Ecosystem Characteristics in Inner Ambon Bay

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Ecosystem Characteristics in Inner Ambon Bay

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Abstract. Inner Ambon Bay has been used as a location for fish farming. The mean seasonal of chemical parameters as much as 3,92 – 6,52 ppm for dissolved oxygen, the surface concentration of nitrate and phosphate each one is 0,05 – 0,143 ppm and 0,014 – 0,6 ppm, meanwhile the pH reach 7,95 – 8,44. The mean seasonal of physical parameters about 30,3 – 34,4 ‰ for salinity and the value of surface temperature is 26,5 – 31,5 °C. This research reviews the condition of an ecosystem in Inner Ambon Bay, consist of nutrients, phytoplankton, zooplankton, and detritus (NPZD) concentrations. The input model uses data on temperature and average nitrate concentration from Ambon Marine Aquaculture Center (Balai Perikanan Budidaya Laut Ambon) which is located on 3,63529 °S and 128,2312 °E. Model simulation is carried out for 4 years (2015 – 2018) with the time step of 6 minutes. The model simulation result shows that the mean nutrient concentration is $3,52 – 3,84$ mmolC/m^3. The verification of nutrient concentration from a model with observation data (nitrate concentration) used a statistics method. The value of RMSE is 0,05 mg/L or 0,5 mmolC/m^3, meanwhile correlation is 0,41. The highest nutrient concentration occurred in the southeast season. It could be influenced by upwelling from Banda Sea that carried high nutrients from the surface.

1. Introduction

Ambon Bay devided into 2 areas namely Inner Ambon Bay (IAB) and Outer Ambon Bay (OAB). IAB has an area of 11.497,5 km^2 and its basin is 40 m deep [1]. IAB is a center for fish farming conducted by the Ambon Marine Aquaculture Center (Balai Perikanan Budidaya Laut Ambon). The physical, chemical, oceanographic, and biological parameters greatly influence the yield of fish farming in IAB. Physical parameters such as temperature and salinity, chemical parameters such as dissolved oxygen, pH, nitrate, phosphate. Biological parameters such as fitoplankton and zooplankton concentration. Geographically, the condition of the waters in the western part of IAB is influenced by the phenomenon of upwelling and downwelling originating from Banda Sea, because it is close to OAB which directly connected with Banda Sea. The eastern waters of IAB are more influenced by rivers which lead to the bay.

The research before states that sea surface temperature in May 2008 was $\pm$ 27,5 °C, in August was $\pm$ 25 °C, and $\pm$28,3°C in November [2]. Salinity in Ambon Bay was higher in southeast season than northwest season caused by upwelling in Banda Sea [3]. Upwelling and downwelling in Banda Sea would influence OAB and IAB waters [4]. The research about salinity in IAB ranged from 33,75 ‰ in

February and 33,5 ‰ in May [5]. The condition of Ambon Bay in 2009 showed that the concentrations of nitrate, nitrit, phosphate, pH, and dissolved oxygen in July higher than in February [6]. Nutrients concentration in the ocean such as phosphate, nitrat, and silicate [7]. Nutrients would influence the growth of phytoplankton [8].

Ecosystem modeling in the ocean using mathematical equations [9] has been carried out in Karimun Jawa waters [10]. The simulation results of model show that in 2016 - 2017 nutrients concentration reached 3,01 mmolC / m³ meanwhile phytoplankton concentration was 3,41 mmolC / m³, zooplankton and detritus concentrations at the end of 2017 were 18,82 mmolC / m³ respectively and 26,15 mmolC / m³ [10]. Verification of phytoplankton result using chlorophyll-a from Aqua MODIS with correlation and RMSE of 38,53% and 0,09.

