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Modeling Predator-Prey Interactions Barramundi in Dogamit Swamp Wasur National Park Merauke

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ABSTRACT

Dogamit, which serves as a habitat for fish species growth, has drawn attention due to its location within a national park and the practice of 'sasi' by the local community as a way to preserve the ecosystem and the species that interact within it. In this research, mathematical modeling variables are explained to describe species' life based on direct observation. As the ecosystem's inhabitants, the dominant predator species in the ecosystem is the Barramundi fish. Historically, this predator species has migrated from the waters of Australia. The aim of this research is to determine the locally stable equilibrium point and analyze the growth trajectories of the species. The testing is conducted based on equilibrium point analysis. There are three equilibrium points, but only one is a non-negative and realistic point for stability testing. This equilibrium point is then tested using the Routh-Hurwitz criteria. Stability is analyzed using the Jacobian matrix to obtain the eigenvalues. All eigenvalues are negative, thus it can be concluded that the model tested is locally stable. A numerical simulation analysis is also provided, involving parameters that support the mathematical model. The parameters are derived from previous relevant studies and realistic assumptions. The numerical simulation analysis method is used to observe the population growth trajectories. The trajectories that appear show similar conditions for both populations. Both populations experience significant fluctuations with an average growth rate of 67%. It takes 3/5 of the species' lifespan for both populations to stabilize again within the ecosystem. The predator-prey populations also demonstrate resilience during fluctuations, indicating that both populations are highly robust in maintaining survival. The characteristics and findings of this research are commonly found only in endemic species populations. Endemic species tend to have long-term survival and endurance, allowing them to dominate their surrounding geographic habitat and maintain ecosystem balance.

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A. INTRODUCTION

The determining factors for ecosystem balance in the environment are referred to as interactions between species, populations and communities. Every interaction that occurs determines the development and survival of living things. To gain a deep understanding of an ecosystem, it is very important to understand the dynamics at play in the predator-prey relationship. The predator-prey interaction model in science is very well known, both in natural and experimental conditions. Selection of prey based on appropriate morphological and behavioral characteristics, detection and predation, camouflage, cooperation, interaction cannibalism, defense mechanisms by releasing chemicals, and defense by evasive movements are forms of behavioral strategies in the natural environment (Nuha et al., 2024). In natural environmental conditions, predator-prey interactions are very difficult to determine. The interactions that occur in the natural environment are largely influenced by factors that influence the balance of the ecosystem as a whole (Pratama, Toaha, et al., 2019). This applies to areas with very high biodiversity, which are usually characterized by diverse plant, animal, plankton and other communities (Al-salman et al., 2021). The more difficult it is to engineer interactions, the stronger the ecosystem will naturally be. In other conditions, there is also a natural form of ecosystem environment because the ecosystem has not been touched. Ecosystems that are located far from the reach of exploitation behavior can also be defined as natural environments because of the development of interactions that occur naturally.

Wasur National Park in Merauke is a nature conservation area that has a wetlands ecosystem. As a wetland ecosystem area, Wasur National Park has a lot of hydrological ecosystem potential in the form of swamps and rivers. The ecosystem that inhabits or inhabits this area is in the form of freshwater species, as well as other aquatic life which constitutes biodiversity. Dogamit Swamp itself is part of a conservation wetland that is included in the administrative area of Naukenjerai district (Binur, 2010; Maloky et al., 2021). Dogamit Swamp has the characteristics of brackish waters (Brackishwater Swamp). Dogamit Swamp holds many species of freshwater and brackish water fish. Rawa Dogamit is also a supplier of fish for consumption by the community in three villages around the Rawa Dogamit area. The strategic geological position of Dogamit Swamp as a habitat and protection for species makes the swamp a swamp rich in fish species (Warsa et al., 2007). Dogamit Swamp is an area that supplies the needs of Tilapia fish (Oreochromis niloticus) and Snapper (Barramundi). Dogamit Swamp represents a case study that fits the research focus. Meanwhile, the species that is the focus of this research is the brackish water Barramundi species. The Barramundi species that lives in dogamite swamp areas is a transmigrating species from Australian waters. The ancestors of this Barramundi species are often found in Australia (Ribeiro, 2015)(Cain & Mitchell, 2021). In fact, this Barramundi species has different characteristics from its ancestors in Australia. Several climatic factors and food reserves make this fish species have different characteristics in the two regions. The division of life zones for the Barramundi species has also been carried out in various regions of Australia (Condon et al., 2019). These species zones represent sensitive indicators of the impact of climate change on brackish water ecosystems.

