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Role of Natural Food in Enhancing the Productivity of Saline Nile Tilapia in the Mangrove Ecosystem of Segara Anakan Lagoon, Brackish Water Culture

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Abstract

Saline Nile Tilapia, Oreochromis niloticus (Linnaeus, 1758) and Milkfish, Chanos chanos (Forskal, 1775) polyculture systems in brackish water culture require natural food to sustain their brackish water fish production. Brackish water culture of Saline Nile Tilapia is developed to improve the productivity of abandoned shrimp or crab pond. At present, there are no studies examining the potential of natural food to improve the productivity of these polyculture systems in the brackish water pond located in Tritih Kulon Village, Cilacap, Central Java. To assess the availability of this food source, the diversity and abundance of plankton in the water body were evaluated through analysis. Therefore, this study aimed to analyze plankton diversity in the water body and the relationship between plankton abundance as a natural feed and saline Nile Tilapia productivity in the brackish water polyculture. Phytoplankton and zooplankton were identified according the plankton characteristic available in the references. The results showed that 21 planktons, comprising 12 phytoplankton species and 9 zooplankton groups, were identified. In spite of low plankton diversity, however, this study proved that the plankton abundance positively supported Saline Nile tilapia productivity in the polyculture system with milkfish, as indicated by low mortality (17,5 ±8,59 %; R^2= 0.825-0.908), absolute high weight gain (208.2 ± 22,5 gr; R^2= 0.881-0.874), and high specific growth (2,28 ± 0.77 % day^{-1}; R^2= 0.87-0.91). The productivity of Saline Nile Tilapia in brackish water polyculture with milkfish is supported by the availability of natural food, with 5.95 to 18.50% of their gut content obtained from plankton.

Keywords: *abundance, brackish water pond, fishery, monoculture, phytoplankton*

Introduction

The Brackish water culture is divided into two different systems, monoculture and polyculture (Cochard, 2017; Hu *et al.,* 2020; Zhu *et al.,* 2022; Jansen *et al.,* 2023). Additionally, brackish water aquaculture can be carried out in areas with abundant natural food sources, such as estuaries and mangrove ecosystems (Duncan *et al.,* 2016; Hilmi *et al.,* 2021b, a; Soedibya *et al.,* 2021; Murniasih *et al.,* 2022). The development of a brackish water polyculture system enhances fish productivity per unit area and maintain water quality (Ekasari *et al.,* 2015; Rose *et al.,* 2015). A brackish water polyculture is an aquaculture system between two or more fish species or aquatic organisms, such as milkfish and prawn or shrimp polyculture (Soedibya 2013; Rachmawati and Samidjan 2014; Nuryanto *et al.,* 2017; Soedibya *et al.,* 2017). Some research reported polyculture between Milkfish and Nile Tilapia (Soedibya, 2013; Mutia *et al.,* 2018; Muyot *et al.,* 2018), while others described a polyculture between prawn or shrimp and Nile Tilapia in brackish water (Mutia *et al.,* 2018; Prabu *et al.,* 2019; Hilmi *et al.,* 2021b, 2022; Murniasih *et al.,* 2022).

Natural food is necessary to support fisheries productivity (Hartati *et al.,* 2017; Albertson *et al.,* 2018; Pusey *et al.,* 2020; Thoral *et al.,* 2021), including in brackish water fish (Kama *et al.,* 2014; Mondal and Chakravortty, 2015; Mondal and Mitra, 2016). The natural food of fish includes plankton, aquatic plants, small invertebrates, benthic fauna, detritus, and bacteria associated with detritus (Mendoza and Henkel, 2017; Andriyani *et al.,* 2018).

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Previous studies showed that plankton availability and abundance are essential for fish growth and productivity (Henmi *et al.,* 2017; Andriyani *et al.,* 2020; Alam *et al.,* 2021).

