.5   | 0.0±0.0      | 3.3±2.6    | 1.96±0.18      | 0.086±0.15            | 13±12      |
|                | a                | a         | ab           | e          | c              | a                     |            |
| Natural I      | 2015             | 4.4±0.8   | 24.3±3.1     | 4.0±0.7    | 0.18±0.03      | 0.012±0.001           | 123±107    |
|                | a                | c         | ab           | a          | a              | a                     |            |
| Natural II     | 2010             | 4.1±0.3   | 16.3±11.8    | 3.9±1.3    | 0.68±0.22      | 0.061±0.040           | 92±81      |
|                | a                | abc       | ab           | c          | bc             | a                     |            |
|                | 2014             | 4.6±0.4   | 16.3±6.0     | 4.1±3.1    | 0.53±0.07      | 0.020±0.002           | 92±81      |
|                | a                | abc       | ab           | bc         | ab             | a                     |            |
| Kondang        | 2016             | 4.6±0.3   | 10.0±0.0     | 2.6±1.4    | 0.69±0.14      | 0.022±0.003           | 116±101    |
| Bunting        | abc               | a          | ab           | c          | ab             | a                     |            |
| Natural        | b                | ab         | b            | d          | a              | a                     |            |
| Sendiki        | 2009 & 2014      | 5.3±0.7   | 21.3±15.9    | 6.8±4.4    | 0.22±0.15      | 0.014±0.05            | 83±79      |
|                | ab               | bc         | ab           | ab         | ab             | a                     |            |

The low DO levels may be influenced by the organic matter content in the waters. The level of organic matter in the waters can be seen from the BOD (Biochemical Oxygen Demand) and COD (Chemical oxygen Demand) value. The results of monitoring of BOD values in the mangrove ecosystems of southern Malang ranged from 2.1-9.6 mg/L and COD values ranged from 13-116 mg/L. The levels of BOD in the estuary are low to moderate and still meet the quality standard value set for marine biota, namely 20 mg/L. The COD levels have a positive correlation with water salinity levels [14].

Based on these results, it showed that human activities around the waters were still able to be supported by this mangrove ecosystem so that the organic pollutants that enter can immediately be purified naturally by the microbes in the waters. This level of organic matter can affect changes in the community structure of aquatic organisms. Each organism has a narrow or wide tolerance range to organic matter. If the organism has a wide tolerance range to organic matter, it is included in the group of organisms that are tolerant of organic matter contamination, and vice versa.

A high BOD level in waters indicates organic pollution in the waters. This organic matter pollution will then affect changes in the community structure of aquatic organisms. Only types of organisms that are tolerant of organic matter pollution will live [15]. This high organic matter pollution also indicated by the high value of suspended solids in the waters. High suspended solids in these waters can inhibit the penetration of the sun and in turn also had an impact on reducing the primary productivity of macroalgae in these waters [16].

The salinity of waters in several mangrove ecosystems in southern Malang ranges from 0-26.3‰. This value is still within normal limits. Meanwhile, nitrate levels ranged from 0.18 to 1.96 mg/L and orthophosphate levels from 0.007 to 0.086 mg/L. The maximum quality standard of nitrate content
for marine life is 0.008 mg / L. Thus, all observed waters have exceeded the specified quality standard value. These results support the high levels of organic matter in water.

Nitrate and orthophosphate levels are strongly influenced by human activities around the waters. These high levels of nitrate and orthophosphate can lead to eutrophication which in turn will result in algae blooming [17]. The nitrate and orthophosphate levels were significantly high in CMC 2013 because a former of this location was pond. Pond activities usually provide additional feed to reared fish so that if the remaining feed is degraded, it is a source of nitrate and orthophosphate in the waters.

3.2 Human activities in surrounding of mangrove ecosystem and it’s correlation with water quality of the study area

Environmental degradation can be caused by human activities that inhabit the ecosystem or environment. The quality of the environment can be affected by human activities around it which can be determined based on the Hemeroby index. The higher the impact of human activities on environmental damage will have an impact on increasing the Hemeroby index value or the greater the Hemeroby index value, the greater the damage to the natural environment due to human activity. The results of determining the Hemeroby index in several mangrove ecosystems in South Malang can be seen in Figure 2.

![Figure 2](image_url)

**Figure 2.** Variation of human activity in some mangrove ecosystem of Southern Malang based on the value of Hemeroby Index

Human activity in CMC is the lowest compared to others so that it still has little effect on environmental quality. Human activity in Tamban is the highest so that it has an impact on increasing the value of the Hemeroby index which is significantly high. Kondang Buntung and Sendiki have mangrove ecosystems that are still natural. However, human activity in the vicinity is quite high, namely agriculture and settlements in Sendiki and tourist activities in Kondang Buntung.