In this study, the species observed was the Barrumundi species which lives and develops in the Dogamit swamp area. The Barrumundi species is the development of a mathematical model that has cannibalistic properties. Population dynamics in previous relevant studies display characteristics of cannibalism, therefore this trait is worthy of consideration in the model. Another characteristic considered in the mathematical model is the nature of the Barrumundi species, namely the Holling II response function. Scouting and monitoring prey is the beginning of the predation process that occurs in this species. Search properties that require predation time are considered in the constructed mathematical model. In other research that also supports the theoretical framework of the research, the characteristics of species that settle and do not migrate on a large scale are also shown. Behavior for shifting prey was also not considered, because it is far from characteristic of the Barrumundi species. All assumptions made in this research are based on relevant research and basic assumptions about the life of the species.

This research has the specific aim of theoretically describing predator-prey interactions through a mathematical model that explains qualitatively the most relevant behavior representing the Barrumundi species. The main research problem is to ensure that the model formed guarantees stable species growth over a long period of time. All analyzes will be provided, namely stability analysis and trajectory analysis. Model stability analysis is provided in the research carried out. Trajectory analysis is also provided to see population growth. The time periods given for analysis of trajectories vary, so that the growth form of the Barrumundi species will be obtained over a long period of time. In particular, the discussion will focus on the predator-prey model which discusses linear stability analysis in determining local stability characteristics. The local stability that will occur will show the behavior of species in an ecosystem in the Dogamit swamp. At the end of the analysis of this research, a numerical simulation is provided based on realistic parameters to test the stability of the predator-prey model. A discussion of the ecological implications on mathematical conclusions and future developments of this research is also reported in the final chapter.

B. METHODS

The type of research used is literature study. This methods section will briefly explain the habitat and species investigated.

1. Study area and sampling design

Dogamit Swamp is a wetland area located in the protected forest of Wasur National Park. Even though it is close to other swamp waters, the Dogamit Rawa protected forest has unique physical, chemical and water oscillation characteristics as well as shape and bathymetry. Structural heterogeneity like this leads to complex integration in various habitats. Analysis of species life was carried out in 3 sections of the station, namely $\left(8^{0}38'40{,}196''LS\right)$ and $\left(140^{0}31'43{,}079''BT\right)$; St.II $\left(8^{0}38'27{,}175''LS\right)$ and $\left(140^{0}31'56{,}023''BT\right)$; St.III $\left(8^{0}38'15{,}096''LS\right)$ and $\left(140^{0}32'9{,}173''BT\right)$. These three stations were chosen based on the access that researchers can reach when observing research data. Visually it will be shown on the mapping map of the given station area, as shown in Figure 1.

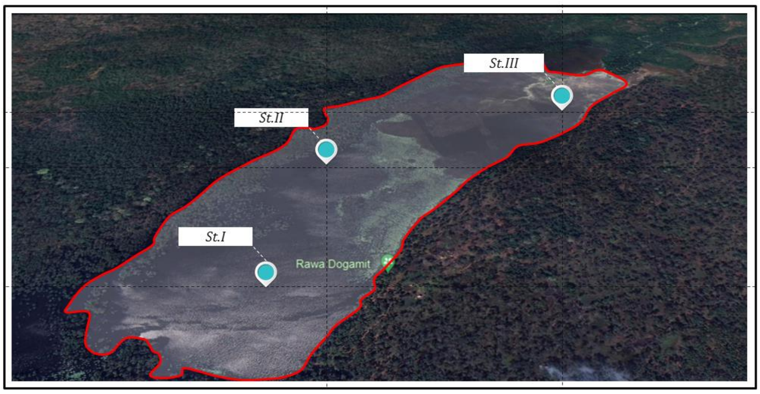

Figure 1. Dogamit Swamp Location

In Figure 1, the location of the research conducted by previous research has been determined (Google Earth, 2024). This research confirms that the choice of research station was due to the location or point of the station being a place that could be reached during the rainy and dry seasons. The reduced water flow during the dry season does not divert the Barrumundi species from moving, so local fishermen often catch fish around this station. Station 1 is included in the shallow swamp category, because the ground surface height and air height are lower when compared to stations II and III. At stations II and III, this is a swamp with high depth, but Barrumundi fish are very numerous in these two locations. The results of research that directly observed Barrumundi fish sites clearly showed that at the St. I location there were no Barrumundi species at all during the time the research was carried out. This also happened in St. III, there were only 2 Barrumundi species in St. III in the research process. Meanwhile, on St. II there are 8 species of Barrumundi. The location on St. II has great potential for the sustainable life of the Barrumundi species. The station selection was only used to see the presence of barumundi fish as samples. The research focus is general for all species that exist in the Dogamit Swamp.