Plankton diversity and abundance support polyculture productivity, as reported from several regions (Soedibya, 2013; Mutia *et al.,* 2018; Kusuma *et al.,* 2019). Some studies reported the support of natural food in the polyculture pond of Nile Tilapia, *Oreochromis niloticus* (Soedibya, 2013; Ahsan *et al.,* 2014; Ekasari *et al.,* 2015; Kusuma *et al.,* 2019; Samidjan *et al.,* 2020). Also, other studies found similar data in Milkfish *Chanos chanos* (Sihombing *et al.,* 2017; Muyot *et al.,* 2018). There are no reports on plankton diversity and abundance in saline Nile Tilapia and milkfish polyculture in the brackish water pond. The data are essential for developing the brackish water polyculture of both species.

Saline Nile Tilapia (Soedibya, 2013; Ekasari *et al.,* 2015; Kusuma *et al.,* 2019) is a tropical fish in shallow waters that thrives in an aquatic ecosystem with varying salinities (Basuki and Rejeki, 2015; Kusuma *et al.,* 2019; Prabu *et al.,* 2019), hence, they can adapt and live in brackish water with a salinity of about 25‰ (Ninh *et al.,* 2014). Furthermore, these species are classified as omnivorous fish because they consume a broad spectrum of feed including phytoplankton, periphyton, aquatic plants, small invertebrates, benthic fauna, detritus, and bacteria associated with detritus (Mendoza and Henkel, 2017; Neal *et al.,* 2018; Takenaka *et al.,* 2018; Teoh *et al.,* 2018; Setyawati *et al.,* 2019; Rahman *et al.,* 2021). The ecological benefits of Saline Nile Tilapia have been used to develop brackish water aquaculture and it has been polycultured with various fisheries products (Soedibya, 2013; Ekasari *et al.,* 2015; Muyot *et al.,* 2018). Therefore, the intensive polyculture of saline Nile Tilapia and Milkfish, *Chanos chanos* has been carried out in ponds (An and Anh, 2020; Samidjan *et al.,* 2020).

Tritih Kulon Village is located in North Cilacap District, Cilacap Regency, Central Java, Indonesia. Furthermore, the village has an area of 503.43 hectares consisting of land and swampy brackish water areas, including mangrove and lagoon ecosystems (Hilmi *et al.,* 2019, 2021a, b). The saline water areas were used by previous studies for shrimp aquacultures, as this was a profitable business for the villagers at that time, due to high prices. However, shrimp production has currently declined, leading to business failure. This condition has persisted in South Java, from Bantul to Cilacap Regencies, for the past four years. The shrimp pond in Tritih Kulon Village was abandoned and unproductive. Therefore, this study offered a solution by outlining the potential for using an abandoned brackish water shrimp farming pond as polyculture area between Saline Nile Tilapia and Milkfish. Studying plankton diversity in a polyculture pilot pond of Saline Nile Tilapia, *O. niloticus*, and Milkfish, *C. chanos* is necessary. Therefore, this study aimed to analyze plankton diversity and abundance as natural food in the brackish water polyculture pond of Saline Nile Tilapia with Milkfish in Tritih Kulon Village.

Materials and Methods

The brackish water culture located in the Tritih Kulon Village, North Cilacap District, Cilacap Regency, Central Java, Indonesia (Figure 1.) (Hilmi *et al.,* 2021a,b,c,d). Furthermore, it is a traditional earthen pond (abandoned former shrimp or crabs pond) with an area of 2000 m^{-2} width.

Pilot pond preparation for polyculture

Water inflow and outflow occur naturally in response to tidal currents (Soedibya, 2013; Muyot *et al.,* 2018; Prabu *et al.,* 2019). This pond was prepared by reversing the bottom for soil oxidation and killing fish disease-causing organisms. The soil acidity was neutralized by adding ten sacks of lime to the surfaces and draining the pool for two weeks. Then, the pond was fertilized using chicken manure and filled with water to a depth of approximately 10 cm, to allow plankton growth. The water level was elevated to a height of approximately 1.5 meters and kept at that level by adjusting the inlet and outlet openings accordingly.