Relationship between human activities with water quality of mangrove ecosystem can be seen from biplot diagram from principal component analyses (PCA), as shown in Figure 3. Mangrove ecosystems in Kondang Buntung and Sendiki, which are natural ecosystems and mangrove ecosystems in Tamban, which were restored in 2009 and 2014, have water quality with high levels of organic matter indicated by high BOD and moderate COD levels. This site also has moderate levels of nitrate and orthophosphate. The source of organic matter and nutrients at this location comes from human activities, namely tourism (Kondang Buntung), agricultural and residential activities (Sendiki) and also pond activities (Tamban). This activity has an impact on the high value of the Hemeroby index. The mangrove ecosystem in the CMC at the restoration results in 2013, which is an ex-pond area, has
the highest levels of nutrients (nitrate and orthophosphate) with the moderate BOD content and low COD levels. Meanwhile, the mangrove ecosystems in other CMC locations and all locations in Bajulmati have better water quality characterized by low levels of BOD, nitrate and orthophosphate. However, COD levels in this location are still quite high. The high of COD levels because of positive correlation with water salinity levels [14].

![Figure 3. Relationship between human activities with water quality in some mangrove ecosystem of Southern Malang using scatter diagram of PCA and Biplot](image)

4. Conclusion
This study showed that the water quality in several mangrove ecosystems in southern Malang varied. In general, the salinity and BOD values had met the standard values for seawater quality for the benefit of marine life. DO levels that had met the quality standard value were only in the mangrove ecosystems of Kondang Buntung, Sendiki and Tamban. The nutritional content in the waters of all mangrove ecosystems is high with Nitrate levels exceeding the Indonesia government quality standards. COD levels have a positive correlation with water salinity levels. Mangrove ecosystem with higher human activities caused degradation of the water quality. Restoration activities at CMC and Bajulmati have had an impact on improving water quality in the mangrove ecosystem.

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References
[1] Bengen D G 2000 Pedoman teknis: Pengenalan dan pengelolaan ekosistem mangrove (Bogor: Pusat Pusat Kajian Sumberdaya Pesisir dan Lautan. Institut Pertanian Bogor).
[2] Retnaningdyah C 2019 Cyanobacterial Harmful Algal Blooms (CyanoHABs): Blooming microcystis di ekosistem perairan tawar dan cara pengendaliannya (Malang: UB Press, 136).
Dinas Kelautan dan Perikanan 2015 *Penyusunan rencana zonasi kawasan konservasi wilayah pesisir kabupaten malang* Laporan Pendahuluan

Dinas Kelautan dan Perikanan 2007 *Inventarisasi kawasan mangrove di Kabupaten Malang.* Laporan Akhir

Whitten T R E, Soeriatmadja and Affif S A 2000 *The ecology of Java and Bali and Singapore* (Periplus)

Wortley L, Hero J M and Howes M 2013 Evaluating ecological restoration success: a review of the literature *Restoration Ecology* **21** 537–543

Reay S D, Norton D A 1999 Assessing the success of restoration plantings in a temperate New Zealand forest *Restoration Ecology* **7** 298–308

Curran M S, Hellweg and Beck J 2014 Is there any empirical support for biodiversity offset policy? *Ecological Applications* **24** 617–632

Murray C and Marmorek D 2003 *Adaptive management and ecological restoration* (Pages 417–428. In: Freiderici P, (ed) Ecological restoration of southwest-ern ponderosa pine forests. Island Press, Washington, D.C.)

González E, Rochefort L, Boudreau S, Hugron S and Poulin M 2013 Can indicator species predict restoration outcomes early in the monitoring process? A case study with peatlands *Ecological Indicators* **32** 232–238

Clesceri L S, Greenberg A E, Eaton A D 1998 *Standard Methods for the Examination of Water and Waste Water* 20th Ed (Washington: APHA)

Kim Y, Zerbe S and Kowarik I 2002 Human impact on flora and habitats in Korean rural settements *Preslia* **74** 409-419

Haas A F, Smith J E, Thompson M and Deheyn D D 2014 Effects of reduced dissolved oxygen concentrations on physiology and fluorescence of hermatypic corals and benthic algae. *PeerJ* **2** e235

Li Z, Sheng Y, Shi W, Sun Q and Mortimer R J G 2016 Influence of salinity on COD measurements in coastal water management *Desalination and Water Treatment* **57** 18338-18345

Cid A, Prado R, Rioboo C, Suarez-Bregua P and Herrero C 2012 *Use of microalgae as biological indicators of pollution: Looking for new relevant cytotoxicity endpoints.* In: Johnsen, M. N. (ed.) Microalgae: Biotechnology, Microbiology and Energy. (New York: Nova Science Publishers, 311-323).

MacIntyre H L and Cullen J J 1996 Primary production by suspended and benthic microalgae in a turbid estuary: time-scales of variability in San Antonio Bay, Texas *Marine Ecology Progress Series* **145**

Kuffner I B and Paul V J 2001 Effects of nitrate, phosphate and iron on the growth of macroalgae and benthic cyanobacteria from Cocos Lagoon, Guam *Marine Ecology Progress Series* **222** 63-72