2. Model Mathematics

This section, we will show the preparation of a predator-prey model that is relevant to Barramundi fish predation. The mathematical model developed as a novelty is a development and adaptation of research carried out by The research was carried out in 6 station areas that represent species of life, the selection of places was based on the help of artificial intelligence technology. The species at the center of the research are also endemic species in the ecosystem. The most prominent difference in this research and previous research is the response function given, namely the Holling II response function. The Holling II response function has assumptions that are relevant to the Barramundi species. This behavior is in the form of reconnaissance before predation possessed by the Barramundi species, the same as the form of reconnaissance in Holling II.

This principle is often referred to as the initial attack rate: at low prey densities, the prey take rate increases almost linearly with prey density because predators easily find their prey. Barramundi also has other characteristics that are in accordance with the Holling II principle, namely, it has a feeling of boredom in predation, so that predation on prey will stop and can replace other prey species. This trait and characteristic is referred to as handling time: when prey density increases, the time the predator spends handling the prey becomes a limiting factor (Pratama & Toaha, 2023)(Ruslau, et al., 2019). Predators began to spend more time handling prey than looking for new prey. The third characteristic that emerges is the saturation asymptote: at very high prey densities, the prey take rate reaches a saturation point because the predator is already busy handling the prey that has been caught. Thus, adding prey does not increase the rate of prey taking, in fact there may be a gradual decrease in predation. Some of the assumptions above are the basis for researchers to take Holling II as a functional response for the Barramundi species in the Dogamit swamp ecosystem. As a weakness of this research, we also cannot claim that all Barramundi species can use the same assumptions, because in each ecosystem region researchers believe that there will be differences in predation. The principle in predator-prey model research is the accuracy of observation data to develop the basic assumptions of the model. The functional model of the Holling II response given has the following mathematical form:

$$h(N) = \frac{\tau N}{1 + ThN},$$

Where τ is the attack rate or the predator's ability to find and catch prey, N is the prey density, and Th is handling time, namely the time it takes for a predator to catch, kill and eat one prey. The Holling II principle has been widely developed in various mathematical versions, but this research takes the basic assumptions from the Holling II formula. Another assumption given is the research variables N is an assumed representativeness for the prey population, P is a population for predators. In other research, the interaction of cannibalism in the Barramundi species was also shown (Mishra et al., 2021). Theoretical cannibalistic interactions have often involved Barramundi species in discussions (Ribeiro, 2015). The limitations of research in direct observation and the study of Barramundi in the Dogamit swamp are low so researchers did not focus on this behavioral analysis study. Researchers will still try to substitute cannibalism behavior into the model being carried to see changes in the dynamics of the model, but will not carry out an in-depth analysis (Li et al., 2019). Further analysis will be developed in future research involving an expert observation team in the Dogamit swamp. The following is a proposed model for population dynamics of the Barramundi species:

$$\begin{aligned} \frac{dN}{dt} &= rN\left(1 - \frac{N}{k}\right) - h(N)P = f(N,P), \\ \frac{dP}{dt} &= \rho(h(N) - aP - \sigma)P = g(N,P), \end{aligned} \tag{1}$$

Model (1) above was developed from previous research from in (Savoca et al., 2020). Model (1) above, it is clear that $N(t)$ and $P(t)$ each shows the density of predators and prey at time t. Prey growth is assumed to take a standard logistic form with r is the intrinsic growth rate and k is the carrying capacity density. The concept of response function (RP) in predators that is in accordance with the assumed characteristics of the Barramundi species is Holling type-II,

$$h(N) = \frac{\tau N}{1 + bN}, \tag{2}$$

All parameters used in model (1) are associated with a positive assumption of species growth. The description of all parameters can be seen in the following Table 1.

Table 1. Parameters, Biological Meanings and Unit

Parameters	**Meaning**	**Unit**
$N(t)$	The susceptible prey population (time dependent),	$[N]$
$P(t)$	Predator population (time dependent),	$[N]$
r	Prey's one intrinsic growth rate,	$[T]^{-1}$
k	Prey's environmental carrying capacity,	$[N]^{-1}$
τ	Maximum predator predation rate,	$[T]^{-1}$
b	Half-saturation constant for predation behaviour,	$[N]^{-1}$
a	Cannibalisme rate,	$[T]^{-1}\,[N]^{-1}$
σ	Mortality rate,	-
ρ	Conversion rate.	$[T]^{-1}$

Mortality in predator species is assumed to be linear, with $\sigma\rho$ is the death rate, with coefficient $\rho<1$ represents the growth efficiency of predators. Based on biological assumptions, all parameters used in model (1), namely β, k, τ, b, ρ is real positive.