Preparation, stocking, and cultivation of fish seeds

The seeds of *Oreochromis niloticus* and *Chanos chanos* were obtained from Brackish Water Aquaculture Research Center (BBPBAP) Jepara, Central Java, Indonesia. The average length of Saline Nile Tilapia seeds was 3.1 ± 0.241 cm, with an average body weight of 5.36 ± 0.21 g. Whilst the initial length of milkfish seeds was 1.5 cm with initial weight was 0.5 g (Ekasari *et al.,* 2015; An and Anh, 2020).

Both fish seed species were acclimatized for 2 h before stocking in a pilot earthen pond, with a density of five individuals per m^2 for Saline Nile Tilapia and a total stocked fish of 10,000 seeds. In contrast, stocking density of milkfish seeds were 3 individuals per m^2. The fish were fed fine pellets for the first two weeks of rearing and then 1000-size pellets once they had grown to a length of 5 cm. After six weeks, they were provided with pellet number 2000 (Soedibya, 2013).

Plankton collection and identification

Weekly samples of plankton were collected for the ten weeks of polyculture periods (August-October

2021). Also, 10 L bucket was used to collect water samples, which were filtered using plankton net number 25. The water samples were filtered ten times to attain a total volume of approximately 100 L. The plankton was obtained in a collection bottle and then removed from the plankton net. The filtered plankton was transferred into sample bottles and preserved using formalin until the final concentration was 4% and two drops of pure Lugol were added (Tsuji and Montani, 2017; Andriyani *et al.,* 2020).

Plankton identification was carried out under a binocular microscope with a magnification of 10 x 40. Plankton identification was done using the figure in the identification keys (Henmi *et al.,* 2017; Sihombing *et al.,* 2017), and plankton abundance was calculated using the formula (Arumugam *et al.,* 2016; Andriyani *et al.,* 2020; Asmarany *et al.,* 2022):

$$\text{Abundance (F)} = [(A/B) \times (C/D) \times (E/F)]\ \text{cell.L}^{-1}$$

Note: A= Water volume in a bottle sample (30 mL); B= Water volume observed (0.06 mL); C= Cover glass width (484 mm^2); D= view field number (20); E= number of plankton individual; F= total volume of filtered water (100 L)

Saline Nile tilapia growth

The absolute growth of body weight (WG) in Saline Nile Tilapia was measured weekly for ten weeks. In addition, a balance with an accuracy of 0.01 g was used to measure the body weight. Absolute body weight growth was calculated as follows (Soedibya, 2013; Muyot *et al.,* 2018):

$$W_G = W_t - W_i$$

Note: W_G= absolute weight growth; Wt= body weight after t-time; Wi= initial body weight

Specific growth rate

According to the method of Rachmawati and Samidjan (2014), Ekasari *et al*. (2015), Soedibya *et al*. (2017) and Soedibya *et al*. (2021) the specific growth rate (µ) was calculated from the initial and final densities during the cultivation period.