2. Methodology

The study area in IAB is located at 3,63529 °S and 128,223 °E. The location is an area of seabass cultivation in floating net cages conducted by the Ambon Marine Aquaculture Center. The data used in this research were temperature and nitrate concentration as an input to ecosystem model. Meanwhile in
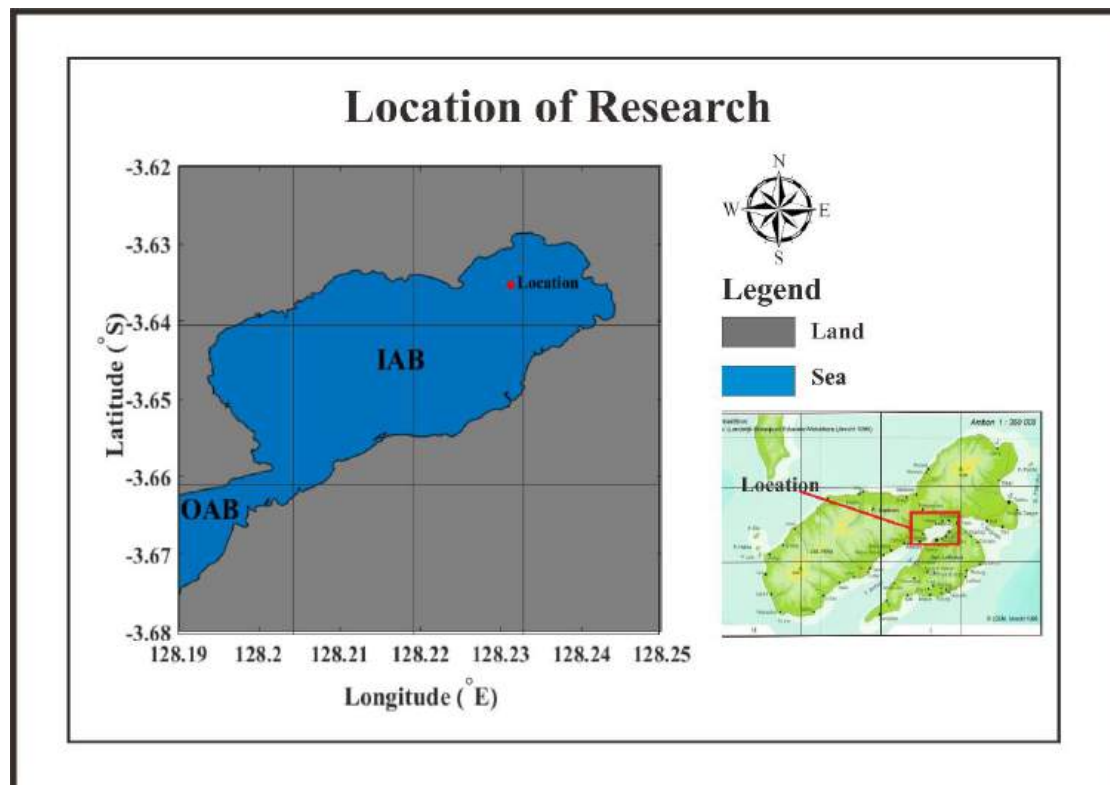

Figure 1. Location of Research in Inner Ambon Bay

order to comprehend the condition in IAB, physical and chemical parameters such as concentration of nitrate and phosphate, pH, salinity, and dissolved oxygen were used. The data which used in this research from observation conducted by the Ambon Marine Aquaculture Center between 2015 – 2018. Verification of nutrients, phytoplankton, zooplankton, and detritus (NPZD) model using data of average nitrate concentration in Ambon Bay.

The model used is an ecosystem model that is developed with the mathematical equations [9] which are listed in equations (1) to (7). The model input used is in the form of sea surface temperature data and nitrate concentration in 2015 – 2018 with a time step of 6 minutes. The initial values in the model has used concentration of nutrients, phytoplankton, zooplankton, and detritus. The initial value

of nutrient is 0,546 mmolC / m^3 , it has used average concentration of nitrate in IAB. The initial value of phytoplankton is 0,072 mmolC / m^3. This value came from data of chlorophyll satellite images obtained by the National Aeronautics and Space Administration (NASA) [11]. The initial value of zooplankton is the average Copepod concentration in Maluku Sea and Banda Sea originating from the National Oceanic and Atmospheric Administration (NOAA) [12]. The initial value of zooplankton is 0,237 mmolC / m^3. The average concentration of Copepod is 2,845 mgC / m^3, the conversion value of mgC / m^3 to mmolC / m^3 is known as 1 mgC / m^3 = 1 / 12,0107 mmolC / m^3, as follows;

$$\text{Concentration of zooplankton} = 2{,}845 \times \frac{1}{12{,}0107} = 0{,}237 \ \text{mmolC} / \text{m}^3$$