C. RESULT AND DISCUSSION

1. Equilibrium Analysis

The proposed model (1) is analyzed using differential linearization $f(N,P)=0$ and $g(N,P)=0$. The aim at this stage is to show in detail the equilibrium point of model (3) which will be used as material for analyzing the stability of the equilibrium point, so that model (1) becomes;

$$\begin{aligned} &\beta N\left(1-\frac{N}{k}\right)-h(N)P=0, \\ &\rho(h(N)-aP-\sigma)P=0, \end{aligned} \tag{3}$$

because model (3) consists of a single predator-prey variable, making it easier for the analysis to be carried out simply. Model (3) has been linearized, so that three equilibrium points appear. Each of these equilibrium points is in a form $E^*=(N^*,P^*)$ are as follows:

$$\begin{aligned} E_1^* &= (0,0) && \Rightarrow \text{ the trivial state (empty ecosystem)}, \\ E_2^* &= (k,0) && \Rightarrow \text{ the predator-free state}, \\ E_3^* &= (P_3^*,N_3^*) && \Rightarrow \text{ the co-existence state}. \end{aligned} \tag{4}$$

The most relevant equilibrium point for further analysis is the equilibrium point $E_3^*=(P_3^*,N_3^*)$. This is done by considering the sustainability of the species life over a long period of time. Ecologically, the analysis of species extinction is highly avoided by ecologists around the world. Equilibrium point E_1^* and E_2^* It always exists in the form of any parameter, so in this research it is shown in real terms. Trivial points are often referred to as simple points in dynamic systems, and are formed naturally in mathematical modelling. Growth that does not change and stops at zero or does not experience growth is called a trivial state. While in condition E_2^* which shows the growth of free prey without the presence of predators. This is very possible to happen in ecosystems that are supported by conducive nature. Growth without predators allows for linear prey growth with carrying capacity. The greater the carrying capacity, the greater the growth of prey that can reproduce. This condition is theoretically and empirically possible, but is not a recommendation for ideal conditions in the ecosystem. This reason will create an equilibrium point E_2^* stability analysis was not carried out. At the equilibrium point E_3^* It is most possible to analyze its stability, due to positive growth for both population species. Long survival for both species is very necessary for ecosystem balance and to avoid species extinction. Coexistence between predators and prey on carrying capacity is possible if the parameters are related to predator mortality σ smaller than the predator's critical value. Variable σ is the main parameter coefficient that covers the intrinsic and extrinsic influences that contribute to predator mortality rates. Predator mortality rates greatly influence predator mortality fluctuations, for example due to predator reactions, stimulus responses, seasons, migration, density and quality of alternative food available to predators, predator-prey food preferences, environmental conditions, pollutants and disease. In model (1), the recommended amount of individual carrying capacity is known as carrying capacity which really supports the development of an increase or decrease in the amount of biodiversity or ecosystem instability (F. Zhang et al., 2019; S. Zhang et al., 2021). As a consequence of these considerations, variables k as a secondary parameter in model (1). The equilibrium point in model (1) is E_3^* It really depends on the secondary parameters already explained. Equilibrium point $E_3^* = \left(P_3^*, N_3^*\right)$ really depends on the characteristic equation that emerges, namely,

$$f(p,n) = ab^2rz^3 + \left(2abr - ab^2kr\right)z^2 + \left(k\rho\tau^2 + ar - bk\rho\sigma\tau - 2abkr\right)z - \sigma\rho k\tau - akr \qquad (5)$$

From the simplification of the characteristic equation, it can be obtained $E_3^* = \left(P_3^*, N_3^*\right)$ their respective equilibrium values are,

$$P_3^* = \frac{u_{(f)}^{\frac{2}{3}} - 2nu_{(f)}^{\frac{1}{3}} - 12mo + 4n^2}{6mu_{(f)}^{\frac{1}{3}}},$$
$$N_3^* = \frac{r\left(k - u_{(f)}\right)\left(bu_{(f)} + 1\right)}{k\tau}.$$

These two equilibrium point values will be analyzed to see the stability of model (1). The analysis was carried out by involving the Jacobian matrix and eigenvalues in the model formed. The Jacobian matrix that emerges from the equilibrium point is,

$$J_{cobian}\left(E_3^*\right)=\begin{bmatrix} j_{11} & j_{12} \\ j_{21} & j_{22} \end{bmatrix}, \tag{6}$$

where,

$$j_{11}=r\left(1-\frac{N^*}{k}\right)-\frac{rN^*}{k}-\frac{P^*\tau}{N^*b+1}+\frac{P^*N^*\tau b}{\left(N^*b+1\right)^2},$$

$$j_{12}=-\frac{\tau N^*}{N^*b+1},$$

$$j_{21}=\frac{\rho P^*\tau}{N^*b+1}-\frac{\rho P^*\tau N^*b}{\left(N^*b+1\right)^2},$$

$$j_{22}=\frac{\rho\tau N^*}{N^*b+1}-2aP^*-\sigma\rho.$$

There is a characteristic equation of the Jacobian matrix form involving the equilibrium point, namely,

$$\lambda^2+a\lambda+b=0 \tag{7}$$

It is clear that there are two factors that are the solution to the characteristic equation for testing eigenvalues based on the Routh–Hurwitz criterion. This criterion is used to test positive local stability point analysis. Further analysis is described in the numerical simulation model (1).

