PLANKTON CONCENTRATION MODELING IN THE SOUTHERN WATERS OF NUSA TENGGARA DURING THE TROPICAL CYCLONE SEROJA

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ABSTRACT

Tropical Cyclone Seroja is one of the unique cyclone phenomena that occured in Indonesian waters. To determine its effect to the plankton concentration in East Nusa Tenggara Waters, 1-D Nutrient, Phytoplankton, Zooplankton, and Detritus (NPZD) ecosystem modeling was carried out. The temperature changes caused by the cyclone has a direct impact on the phytoplankton concentration and indirectly on zooplankton. The simulation shows that the peak concentration of phytoplankton due to TC Seroja occurred on 8-10 April 2021 (3.49 mmolC/m^3), while for zooplankton it occurred on 20-22 April 2021 (8.55 mmolC/m^3).

Keyword: *Ecosystem model, Plankton, Tropical Cyclone Seroja.*

PENDAHULUAN

Studies related to the abundance and role of plankton in the ocean have been studied quite a lot. However, studies specializing in zooplankton are still few and difficult to do thoroughly. One of the studies related to the abundance of zooplankton was conducted by Wimalasiri et al in the Indian Ocean (Godet et al., 2020). However, this research is still space-limited since it only uses sampling data at several observation stations along the Sri Lankan coastline. As written in (Ratnarajah et al., 2023), research related to zooplankton requires an approach with modeling methods to facilitate global monitoring.

The development of the zooplankton model is quite difficult and faces various challenges. Some models take into account changing climate. There are also a models that considers calcifiers and prey, to the complex species-specific behavior of mesozooplankton (Ratnarajah et al., 2023). One of the ecosystem models related to zooplankton is a 1-dimensional model ecosystem model from Fennel and Neumann (Fennel & Neumann, 2014). The ecosystem modeling will be carried out which includes calculation of nutrients, phytoplankton, zooplankton, and detritus (NPZD).

One phenomenon that is closely related to the dynamics of plankton abundance in the ocean is tropical cyclone (TC). In general, TC will cause upwelling followed by an increasing of nutrient and plankton. The increases of phytoplankton can be identified through satellite imagery, while increases in the abundance of zooplankton are more difficult to detect. Thus, the purpose of this study was to examine the effect of TC on the zooplankton abundance, especially during Tropical Cyclone Seroja. For Numerical simulation, we ran for 10 years period (2012 – 2021) with a 1.25-year warm-up period using model ecosystem model from Fennel and Neumann (Fennel & Neumann, 2014). Then for the analysis, we focused on the period of TC Seroja (March-April 2021). The study area is presented in Figure 1.

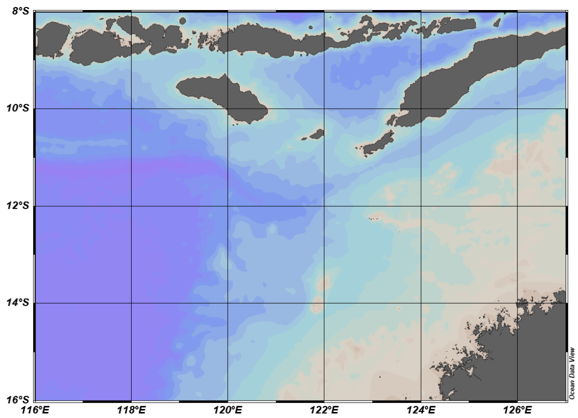

Figure 1. Studi Area

DATA AND METHOD

Input for the ecosystem model is daily temperature and nutrients data. In the ecosystem model built by Fennel and Neumann (Fennel & Neumann, 2014), they use are nitrate as nutrient. Daily temperature data obtained from the HadISST Average Sea Surface Temperature(Rayner et al., 2003). Initial value of nitrate was obtained from WOA 2013 (Garcia et al., 2014) with a value 0.027 mmolC/m^3/d. This value has been converted using the Reidfield ratio so that the concentration in carbon units is obtained. Other data used is chlorophyll-a data to verify model results of phytoplankton abundance. Daily chlorophyll data was obtained from Aqua MODIS satellite.

In this study, we used the NPZD (Nutrient, Phytoplankton, Zooplankton, Detritus) ecosystem model NPZD. In this ecosystem model, NPZD values are integrated from the surface to 50 meters. We used equations from Fennel and Neumann (Fennel & Neumann, 2014) which the representative meaning of each symbol can be seen in the appendix (Table 2). We only consider fluctuations in plankton concentration due to changes in temperature.

$$\frac{d}{dt}N = -M(N)P + l_{PN}P + l_{DN}D + l_{ZN}Z + Q_N^{import} + L_{FN} \quad (1)$$

$$\frac{d}{dt}P = M(N,t)P - l_{PN}P - g(P)Z - l_{PD}P \quad (2)$$

$$\frac{d}{dt}Z = g(P)Z - (l_{ZD} + l_{ZN})Z - G_F \quad (3)$$

$$\frac{d}{dt}D = l_{ZD}Z + l_{PD}P - \left(l_{DN} + l_{DD_{sed}}\right)D + L_{FD} \quad (4)$$

$$\frac{dD_{sed}}{dt} = l_{DD_{sed}}D \quad (5)$$

$$M(N) = \frac{rN^2}{\alpha^2 + N^2} \quad (6)$$

$$Q(t) = [\theta(t - d_0) - \theta(t - d_{365})](t - d_0)\frac{0,9}{d_{220}} \quad (7)$$