The initial value of detritus is zero because it is considered that at the beginning of the simulation there were no dead organisms which turned into detritus.

$$M(N) = \frac{rN^2}{\alpha^2 + N^2} \tag{1}$$

$$r = r_{max}\theta(T - T_0)\Delta d(t)\exp(\alpha T) \tag{2}$$

Equation (1) used to determine nutrients uptake, namely nutrients needed by phytoplankton for the growth. Nutrients uptake influenced by sunlight intensity (r) which entered in the ocean, bulk nutrient (N), and half saturation (α). Equation (2) used to calculate sunlight intensity (r). Equation (3) used to determine nutrient changes in the time, nutrients reduced due to nutrient uptake and going to increased when the rate of phytoplankton changes into nutrients $(l_{PN}P)$, the rate of detritus changes into nutrients $(l_{DN}D)$, the rate of zooplankton into nutrients $(l_{ZN}Z)$, and nutrients input from (Q_N^{import}) in the ocean increased.

$$\frac{d}{dt}N = -M(N)P + l_{PN}P + l_{DN}D + l_{ZN}Z + Q_N^{import} \tag{3}$$

$$\frac{d}{dt}P = M(N)P - l_{PN}P - g(P)Z - l_{PD}P \tag{4}$$

$$\frac{d}{dt}Z = g(P)Z - (l_{ZD} + l_{ZN})Z \tag{5}$$

$$\frac{d}{dt}D = l_{ZD}Z + l_{PD}P - \left(l_{DN} + l_{DD_{sed}}\right)D \tag{6}$$

where;

$$\frac{dD_{sed}}{dt} = l_{DD_{sed}D} \tag{7}$$

Equation (4) used to determine phytoplankton changes in the time, the value will gain when nutrient uptake increased. Meanwhile, it will decreased when the rate of phytoplankton changes into nutrients $(l_{PN}P)$, zooplankton grazing from phytoplankton $(g(P)Z)$, and the rate of phytoplankton changes into detrius $(l_{PD}P)$. Zooplankton changes in the time, equation (5) increase when the value of $(g(P)Z)$ is high, the rate of zooplankton changes into detritus $(l_{ZD}Z)$ and the rate of zooplankton changes into nutrients $(l_{ZN}Z)$ is low. Equation (6) show detritus will go up when the value of $(l_{ZD}Z)$, $(l_{PD}P)$ increase, meanwhile the concentration of $(l_{DN}D)$ and $\left(l_{DD_{sed}}D\right)$ should be low.

The NPZD model using nitrate concentration from observation as verification data. The observation is conducted by Deep Sea Research Center, Indonesian Institute of Sciences (Lembaga Ilmu Pengetahuan Indonesia)-Ambon 2 – 4 times a year, representing each season. Verification process use statistical method with formula of root mean square error (RMSE) and correlation. RMSE value is applied to find out the difference between model result and observation data. The value of correlation gain the apprehension of the relation between model and observation data.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - x_i)^2}{n}} \tag{8}$$

$$CC = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2(y_i - \bar{y})^2}} \tag{9}$$

Where,

x	= observed values	$\bar{y}$	= average of forecasts
$\bar{x}$	= average of observed value	n	= number of samples
y	= forecasts	i	= data sequence

3. Result and Discussion

In this research will discuss about the condition of Inner Ambon Bay based on physical and chemical parameters using observation data. Furthermore, the condition of ecosystem in IAB has been simulated using an ecosytem model. The input model used nitrate concentration and sea surface temperature. Meanwhile the output model such as nutrient, phtoplankton, zooplankton, and detritus concentrations.