2. Numerical Simulation

In the numerical simulation section, the simulation form of the parameters that have been assumed in the initial discussion will be shown. The parameters taken are based more on previous research and assumptions that are relevant for each parameter in the ecosystem. Some of the parameter values given are as follows; $r=1.44$, $k=100$, $\rho=0.6935$, $\tau=1.55$, $\sigma=0.8$, $a=0.0004$, and $b=0.008$. Model (1) which is simulated gives the equilibrium point,

$$\begin{aligned} E_1^* &= (0,0) && \Rightarrow \text{ the trivial state (empty ecosystem),} \\ E_2^* &= (100,0) && \Rightarrow \text{ the predator-free state,} \\ E_3^* &= (0.521751197, 0.9280425783) && \Rightarrow \text{ the co-existence state.} \end{aligned} \tag{8}$$

From the previous description of the equilibrium point, it is mathematically clear that the stability point analysis is carried out at the equilibrium point $E_3^*=(0.521751197, 0.9280425783)$. The next analysis provided is testing the potential equilibrium point to be tested on the Jacobian matrix to see sustainable local stability. The Jacobian Matrix is given as follows,

$$J_{cobian}\left(E_3^*\right)=\begin{bmatrix} -0.00155885601 & -0.8053528046 \\ 0.9893002348 & -0.0037121706 \end{bmatrix}. \tag{9}$$

The characteristic equation associated with the Jacobian matrix above is:

$$\lambda^2 + 0.005271026610\lambda + 0.7967415054 = 0 \tag{10}$$

From the characteristic equation, the eigen factors are obtained, namely $\lambda_1 = -0.002635513305$ and $\lambda_2 = -0.002635513305$. It is clear that the eigen factors associated with the characteristic equation are negative twin roots $(\lambda < 0)$. The characteristic equation only has one unique twin solution and that point is the vertex of the solution to the equation. The dynamic system in this model analysis shows the condition that the dynamic system reaches a stable condition. This is because the exponential of negative values will go to zero as time goes by. The dynamic system will return to the equilibrium point without being isolated after the dynamic system is disturbed. From the mathematical calculations shown in the explanation above, it is clear that a locally stable equilibrium point can be the basis for positive population growth of the Barrumundi species. The growth shown apparently does not have a significant effect on the nature of existing cannibalism. The sensitivity of the model can be shown in the relationship between the cannibalism variable and the dynamic system of the model (1). Predatory species that carry out cannibalism or prey on their own friends will not make the Barrumundi species extinct. The simulated model really strengthens these characteristics. Stable population growth has the potential for exploitation or harvesting efforts.

3. Trajectories

This section, an analysis of the shape of the trajectories emerging from model (1) is shown. The shape of the trajectories cannot be separated from the parameters chosen from the previous discussion. Parameters really determine the shape of existing trajectories. Parameter changes are not given in this analysis, because this research focuses on forms that are constant in units of time. The purpose of this trajectory analysis is to see the direction of population growth towards the local stability point formed by model (1). The assumed initial condition to start trajectory analysis is the initial value $N(0) = 0.52$ and $P(0) = 0.93$. The trajectory picture that appears is as shown in Figure 2, Figure 3 and Figure 4.