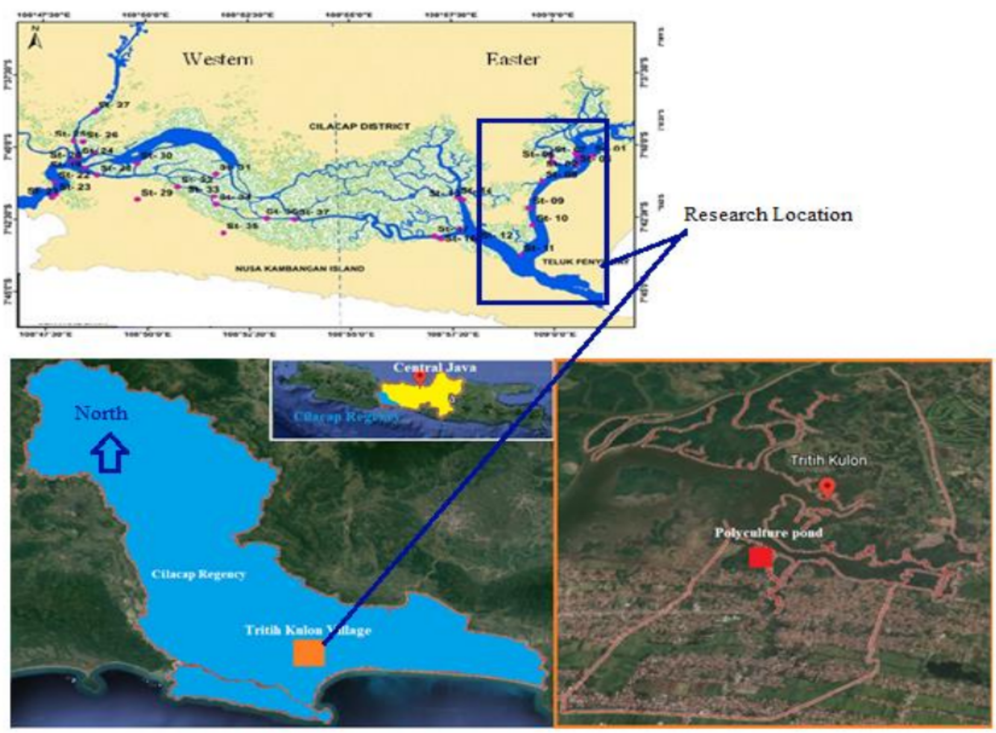

Figure 1. Location of Tritih Kulon Village, North Cilacap District, Cilacap Regency Central Java indicating the polyculture pond of *Oreochromis niloticus* and *Chanos chanos*

$$\mu = \frac{\ln(x2) - \ln(X1)}{t2 - t1}$$

Where X2 and X1 are the final and initial densities, t2 and t1 are the final and initial cultivation time, respectively. The specific growth rate was noted as cells.day^{-1}, and this study calculated phytoplankton doubling time based on the specific growth rate according to the following equation:

$$g = \frac{\ln 2}{\mu}$$

The relation between plankton to Saline Nile tilapia growth

Based on weekly plankton abundance and Saline Nile Tilapia growth, this study estimated the potential of plankton to support saline growth. The data on plankton diversity and abundance were descriptively analyzed in this study, and the result was compared to the information available in previous publications. Additionally, Pearson correlation and regression were used to analyze the potential of plankton to support Saline Nile tilapia growth (Karl and Church, 2017; Hilmi *et al.,* 2020).

Result and Discussion

Natural food diversity and abundance

Plankton identification from the brackish water polyculture pond of Saline Nile Tilapia and Milkfish found about 21 plankton species, comprising 12 phytoplankton and 9 zooplankton species. Table 1 showed the weekly plankton diversity, diversity index, and absolute abundance.

Table 1 demonstrated that the phytoplankton obtained consisted of three classes, including Cyanophyceae, Dinophyceae, and Bacillariophyceae. Similarly, six zooplankton classes, namely Codonillidae, Arthropoda, Protozoa, Mollusca, Crustacea, and Rotifera, were observed during the study. The results showed that the diversity of plankton classes was lower than in other studies. Specifically, a smaller number of plankton classes was recorded compared to the studies conducted by Nugroho *et al*. (2020) and Sastranegara *et al*. (2020) in the Segara Anakan estuary. The difference is that this study was conducted in a semi-closed ecosystem and narrow areas, while Nugroho *et al*. (2020) and Sastranegara *et al*. (2020) were carried out in open water and broader areas covering across Segara Anakan estuary. Previous studies reported that wider and more variable habitats may result in phytoplankton diversity (Wiyarsih *et al.,* 2019; Priska *et al.,* 2020).