3.1. Physical Condition in Inner Ambon Bay

The physical parameters in the surface consist of temperature and salinity, sea surface temperature in IAB 2016 - 2018 can be seen in Figure 2. The average of sea surface temperature in March 2016 reached 31 °C then decreased in August to reach 27,5 °C. The average of sea surface temperature in November reached 31,5 °C. In March, the sea surface has a high temperature during the northwest season. There are downwelling phenomenon in Banda Sea. The distribution of high sea surface temperatures was not affect the condition in IAB immediately, but took several weeks. Sea surface temperature in August was low due to the presence of upwelling process in Banda Sea. The average of sea surface temperature throughout 2016 was quite high compared to 2017 and 2018. The lowest temperature occurs in July 2018 which is equal to 26,5 °C.
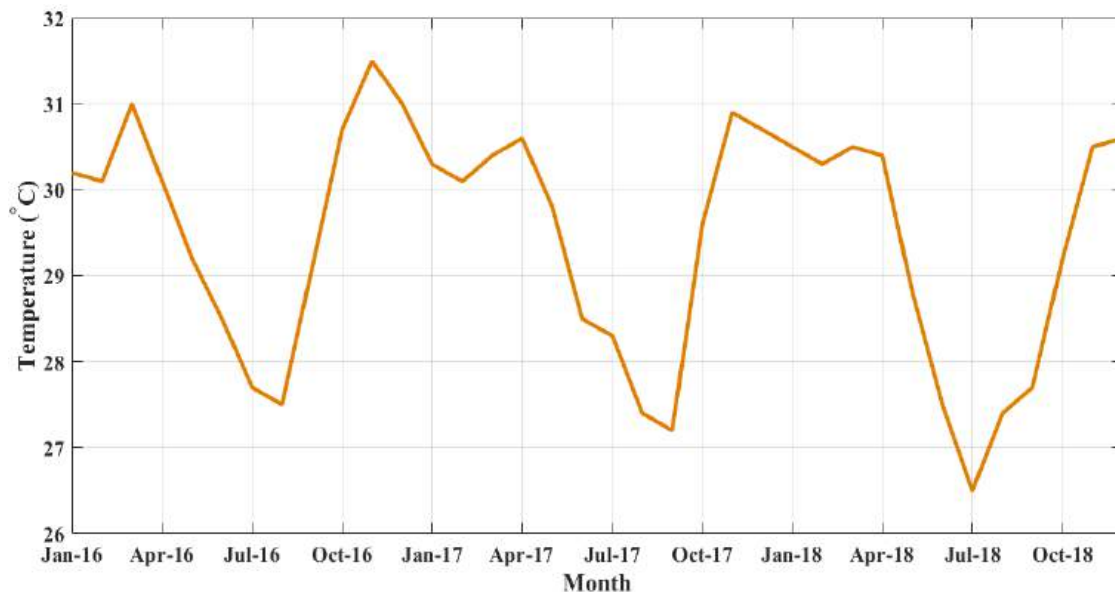

Figure 2. Sea Surface Temperature (SST) Monthly in Inner Ambon Bay

Sea surface salinity in Ambon Bay at the position of 3,63529 °S and 128,2312 °E seen in Figure 3. The highest sea surface salinity during 2016 - 2017 occurred in February 2016 of 34,4 ‰ and the

lowest occurred in June 2018 amounting to 30,3 ‰. Salinity measurement results in IAB also influenced by freshwater and nutrients input from the river. Moreover, the location where the data collection is an aquaculture area allows the existence of minerals from fish feed remnants. Salinity in IAB ranged from 30,8 – 34,4 ‰ in 2016, reached 30,7 – 33,7 ‰ in 2017, and it was about 30,3 – 33,8 ‰ in 2018.