M (N) term is a Michaelis-Menten formula which states nutrient uptake. The effect of solar irradiation time represented by r, while the terms G (P,t) in equations (2) and (3) express the zooplankton grazing rate. For cage simulations, the reproduction time is modified to the desired seeding time. The interactions used in equations (1) to (6) can be summarized by the scheme in Figure 2. While the behavior of grazing plankton and its relation to temperature is described in equation (7). Further information regarding equation (1) to (7) can be seen in Table 1 in the appendix.

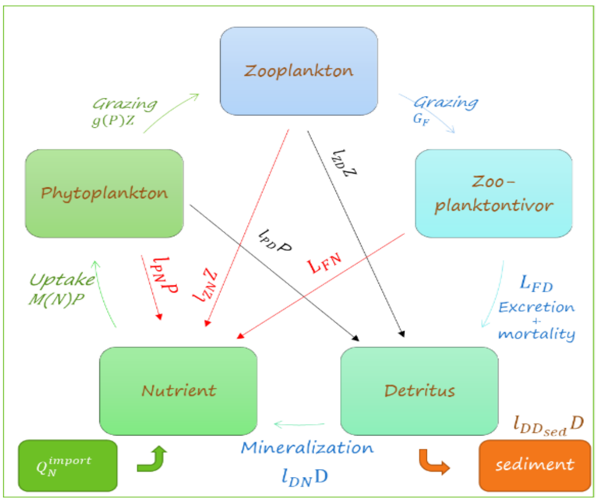

Figure 2. NPZD Ecosystem Model Scheme

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RESULTS AND DISCUSSION

Model Results

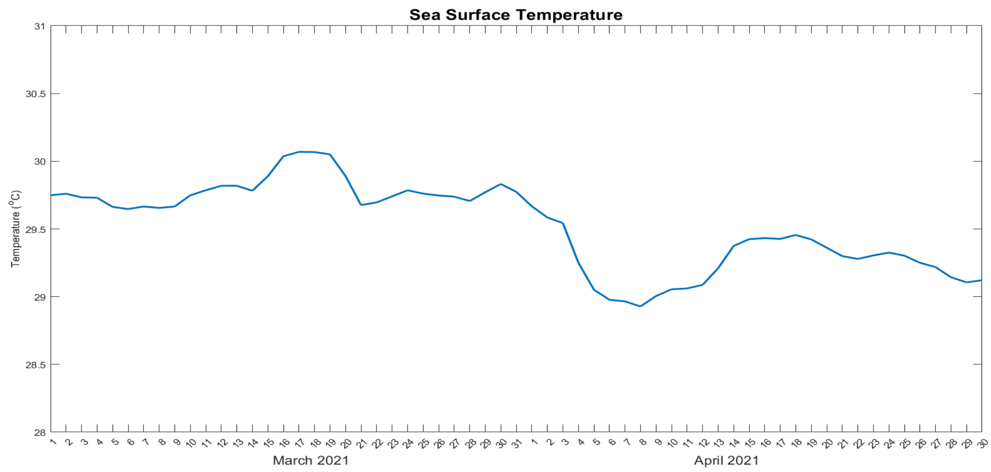

Figure 3. SST in the study area in March – April 2021

Figure 3 shows the Sea Surface Temperature (SST) condition in the study area. The SST was spatially averaged to obtain SST in the form of a time series. It can be seen that in the first week of April there was a sudden decrease in SST and then increased again the following week. This change in SST is during the period of the Tropical Cyclone (TC) Seroja, namely 3-15 April 2021. A brief decrease in SST may indicate upwelling caused by TC Seroja (Avrionesti, Khadami, & Purnaningtyas, 2021).

Verification of Chlorophyll-a with phytoplankton from the results of 1D ecosystem model simulation carried out in the form of anomaly values (Figure 4). Based on the verification results, there is a similar pattern between the satellite data and the model results. Therefore, there is a five-days gap, especially at peak concentrations of phytoplankton where the simulation results are slower than satellite data. The phytoplankton concentration from simulation results has the range between 0.51 to 0.53 mmolN/m^3, while the chlorophyll-a data from satellite has values between 0.2 to 0.35 mmolN/m^3. The correlation pattern between the two is 0.86 if the phase between the two is equalized. Therefore, adjustments were made by shifting the simulation results five days back.

