PUMMA (Perangkat Ukur Murah untuk Muka Air) performance for water level monitoring of mangrove ecosystem in Pangandaran

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Abstract. PUMMA is a real-time tide gauge that has been operating in several locations in Indonesia. One of them was installed in a mangrove area of Pangandaran that supports both the fisheries and tourism sectors. Tidal dynamics is one of the factors that can affect fish abundance in the mangrove ecosystem. PUMMA Pangandaran monitors the water levels of the mangrove ecosystem in real-time 24/7 and produces CCTV images. This paper aims to analyze the performance of the PUMMA in Pangandaran based on data from water level measurements and image quality from CCTV. The results show that the tidal range in the waters of the mangrove ecosystem in Pangandaran is 1.3 m, with the maximum and minimum high tides being 0.79 m and -0.53 m. The tidal type in the mangrove ecosystem in Pangandaran is semidiurnal and affected by geometry of the estuary. The water level in the mangrove area was influenced by sediments that form a sandbar at the mouth of the Ciputrapinggan River, which controls the fluxes of seawater. There is a data gap of 368 hours during the operation period of PUMMA, and mostly due to technical problems that often occurred at the beginning of the installation. However, after March and April, its performance was improved with only three hours data gap. For the quality of CCTV images, good quality contributed to about 76.67% and only 5.06% on bad quality. Overall, PUMMA’s performance showed excellent reliability in monitoring the water levels and the conditions of the mangrove ecosystem.

1. Introduction

Tide gauges with ultrasonic sensors have long been developed and are widely used to monitoring the dynamics of tides, including in Indonesia [1][2][3][4]. Generally, these devices can be found in ports to support shipping and port activities [5]. In addition to these purposes, the devices have also been used for monitoring the water level in rivers and possibility to detect the onset of floods and tsunamis in the sea that cause water level anomalies [5][6][7]. The advantages of this tide gauge are can send, store, and display data automatically and can be accessed quickly and in real-time [8].

PUMMA (Perangkat Ukur Murah untuk Muka Air Laut) is a tide gauge measuring device with an ultrasonic sensor, which is also equipped with CCTV to produce images for verifying environmental
conditions. PUMMA was designed from previous system developed by the Indonesian Science Institute [6] and further developed based on the Inexpensive Device for Sea Level Measurement (IDSL), with adjustments to various components that are easily available domestically and affordable [7][8]. PUMMA is controlled by an embedded system to produce data series with automatic data transfer via the internet network and solar panel as a source of electricity. Several parameters measured by PUMMA are water level, the temperature inside the electronic panel box, and battery voltage. The features of PUMMA are: the ability to transmit measurement data at intervals of less than 10 seconds; the process of sending data less than 30 seconds; measurement accuracy of approximately 0.5 cm; and image data can be sent following predetermined time intervals and at certain times.

One of PUMMA's has been operating in Pangandaran, monitoring the water level and the condition of the mangrove ecosystem, which is part of the Ciputrapinggan Estuary, in real-time for 24/7. As a meeting area between rivers and sea, estuaries are dynamic so that environmental changes can take place quickly [9]. The estuary is also the location of sedimentation, garbage accumulation, and the entry and exit of fishing boats [10]. Most of the river mouths are suitable areas as well as natural habitats for mangroves [11].

On the coastal area of Pangandaran, mangroves are an essential ecosystem because they support the fisheries and tourism sectors [12]. In the vicinity of the mangrove ecosystem where PUMMA is installed, at least 19 species are recorded in 2015 and are habitats for various fish, bivalves, birds, and other biotas [13][12]. Tidal dynamics are factors that can support the abundance of fish in areas with mangroves vegetation [14]. The installation of PUMMA in the mangroves ecosystem, which is also part of the estuary, is expected to provide additional data and information explaining the hydro oceanographic aspects. Since this area is experiencing closure of the river channel due to the construction of the Cikidang Fishing Port, flooding during heavy rain and high tide has the potential to be occurred and cause puddles that will harm the community around the area. Therefore, the PUMMA as an initial design for its purpose as a tsunami early warning monitoring based on sea-level changes was deliberately installed in the area to test the performance of the device in sending water level data and taking pictures from CCTV cameras so that weaknesses and shortcomings can be analyzed for development. This paper aims to analyze the performance of the PUMMA based on data from measurements of water level and image quality from CCTV in monitoring the mangroves ecosystem in Pangandaran.

2. Data and Methods

Performance tests were carried out to PUMMA devices installed in Pangandaran, West Java, since December 2020 (Figure 1). The analysis was carried out on water level data and CCTV images recorded by PUMMA from January to April 2021 (4 months). Those data are stored in KKP's server and can be accessed through https://pumma.kkp.go.id. The parameters used as a benchmark in assessing PUMMA's performance are the results of measurements of sea-level elevation (tidal), data gaps, and image quality from CCTV. Sea-level elevation data is the main parameter that is important from PUMMA. The elevation value is measured in second intervals and sent to the server to be displayed on the dashboard. In analyzing the accuracy of the PUMMA instrument, data validation was carried out with another closest tide gauge instrument, namely the IDSL which was installed in Batu Karas, Pangandaran and can be accessed through https://webcritech.jrc.ec.europapage. EU/TAD_server/Device/485.
Gap data analysis was carried out by counting the number of empty data from the PUMMA server, which was then calculated using descriptive statistics, namely: the number of gaps, total gaps, duration, mode, median, average, minimum, maximum, and range of the existing gap data. At the same time, the analysis of CCTV images is carried out by calculating the percentage of the number of images with good quality (bright images and clear water level elevation), moderate (less bright images, noise, and clear water level elevation), and poor (blurry/dark images, there is much noise, and the water level is not visible).