Figure 3. Sea Surface Salinity (SSS) Monthly in Inner Ambon Bay

3.2. *Chemical Condition in Ineer Ambon Bay*

Chemical parameters is reviewed based on the measurement results in the form of nitrate and phosphate concentrations, dissolved oxygen, and pH. Figure 4. shows monthly nitrate concentration throughout 2016 - 2018. The highest nitrate concentration is 0,14 ppm which occurred in October 2017 with an average of 0,05 ppm. Figure 5. shows the average of monthly phosphate concentration in IAB during 2016 - 2018. The average of phosphate concentration reached 0,014 – 0,589 ppm in 2016, ranged from 0,015 – 0,258 ppm in 2017, and in 2018 was about 0,015 - 0,6 ppm. Nitrate and phosphate concentrations are the main nutrients needed by phytoplankton to support their growth and development.
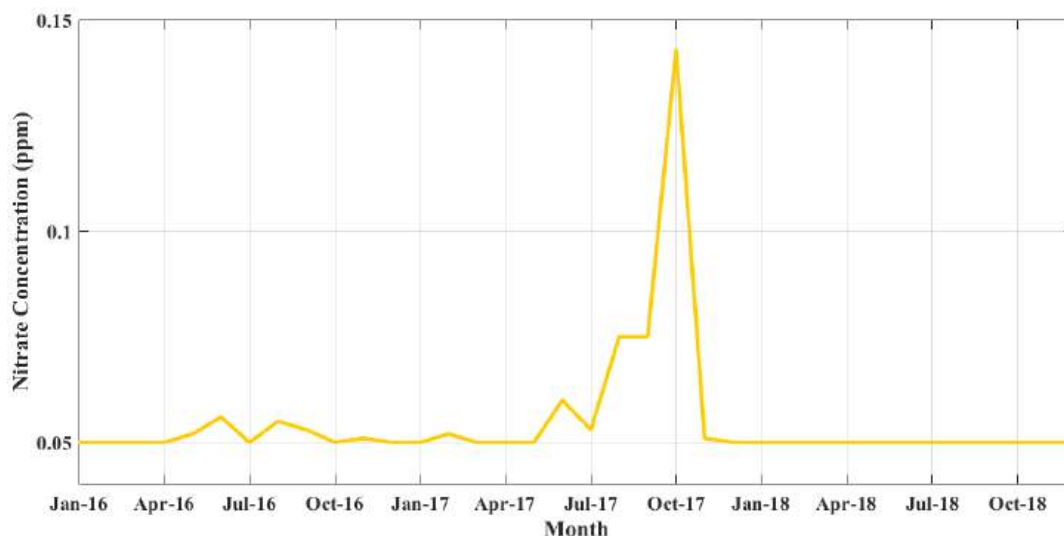

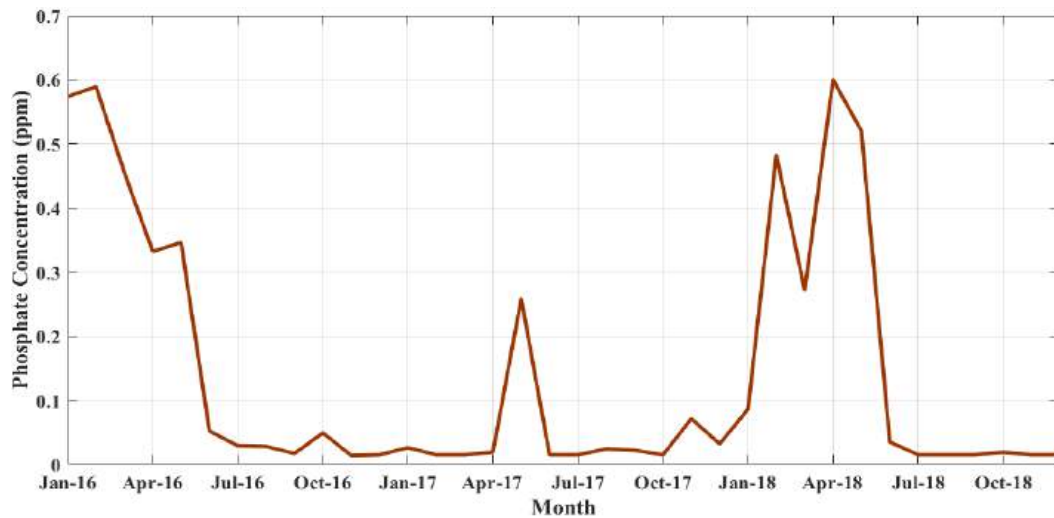**Figure 4.** Nitrate Concentration in Inner Ambon Bay