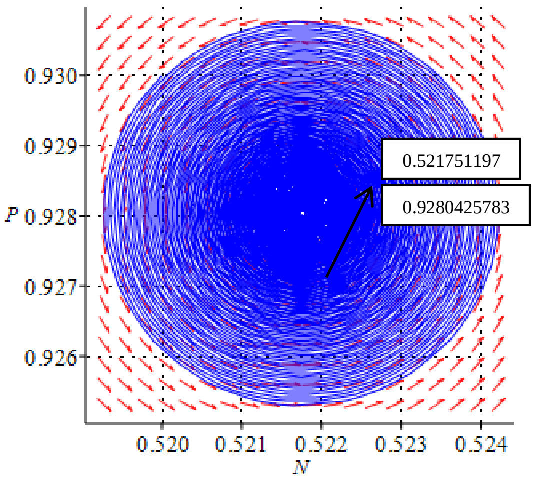

Figure 2. Approximate Local Stable Equilibrium Value Model

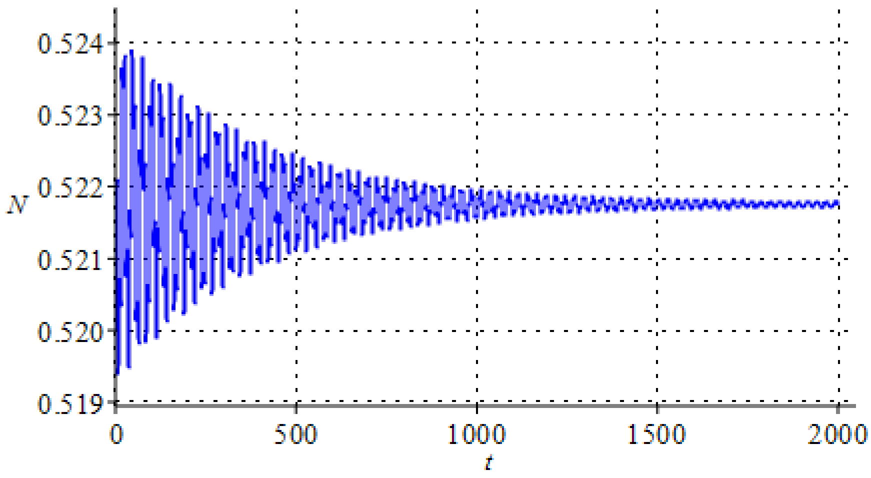

Figure 3. Trajectories Population Susceptible N

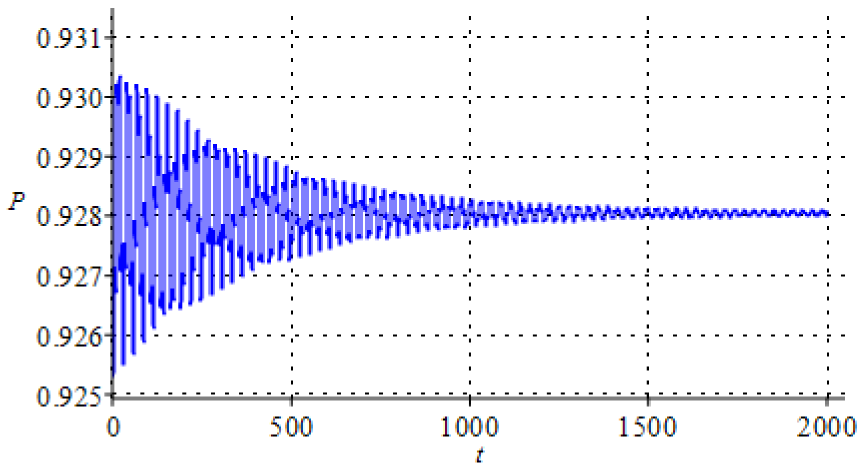

Figure 4. Trajectories Population Susceptible P

The trajectories above have illustrated the equilibrium point scheme and the form of population growth of the Barramundi species. Fig 2 has seen a locally stable equilibrium point value over a long period of time. The vicinity of a stable equilibrium point value determines the sustainability of population dynamics. The equilibrium point around it will also provide a form of positive growth. The growth of the equilibrium point cycle is in the direction of time t , the longer it takes to grow, the greater the point of stability that meets it. All points that are on the stability trajectory in Fig 2 will produce local stability in the model. While in Fig 3 You can see population growth with very sharp fluctuations at the beginning of the disturbance. In ecosystem life, this often happens because the balance system of the predator population is disturbed. The same thing usually happens to prey species at the beginning of predation. In predator and prey species, the fluctuations that occur are very similar and have high significance. In a short time, ups and downs in growth can occur 2 or 3 times leading to stability. Predation on the rising curve will be proportional to the falling growth curve. Dynamic processes like this tend to have stronger interactions in ecosystems with natural carrying capacity and are not overexploited. Model (1) with the simulation provided shows that the model is not easy to stabilize. Model (1) takes a very long time to reach a local stable state.

The discussion there were several things that became interesting regarding the limitations and sustainability of knowledge about population dynamics. The place where the species' ecosystem is born plays an important role in shaping the characteristics or traits of the species. Dogamit Swamp is also a determining factor in the growth and development of Barramundi species. In the model form described above, it is clear that carrying capacity also determines the equilibrium value factor. The basic assumptions in the model are the basic things that begin the development of knowledge of population dynamics. Likewise, the Dogamit swamp has the characteristics of a living swamp. Dogamit Swamp is a swamp that has never dried up in its development to date, this has caused the growth of species to occur from generation to generation. Exploitation efforts were also not carried out significantly, because the local community still upholds "sasi'' or the traditional tradition of maintaining a sustainable ecosystem. However, exploitation parameters can still be considered in the future. Exploitation efforts are considered if species growth based on model (1) has grown in a positive direction. The shape of the Dogamit swamp never dries out, making the swamp water likely to be a place for disease to grow. Like the concept of water that never flows, of course various types of diseases will quickly grow. So from these assumptions, it is appropriate that model (1) should be developed in the scheme of species that have or suffer from disease. The potential for the Barramundi species, which is a predator of the Dogamit swamp, to suffer from disease or become a spreader of infection is very possible. Moreover, this predator is included in the category of very wild aquatic species, eating all kinds of prey.