Table 1 showed that 12 phytoplankton and 9 zooplankton species were observed during the study. The data indicated low species diversity of phytoplankton which was also supported by a low phytoplankton diversity index, ranging between 1.44 and 2.23 and 1.85 to 2.06 for zooplankton (Table 1.). However, previous studies were carried out in wider areas across Segara Anakan estuary (Nugroho *et al.,* 2020; Sastranegara *et al.,* 2020); Tidung Island (Rachman, 2020), and with heterogenous ecological conditions (Wiyarsih *et al.,* 2019). Previous studies noted that different ecosystems have varying plankton diversity due to differences in ecological factors and nutrient availability. Therefore, a lower phytoplankton diversity was found than those previous studies.

Table 1 also showed that phytoplankton and zooplankton abundance ranged from 455 to 908 cell.L^{-1} and 253 to 463 cells.L^{-1}, respectively, indicating low plankton abundance. The data also indicated that the brackish water polyculture pond was less fertile or at the mesotrophic level. Therefore, further study on the trophic level of the pond is necessary to estimate the trophic index (Ismail *et al.,* 2018).

This study obtained lower phytoplankton and zooplankton abundance than previous studies in the Segara Anakan estuary (Wiyarsih *et al.,* 2019; Nugroho *et al.,* 2020; Sastranegara *et al.,* 2020) due to differences in sampling locations width and variability of water salinity. Furthermore, this study was conducted in a narrow brackish water pond, while previous studies were carried out in wide areas across the Segara Anakan estuary. The difference in sampling coverages and variability results in different phytoplankton diversity and abundance because each sampling site has their fertility (Wiyarsih *et al.,* 2019; Priska *et al.,* 2020). Moreover, variations in the physical environments influence plankton diversity and abundance (Pratiwi *et al.,* 2016; Ormańczyk *et al.,* 2017; Putri *et al.,* 2019).

The abundance of natural food, particularly plankton, can be used to estimate the potential to support Saline Nile Tilapia polyculture with Milkfish. Furthermore, Bacillariophyceae provided the highest support because it was the most abundant phytoplankton in the brackish water polyculture pond, followed by Dinophyceae, and Cyanophyceae had the lowest potential (Table 1.). For the zooplankton groups, *Nitzia, Diatoma, Chaetoceros*, Rotifera, Chodonillidae, and Arthropoda supported Saline Nile Tilapia productivity in polyculture with Milkfish. Also, the support of natural food on Saline Nile Tilapia productivity is strengthened by comparing the abundance and gut content analysis. Additional support was also obtained from correlation analysis