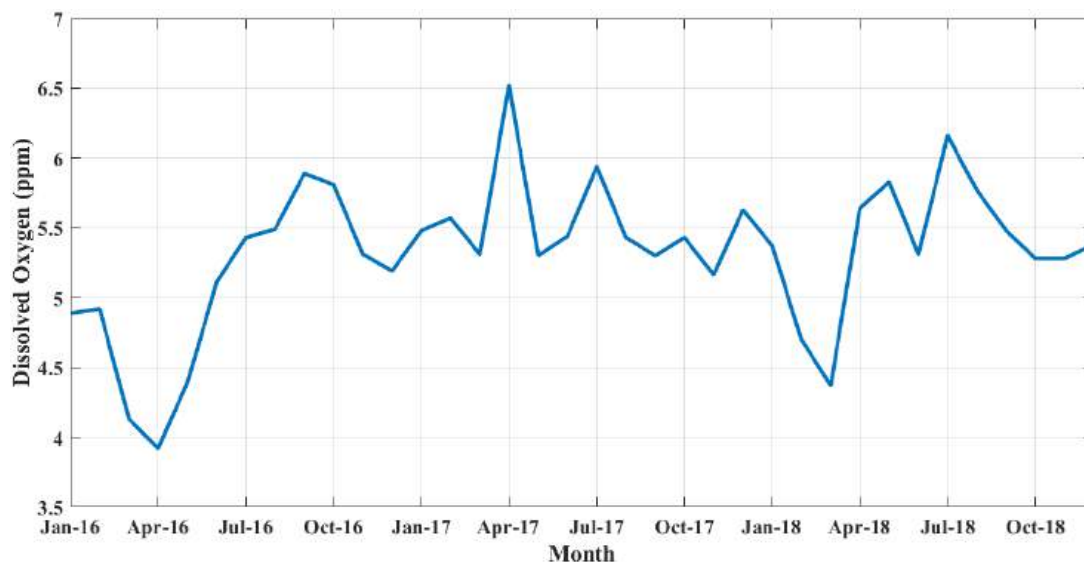**Figure 5.** Phosphate Concentration in Inner Ambon Bay

Figure 6. Dissolved Oxygen Monthly in Inner Ambon Bay

Figure 6. depicting the monthly of dissolved oxygen concentration in IAB, dissolved oxygen in 2016 ranged from 3,92 – 5,89 ppm, in 2017 was around 5,16 – 6,52 ppm, and in 2018 ranged from 4,37 – 6,16 ppm. Dissolved oxygen on the surface tends to be higher because of the process of diffusion of oxygen from air and photosynthesis process. High dissolved oxygen going to increase the fertility of a waters because oxygen supports the life of marine life. Figure 7. shows that pH in IAB with average values from 7,95 to 8,44 in 2016, in 2017 was about 8,21 – 8,42, and ranged from 8,2 to 8,37 in 2018.
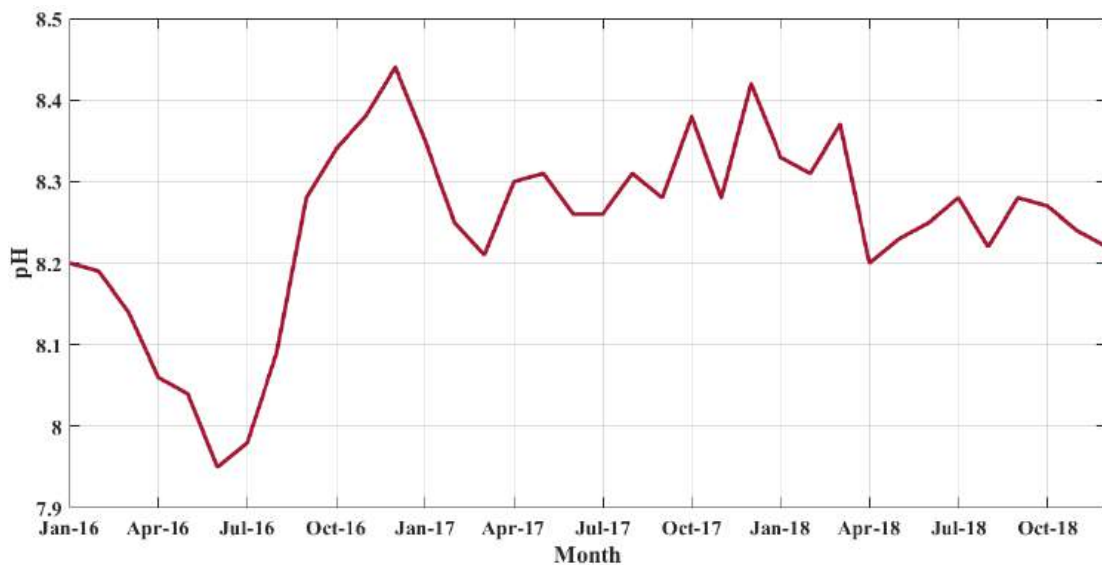
Figure 7. pH Monthly in Inner Ambon Bay