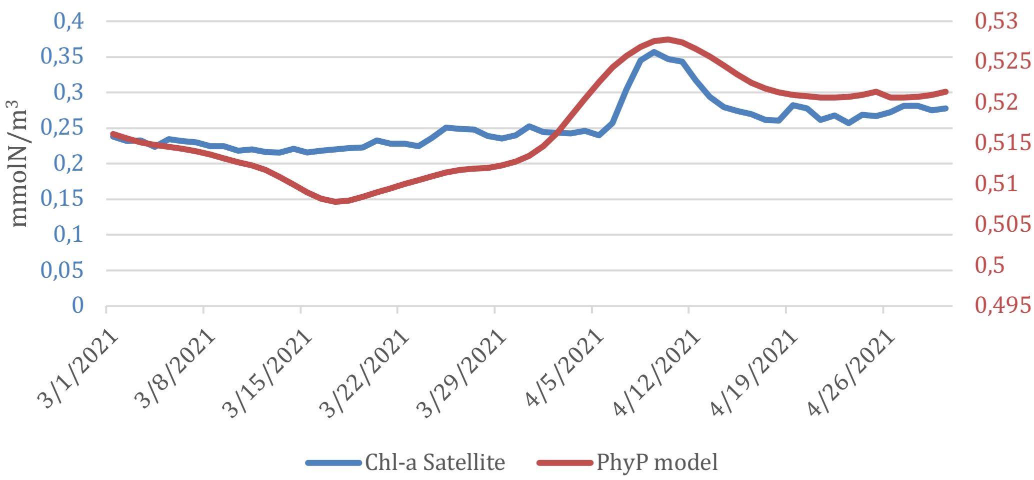

Figure 4. Verification between model and satellite

Simulation of plankton concentration can be seen in Figure 5. It can be seen that the increase in plankton begins with an increase in phytoplankton with a peak on 8-10 April 2021 (3.49 mmolC/m^3). This increase was then followed by an increase in zooplankton concentrations that reached its peak (8.55 mmolC/m^3) on 20-22 April 2021, about one week after the cyclone ended. When compared between figures 2 and 5, it can be seen that the decrease in SST has a direct impact on increasing the concentration of phytoplankton.

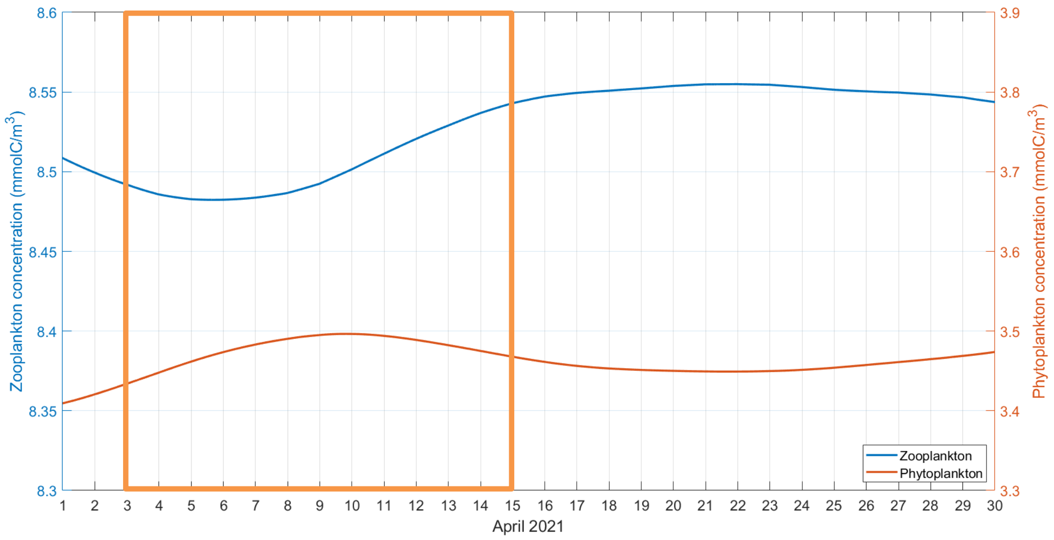

Figure 5. Model Result for Phytoplankton and Zooplankton Concentrations

Discussion

Based on these results, it can be seen that there is an increase in plankton concentration which briefly occurs during TC Seroja. The verification results shows that model results are overestimated even though the pattern is similiar to the original conditions. This may occur due to several factors. First, the model calculate phytoplankton as a whole, not only chlorophyll-a biota. Second, the spatial alignment is too broad and dismiss the influence of the coast. Third, since in this study the input only observed to temperature fluctuations and dismiss the nutrient fluctuations, it may reducing the accuracy of the simulation. Thus, in the future there is still potential to improve the accuracy of the simulation results. In addition, the simulation results of zooplankton concentrations cannot be verified due to the difficulty in obtaining comparative data.

SUMMARY

The Seroja tropical cyclone has an impact to the brief increasing of plankton concentration in the study area, both phytoplankton and zooplankton. The temperature changes caused by the cyclone has a direct impact on the phytoplankton concentration and indirectly on zooplankton. The peak concentration of phytoplankton due to TC Seroja occurred on 8-10 April 2021 (3.49 mmolC/m3), while for zooplankton it occurred on 20-22 April 2021 (8.55 mmolC/m3).

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