3. Results and Discussion

3.1 Water Level

The results of observations of water elevation data measured by PUMMA between January and April 2021 in the waters of the Pangandaran mangrove ecosystem show the tidal range is 1.33 m. PUMMA also shows that the minimum tidal height is -0.54 m, and the maximum tidal height is 0.79 m (Figure 2). The Formzahl value of 0.51 indicates that the tidal type is mixed predominantly semidiurnal. This type agrees to IDSL and BIG devices results.
Overlaid predictions data based on PUMMA, IDSL and BIG devices are presented in Figure 3. The correlation coefficient between PUMMA and IDSL and PUMMA and BIG devices are 0.805 and 0.896, respectively. The standard deviation of these three monitoring tools shows that there is a difference between PUMMA, BIG, and IDSL, where the PUMMA value is more minor (SD± 0.261) compared to the two tools which have similar SD values (SD± 0.416 and SD± 0.429). It seems that changes of water level in the mangrove area tend to be more stable and only influenced by tidal conditions. In addition, the installation location of PUMMA is an area that is still inundated at low tide due to sedimentation towards the estuary. Meanwhile, BIG and IDSL devices were located 500 meters to the sea, more ideal area for tidal measurement.

**Figure 3.** Overlay of water level data obtained by PUMMA, IDSL, and BIG devices for January-April 2021.
3.2 Data Gaps analysis

Figure 4 shows water level data gaps (left) and descriptive statistics (right) from PUMMA between January and April 2021. There were 7 data gaps during the period, an interval of at least 1 hour and a maximum of 254 hours or 10.58 days. The overall duration of the break is 368 hours or 15 days and 8 hours. The most considerable data gap interval is the 254 in February. The highest inequality intensity found between January and February, i.e. three times/month.

Figure 4. Histogram of gap (left) and descriptive statistics (right) from PUMMA water level data during January-April 2021

Meanwhile, for March, there is no data gap and PUMMA works perfectly to monitor and transmit data in its entirety (24/7). However, in April a data gap for 3 hours was found. Generally, this kind of data gaps, (in a short time between 1 and 20 hours), are mainly caused by communication network (GSM) interference. On the other hand, long time intervals data gap (80 hours to 254 hours) are caused by Internet of Things (IoT) platform used by PUMMA system. Of course, this is a serious concern for us to immediately find a solution to use a more stable IoT service platform.

3.3 CCTV Image

The main purpose of taking pictures from CCTV is to find out if there are changes in the environment around the location of PUMMA and to confirm the water level measured by the ultrasonic sensor. CCTV was set to takes pictures every 10 minutes under normal conditions and every 1 minute when the water level falls or rises below or above a certain limit drastically or suddenly. The sudden change in water level is a sign that something is happening in the environment, so adequate documentation is needed. Several conditions can trigger a closer shooting, such as bad weather, floods, tsunamis, or the presence of nuisance objects that are right under the sensor. The results of CCTV performance during the January-April 2021 period are presented in the Table 1 & 2.

Table 1. Percentage of image quality from PUMMA’s CCTV per month

| Month  | Good quality | Mid-Quality | Bad Quality |
|--------|--------------|-------------|-------------|
| January| 75.44        | 24.43       | 0.13        |
| February| 72.51       | 24.42       | 3.07        |
| March  | 75.52        | 13.61       | 10.87       |
| April  | 83.52        | 14.29       | 2.20        |
| Total  | 76.67        | 18.27       | 5.06        |
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Table 2. Total percentage of image quality from PUMMA’s CCTV based on their classification

| Image Quality | Daylight | Night |
|---------------|----------|-------|
| Good quality  | 52.17    | 24.50 |
| Mid-Quality   | 0.37     | 17.90 |
| Bad Quality   | 0.98     | 4.08  |

The percentage of image quality from CCTV recording per month is presented in Table 1. Totally, there are 5.06% of images with bad quality during the observation period and generally occur at night. Bad quality is generally caused by disturbances, which can be caused by heavy rain conditions so that rainwater covers the camera and unfinished image data transmission due to GSM signal interference. At night under normal conditions without interference from outside light or noise, CCTV can produce images with good quality (24.50%), and the water level is visible (Table 2). In comparison, the image with good quality is 76.67% which is mostly produced during daytime and images with medium quality (18.27%) were mostly recorded at night with light interference from outside and less noise and when the weather was not good, such as heavy rain. The presence of cobwebs can also contribute to poor image quality at night. The image classification from CCTV PUMMA can be seen in Figure 5.

Figure 5. CCTV images quality classification during daylight (top) and night (bottom)

4. Conclusions
The results of this test have successfully demonstrated the performance of PUMMA device installed in Pangandaran. PUMMA has succeeded providing adequate data to be used in monitoring sea water level. The water level elevation data produced by PUMMA correlates well with the measurement results by BIG and IDSL devices. The excellent performance of PUMMA occurred in March, where no data gap were found. From our analysis, the existing data gap occurs mainly due to signal interference or GSM telecommunication network constraints and IoT platform issues. PUMMA’s CCTV can produce good quality images where the water level can be seen day or night times. However, at night, interference or light from outside will produce noise, contributing to the number of images with medium and poor quality. Overall, PUMMA shows good reliability and can be used in monitoring the mangrove ecosystems as well as estuaries.
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NRP, DN. Conceptualization, writing, data investigation, statistical and formatting. SH, A Set. Reviewed and edited the manuscript. RB, Ma, SWW, AK, SW, FYP. Data collections. NTM. Water level analysis.