3.3. Ecosystem Condition in Inner Ambon Bay Based on Modelling

Verification of the NPZD model results in the form of nutrient data from model results with data on nitrate observation. Comparison of the model results and observation data is shown in Figure 8. The nutrient concentration based on observation data in March 2016 is very high compared with the results of model. The difference of result is caused by the nutrient input originating from the river, meanwhile nutrient input from the river in model is not considered. In the next day, it shows that nutrients concentration from the model result is almost identical as the observation data. The result based on statistical method with parameters such as Root Mean Square Error (RMSE) and correlation showed good result. The value of RMSE is 0,05 mg / L, whereas the correlation is 0,41.
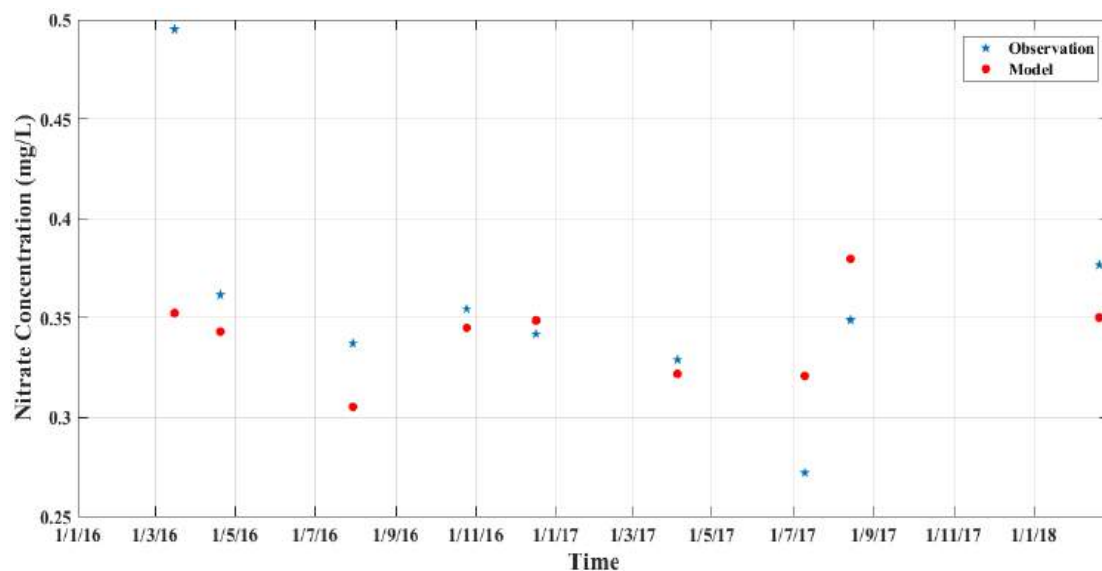