Table 1. The diversity and abundance of plankton in the brackish water system

Classis/Species	Abundance (cell.L^{-1}) in sampling plots										Confindence interval
	1	2	3	4	5	6	7	8	9	10	
Phytoplankton											
Cyanophyceae											
Oscillatoria	822	121	251	311	184	286	384	611	167	282	341.9±217.29
Dinophyceae											
Peridinium	1.302	212	114	221	377	211	306	288	601	719	435.1±357.50
Prorocentrum		412	218	174	89	281	241	418	291	339	246.3±133.42
Bacillariophyceae											
Navicula	481	504	417	385	1.298	738	781	552	828	829	681.3±275.43
Nitzia	781	1.027	818	1.219	3.036	1.833	2.077	1.865	2.199	3.071	1,792.6±838.09
Rhizosolenia	241	438	221	371	218	638	721	811	719	693	507.1±234.34
Diatoma	1.799	2.385	1.755	1.544	311	1.539	2.190	3.082	2.710	2.804	2,011.9±808.14
Striatella	422	390	271	315	278	529	481	365	391	380	382.2±82.38
Pleurosigma	251	622	315	128	276	383	485	391	588	429	386.8±152.79
Chaetoceros	204	281	316	285	3.138	1.89 2	926	819	692	539	909.2±928.53
Coscinodiscus	151	189	326	618	261	522	419	791	839	549	466.5±239.83
Fragillaria		765	433	221	141	523	409	591	285	263	363.1±226.94
total	6454	7346	5455	5792	9607	9375	9420	10584	10310	10897	
abundance (cell.L^{-1})	645	612	455	483	801	781	785	882	859	908	
Diversity	1,44	2,14	2,18	2,18	1,81	2,23	2,22	2,20	2,17	2,09	
Zooplankton											
Codonillidae											
Tintinnopsis	219	316	467	361	363	412	504	629	523	528	432.2±120.99
Arthropoda		263	329	442	388	327	628	721	572	422	409.2±204.20
Protozoa	241	421	329	289	207	284	286	275	319	318	296.9±57.15
Mollusca	352	327	287	391	319	321	319	428	329	409	348.2±45.85
Crustacea	252	316	337	209	281	255	777	489	417	379	371.2±165.69
Rotifera											
Lapadella	174	215	255	186	228	347	429	519	438	379	317±121.34
Brachionus	306	218	203	408	391	436	389	328	372	351	340.2±78.13
Cephalodella	231	242	429	291	207	230	281	361	369	328	296.9±72.97
Colurella	250	362	274	422	501	427	389	421	408	367	382.1±74.35
Total	2025	2680	2910	2999	2885	3039	4002	4171	3747	3481	
abundance (cell.L^{-1})	253	298	323	333	321	338	445	463	416	387	
Diversity	2,06	1,95	1,92	1,88	1,88	1,94	1,85	1,85	1,89	1,93	

between natural food abundance and productivity parameters.

The Potential of Natural Food to Support Saline Nile Tilapia Productivity in Brackish Water Polyculture

The potential of natural food to support Saline Nile Tilapia productivity is indicated by the abundance of zooplankton and phytoplankton in the gut compared to the natural abundance. Furthermore, the abundance of phytoplankton and zooplankton in natural food were 721±163,2 cells.L^{-1} and 358± 67,6 cells.L^{-1}, respectively. Table 2 showed that the amount of phytoplankton and zooplankton inside the gut of saline Nile Tilapia were 73.8±43.71 and 35.9 ± 8.59, respectively.

Table 2 showed that an increase in natural food abundance had a positive effect on the absolute growth and specific growth rate of Saline Nile Tilapia. However, plankton abundance had negative impact on mortality. The data depicted that natural food abundance had a positive impact on productivity, as shown by low mortality, high absolute weight growth, and high specific growth rate with a value of 17,5 ±8,59 %, 208.2±22,5 gr, and 2,28±0.77%.day^{-1}, respectively. In addition, Saline Nile Tilapia productivity is affected by several factors, including food abundance and ecological characteristics. Previous studies showed that natural food had a positive impact on specific growth and survival rate (Soedibya, 2013; Soedibya *et al*., 2017; Soedibya *et al*., 2021). Other studies also reported that water salinity, diseases, and natural food influenced absolute growth, specific growth rate, and fish survival (Soedibya, 2013; Basuki and Rejeki, 2015; Ekasari *et al*., 2015; Kusuma *et al*., 2019). This support was strengthened by the correlation analysis between plankton abundance and productivity parameters.

The correlation between phytoplankton abundance and Saline Nile Tilapia growth

According to R^2 values ranging from 0.8707 to 0.9069, there is a strong positive correlation between phytoplankton abundance and specific growth rate. Similar correlations were observed between phytoplankton abundance and absolute growth, with R^2 values ranging from 0.8736 to 0.8814. These values illustrated that an increase in phytoplankton abundance was significantly followed by Saline Nile Tilapia growth. However, a negative correlation was observed between phytoplankton abundance and the mortality of the fish, with R^2 values ranging between 0.8250 to 0.9075 (Figure 2). The R^2-values of mortality proved that an increase in phytoplankton abundance was followed by low mortality. Furthermore, the correlation data demonstrated that phytoplankton abundance supported Saline Nile Tilapia productivity in the brackish water polyculture system with Milkfish. The phytoplankton give positive impact to support Nila growth and weight and give decreasing rate for mortality of Nila saline.