Based on the results of research observations, the species that survive for a long time are those that live in deep water areas. Station III turns out to be the place where most Barramundi species can be found, when compared with station II and station I. This can also happen because station III is a gathering place for Barramundi food sources. Another interaction that is crucial in the development of population dynamics models is intraspecific interactions. This interaction often occurs with wild predators and is very similar to cannibalism (Li et al., 2019; Mishra et al., 2021; Strauss et al., 2016). Intraspecific interactions are more inclined towards mutual defense in the struggle for food resources, while the characteristic of cannibalistic interactions is eating members of the same species if their food resources have run out. Cannibalism parameters can be submitted as a next research proposal, as a development of the dimensions of the dynamic system.

D. CONCLUSION AND SUGGESTIONS

This research uses variables that are arranged based on the characteristics of the Barramundi predator as an inhabitant of the Dogamit swamp. The Dogamit swamp, which is still preserved, is one of the research interests. Variable deployment $N(t)$ for predator species and $P(t)$ for prey species. All basic assumptions about the nature and characteristics of predators are given based on the results of observations and scientific theory studies based on relevant research. The mathematical model formed supports the growth of the Lotka-Poltera dynamic model. Predator species are represented by the Barramundi species and prey are all species that live in the Dogamit swamp. This assumption was given after the results of research observations were carried out, predator species eat all types of resources. The dynamic model formed is model (1) which creates an equilibrium point co-existence state $E_3^* = (P_3^*, N_3^*) = (0.521751197, 0.9280425783)$. The realistic equilibrium point considered is one where the non-negative equilibrium point is analyzed using the Jacobian matrix to obtain eigenvalues. The eigenvalues that appear indicate that the Routh-Hurwitz criteria for the population dynamics model are fulfilled for a locally stable equilibrium point. Each eigenvalue that emerges from model (1) is $\lambda_1 = -0.002635513305$ and $\lambda_2 = -0.002635513305$. These two eigenvalues show clearly that the equilibrium point of $E_3^* = (P_3^*, N_3^*)$ has stabilized locally. Meanwhile, in trajectory analysis, the growth of each population forms similar fluctuations. There is always significant growth and there is also low growth in the Barramundi population. This is because in terms of habitat and life in the ecosystem, predator and prey species also have similarities. This is because fish that live in the Dogamit swamp ecosystem do not have circulation to large waters. Another interesting finding is that when the two populations experience disturbances in model (1), their stable growth takes a very long time. Population growth that takes a very long time to a point of stability usually occurs due to ecosystem demographic factors, environmental changes and migration. Ecosystem demographic factors and environmental changes are the most common factors. This is also confirmed in relevant previous research, which states that demographic factors greatly influence the stability of a mathematical model. These factors are strongly supported by carrying capacity parameters and other variables. Other research also explains that stability over a long period of time usually occurs because of the unique traits/characteristics possessed by the species, usually occurring in endemic species. The existence of endemic species is very important for local species, because these species usually play a key role in the food chain and maintain the ecological balance in their habitat. This happens to the Barramundi fish species which lives in the Dogamit swamp waters.

This research basically only focuses on the predator species, namely the Barramundi species, while the prey species and other species around it have not been taken into account in real terms. In future research, the model can be studied in depth by involving the type of predation variable and considering the stage-structure for the Barramundi species specifically. The urgency is that not all species have the same development when they are small and mature. Like this barramundi fish, it can have sex changes when it reaches adulthood, which occurs naturally. Other ecological studies also show differences in predation traits and life age characteristics before and after barramundi sex change. This variable can be studied in depth to explore the potential for knowledge in mathematical modeling in the future. The stage-structure variable will greatly influence the dynamic model that is prepared because it is more realistic for describing population growth. The more realistic the modeling is, the more it will depict real ecosystem life.