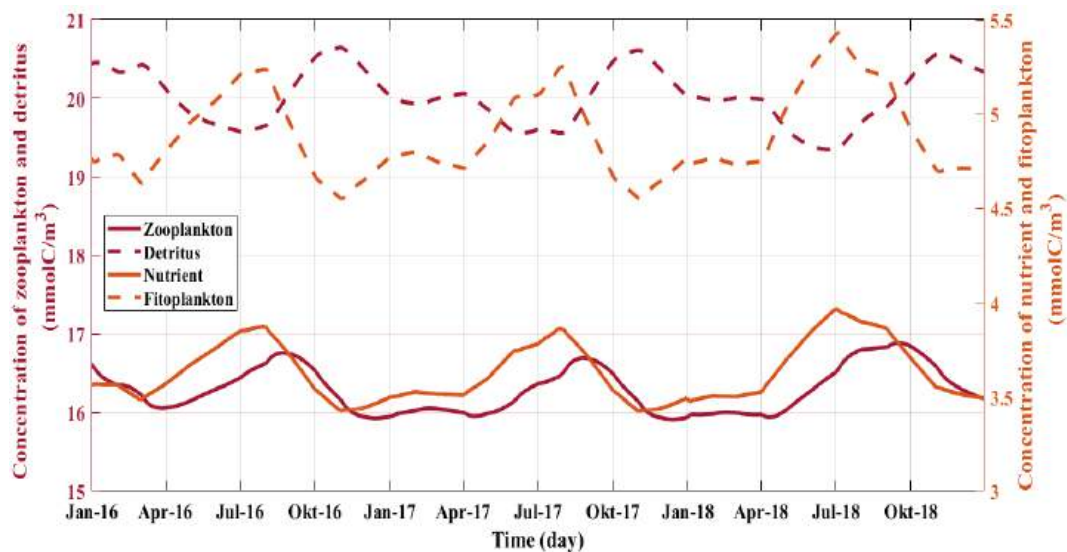**Figure 8.** Nitrate Comparison between Model and Observation

Figure 9. NPZD Concentration in Inner Ambon Bay

Figure 9. shows the concentration of nutrients, phytoplankton, zooplankton, and detritus for 3 years (2016 - 2018). Nutrient concentration was higher when sea had optimum temperature (about 27 - 28 °C). Figure 4. shows that the concentration of nutrient as a model input reached 0,14 mg / L or 1,4 mmolC / m^3, at the same time Figure 9. shows nutrient concentration of model result is 3,48 mmolC / m^3. The difference between both of them reached 2,08 mmolC / m^3. It shows that the model results have been intergrated with other parameters which affected the increasing of nutrient concentration.

Phytoplankton concentration have same pattern with nutrients concentration. Nutrients concentration would gain in the middle of a year and followed by the increasing of phytoplankton concentration. Zooplankton concentration pattern would follow the pattern of phytoplankton concentration with time lag. It shows the duration of zooplankton life till dead and become detritus. Figure 9. shows that detritus in the nature influenced by the dead of zooplankton instead of phytoplankton.

Figure 9. shows the concentration of nutrient which reached 3,43 – 3,87 mmolC / m^3 in 2016. Meanwhile in 2017, nutrient concentration was 3,42 – 3,86 mmolC / m^3 and it attained 3,47 – 3,97 mmolC / m^3 in 2018. The highest nutrient concentration in Figure 9. occured in southeast season and the lowest nutrient concentration occured in northwest season. The highest nutrient influenced by low sea temperature, whereas the lowest nutrient influenced by high sea temperature. Figure 9. shows that the highest nutrient concentration occured in southeast season 2018. It reached 4,9 mmolC / m^3. Phytoplankton concentration based on Figure 9. in 2016 gained 4,55 – 5,23 mmolC / m^3. In 2017, it reached 4,55 – 5,25 mmolC / m^3. It was 4,69 – 5,43 mmolC / m^3 in 2018. Detritus concentration in Figure 9. was 19,58 – 20,65 mmolC / m^3 in 2016. It reached 19,55 – 20,61 in 2017 and about 19,35 – 20,58 mmolC / m^3.

4. Conclusions

Conditions in Ambon Bay based on physical parameters throughout 2016 - 2017 was appropriate for cultivation, with the ranging of temperatures from 26,5 to 31, 5 °C. Salinity in IAB reached 30,3 to 34,4 ‰. Water conditions based on chemical parameters have a pH with a small difference ranged from 7,95 to 8,44, while phosphate concentrations were higher than nitrate concentrations. Dissolved oxygen in IAB relatively low, which gained 3,92 – 6,52 ppm. The simulation results of ecosystem models using statistical methods showing the value of RMSE and correlation have good results. The RMSE value was 0,05 mg / L with a correlation of 0,41.

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