The correlation between zooplankton abundance and Saline Nile Tilapia productivity

Zooplankton abundance correlated positively with absolute and specific growth rates, with R^2 values ranging from 0.5811 to 0.6821 and 0.5308 to 0.6243, respectively. This indicated that a rise in zooplankton was followed by an increase in Saline Nile Tilapia growth. However, a negative correlation was observed between zooplankton abundance and Saline Nile Tilapia mortality, with R^2 values ranging from 0.5068 to 0.6242 (Figure 3.), where the increase of zooplankton abundance is accompanied by lower mortality. The data demonstrated that zooplankton, as a natural food, promotes Saline Nile Tilapia productivity in a brackish water polyculture system. The similar with impact of phytoplankton, zooplankton also give positive impact to support Nila growth and weight.

The comparison of R^2 values in Figures 2 and 3 showed that zooplankton has a lower support for Saline Nile Tilapia productivity than phytoplankton. Additionally, zooplankton abundance significantly

Table 2. The potential natural feeding, growth and gut content of Nile of Tilapia

Station	Phytoplankton		Zooplankton		Nile Tilapia						
					Fish Growth			Potential of Gut content		Percent of Gut content	
	Abundance (ind.L^{-1})	Diversity	Abundance (ind.L^{-1})	Diversity	Mortality (%)	Weight absolute (gr)	Specific growth (%.day^{-1})	Phytoplankton in gut content (Ind.ml^{-1})	Zooplankton in gut content (Ind.ml^{-1})	Percent of n gut content of phytolankton (%)	Percent of n gut content of zooplankton (%)
1.	645	1,44	253	2,06	28,67	194,03	1,48	46	34	7,1 (46/645)	13,4
2.	612	2,14	298	1,95	25,33	187,04	1,37	44	23	7,2	7,7
3.	455	2,18	323	1,92	27,33	171,3	1,3	43	31	9,5	9,6
4.	483	2,18	333	1,88	25,33	187,04	1,51	63	22	13,0	6,6
5.	801	1,81	321	1,88	10,67	223,1	2,71	64	35	8,0	10,9
6.	781	2,23	338	1,94	16,67	201,3	2,51	52	33	6,7	9,8
7.	785	2,22	445	1,85	15,33	229,4	2,94	33	36	4,2	8,1
8.	882	2,2	463	1,85	10,67	230,2	2,95	126	56	14,3	12,1
9.	859	2,17	416	1,89	7,33	224,6	2,82	99	65	11,5	15,6
10.	908	2,09	387	1,93	6,67	233,53	3,23	168	24	18,5	6,2
average	721	2,07	358	1,91	17,4	208,15	2,28			100,0	100,0
Stdev	163,1	0,25	67,59	0,06	8,59	22,54	0,77				