REFERENCES

Al-salman, A. M., Páez, J., & Putra, K. (2021). A modeling study of predator – prey interaction propounding honest signals and cues. *Applied Mathematical Modelling*, *89*, 1405–1417. https://doi.org/10.1016/j.apm.2020.08.028

Binur, R. (2010). Komposisi jenis ikan air tawar di daerah lahan basah Kaliki , Merauke Papua. *Iktiologi Indonesia*, *10*(2), 165–178. http://jurnal-iktiologi.org/index.php/jii/article/view/168

Cain, P. W., & Mitchell, W. A. (2021). Modelling the sequential behaviours of simultaneous predator and prey patch use. *Animal Behaviour*, *177*((7)), 49–58. https://doi.org/10.1016/j.anbehav.2021.04.016

Condon, K., Bochow, S., Ariel, E., & Miller, L. (2019). Complete Genome Sequences of Betanodavirus from Austalian Barramundi (Lates calcarifer). *Microbilogy Resource Announcements*, *8*(16), 18–19. https://doi.org/https://doi.org/10.1128/MRA .00081-19.

Google Earth. (2024). *Rawa Dogamit*. Google Earth. https://earth.google.com/web/

Li, J., Zhu, X., Lin, X., & Li, J. (2019). Impact of cannibalism on dynamics of a structured predator-prey system. *Applied Mathematical Modelling*, *78*(19), 1–19. https://doi.org/10.1016/j.apm.2019.09.022

Maloky, S., Mote, N., & Melmambessy, E. H. P. (2021). Keanekaragaman Jenis Ikan Di Perairan Rawa Dogamit Taman Nasional Wasur Merauke. *ACROPORA: Jurnal Ilmu Kelautan Dan Perikanan Papua*, *4*(2), 48–53. https://doi.org/10.31957/acr.v4i2.1904

Mishra, P., Raw, S. N., & Tiwari, B. (2021). On a cannibalistic predator–prey model with prey defense and diffusio. *Applied Mathematical Modelling*, *90*(21), 165–190. https://doi.org/10.1016/j.apm.2020.08.060

Nuha, A. R., Nasib, S. K., & Nashar, L. O. (2024). Dynamical Analysis of a Predator-Prey Model Involving Intraspecific Competition in Predator and Prey Protection. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *8*(3), 706–723. https://doi.org/https://doi.org/10.31764/jtam.v8i3.22154 Th

Pratama, R. A., Ruslau, M. F. V., Nurhayati, & Laban, S. (2019). Analysis stability of predator-prey model with Holling type I predation response function and stage structure for predator Analysis stability of predator - prey model with Holling type I predation response function and stage structure for predator. *ICROEST*. https://doi.org/10.1088/1755-1315/343/1/012161

Pratama, R. A., & Toaha, S. (2023). Analysis Dynamics Two Prey of a Predator-Prey Model with Crowley – Martin Response Function. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *7*(3), 864–875. https://doi.org/https://doi.org/10.31764/jtam.v7i3.14506

Pratama, R. A., Toaha, S., & Kasbawati. (2019). Optimal harvesting and stability of predator prey model with Monod-Haldane predation response function and stage structure for predator. *The International Conference on Geoscience*. https://doi.org/10.1088/1755-1315/279/1/012015

Ribeiro, F. F. (2015). *Cannibalism in Barramundi Lates calcarifer : Understanding Functional Mechanisms and Implication to Aquaculture*. Flinders University. https://theses.flinders.edu.au/view/03b7781d-eedc-4ff0-98ab-53a8cb5f9e98/1

Savoca, S., Grifó, G., Consolo, G., Panarello, G., Albano, M., Giacobbe, S., Capillo, G., & Spanó, N. (2020). Modelling prey-predator interactions in Messina beachrock pools. *Ecological Modelling*, *434*(July), 109206. https://doi.org/10.1016/j.ecolmodel.2020.109206

Strauss, T., Kulkarni, D., Preuss, T. G., & Hammers-wirtz, M. (2016). The secret lives of cannibals : Modelling density-dependent processes that regulate population dynamics in Chaoborus crystallinus. *Ecological Modelling*, *321*(16), 84–97. https://doi.org/10.1016/j.ecolmodel.2015.11.004

Warsa, A., Astuti, L. P., & Satria, H. (2007). Sungai Maro : Salah Satu Sumber Plasma Nutfah. *BAWAL*, *1*(31), 183–189. http://ejournal-balitbang.kkp.go.id/index.php/bawal/article/view/3805

Zhang, F., Chen, Y., & Li, J. (2019). Dynamical analysis of a stage-structured predator-prey model with cannibalism. *Mathematical Biosciences*, *307*(August 2018), 33–41. https://doi.org/10.1016/j.mbs.2018.11.004

Zhang, S., Zhang, T., & Yuan, S. (2021). Dynamics of a stochastic predator-prey model with habitat complexity and prey aggregation. *Ecological Complexity*, *45*(June 2020), 100889. https://doi.org/10.1016/j.ecocom.2020.100889