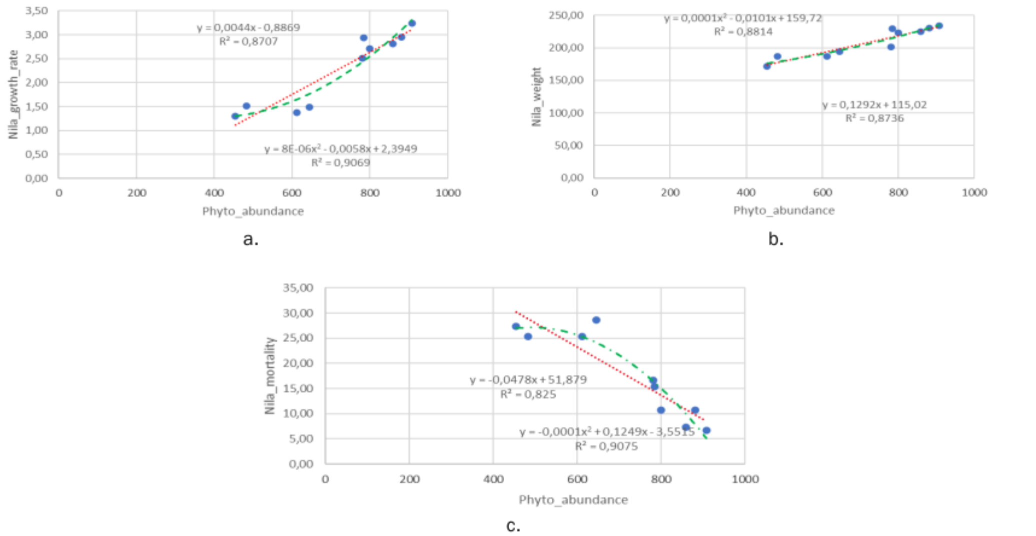

Figure 2 Relationship between abundance of phytoplankton with Nila Tilapia growth a. growth rate; b. weight; c. mortality

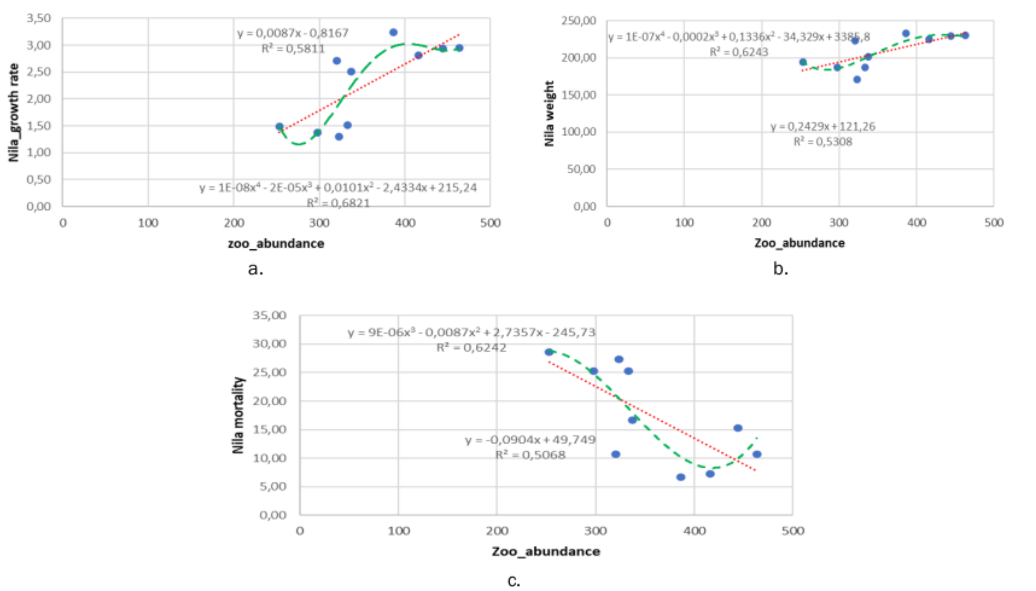

Figure 3. Relationship between abundance of zooplankton with Nila Tilapia growth a. growth rate; b. weight; c. mortality rate

supports Saline Nile Tilapia productivity, because R^2 values between zooplankton abundance and productivity parameters were above 0.5. Previous studies emphasized the importance of natural food sources in fisheries productivity (Albertson *et al.*, 2018; Thoral *et al.*, 2021; Wibowo *et al.*, 2022).

Conclusion

A total of 21 plankton species, which consisted of 12 phytoplankton and 9 zooplankton species were found in a brackish water polyculture pond in Tritih Kulon Village. The parameters and correlation analysis provided strong evidence that natural food abundance significantly supports Saline Nile Tilapia productivity, as indicated by low mortality, high absolute growth, and specific growth rate.

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