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RESEARCH ARTICLE

# Role of Insect Pests in Minapadi Systems as Natural Feed for Catfish and Their Impact on Pest Control

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**ABSTRACT**

Minapadi is a term for the integrated cultivation of rice and fish. This study aimed to: (1) determine the potential of insect pests from the rice field ecosystem as a natural feed source for catfish in a Minapadi system; and (2) analyze the system's effectiveness in naturally controlling insect pest populations in rice. Three experimental plots were established: Plot A combined a rice field with a catfish pond equipped with a light trap; Plot B combined a rice field with a catfish pond without a light trap; and Plot C was a rice field alone, serving as a control. The methodology encompassed land preparation and plot layout, maintenance of rice and catfish, insect sampling, measurement of rice plant growth parameters, assessment of catfish weight and protein content, and statistical data analysis. The potential of insects as feed was indicated by the significant abundance of captured insects, categorized as either pests or natural enemies. Insect abundance across all plots increased weekly during observations. The insect pest diversity index was moderate in the integrated plots (A and B) and low in the control plot (C). The diversity index for natural enemies was moderate across all three plots. Statistical analysis revealed that the variation in insect pest abundance and diversity did not significantly influence the protein content levels measured in the catfish. Over all, Minapadi framework demonstrates promise as a component of integrated pest management however supplemental strategies such as light traps may be necessary to enhance control of specific pest populations.

## Introduction

Rice is a vital crop in Indonesia, serving as the staple food for the majority of the population. Insects are important biological components of rice field ecosystems because many species function as plant-disturbing organisms (PDOs) or rice pests. Numerous studies have reported the diversity of insect pests in rice field ecosystems [1–4]. At each growth stage of the rice plant, different types and densities of insect pests are present [2].

Farmers often rely on insecticides to control insect pests, and excessive application can contribute to environmental degradation. Therefore, integrated pest management is required, including biological control through the utilization of natural enemies and diversification of agricultural production via polyculture systems [5]. One such alternative is Minapadi cultivation, an integrated rice–fish farming system that can help regulate insect pest populations. Fish act as natural predators by consuming insect pests, thereby reducing pest pressure. At the same time, the fish benefit from a natural food source, while rice plants benefit from improved growing conditions due to weed suppression and reduced pest populations [6]. The Minapadi system is suitable for development in both highland and lowland areas, particularly in irrigated rice fields, and has been shown to increase farmers' income through dual production of rice and fish.

Fish species commonly cultivated in Minapadi systems include carp (*Cyprinus carpio*), tilapia (*Oreochromis mossambicus*), nile tilapia (*Oreochromis niloticus*), and nilem fish (*Osteochilus vittatus*) [6]. Catfish (*Clarias*

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*batrachus*) are also widely cultivated due to their high market demand and tolerance of low water quality conditions [7]. Catfish are predominantly nocturnal [8], making the use of light traps at night a potential strategy to attract insects and provide additional natural feed in Minapadi systems.

In general, freshwater carnivorous and omnivorous fish utilize aquatic insects or insects that fall into the water as natural feed, either as a primary or supplementary food source. This can be determined by the proportion of insects found in fish digestive tracts. Insect orders commonly identified in fish intestines include Hymenoptera, Anisoptera, Ephemeroptera, and Diptera [9]. Crop diversification also plays an important role in supporting food security, as failure in one commodity can be compensated by the success of another [6,10–12]. Previous studies have demonstrated that the Minapadi system can increase both rice and fish yields compared to non-Minapadi systems [13]. Additionally, the surface soil of rice fields, which serves as the base of fishponds, provides better conditions for aquaculture than excavated land, particularly in terms of water quality and organic matter decomposition [14].

The selection of fish species is critical to achieving optimal production, especially in polyculture systems. Appropriate species selection helps minimize competition for food and microhabitats. Fish exhibit different feeding behaviors and spatial preferences within the water column, including surface, mid-water, and bottom zones. These differences reduce interspecific competition and enhance overall system efficiency [15].

Although the Minapadi system has been widely practiced, quantitative analyses evaluating the effectiveness of insect pest abundance and diversity as a substitute for pellet feed remain limited. Furthermore, there is a lack of research assessing the potential of the Minapadi system to naturally control rice pest populations as an alternative to conventional pest control technologies. Therefore, this study aims to: (1) determine the potential abundance and diversity of insect pests in rice field ecosystems as a natural feed source for catfish cultivated under the Minapadi system; and (2) analyze the effectiveness of the Minapadi system in controlling insect pest populations.

## Materials and Methods

### Study Site

This research was carried out in the rice-producing region of Donotirto Village, located within the Kretek District of Bantul Regency, Special Region of Yogyakarta. The site was selected due to its reliable irrigation infrastructure and its status as a major contributor to rice production in Bantul. For the purposes of the experiment, a specific plot of land was prepared according to a detailed layout. Figure 1 provides a geographical overview of the broader study area within the regency. The design of this experimental setup, including the plot arrangement and treatments, is visually documented in Figures 2 and 3.

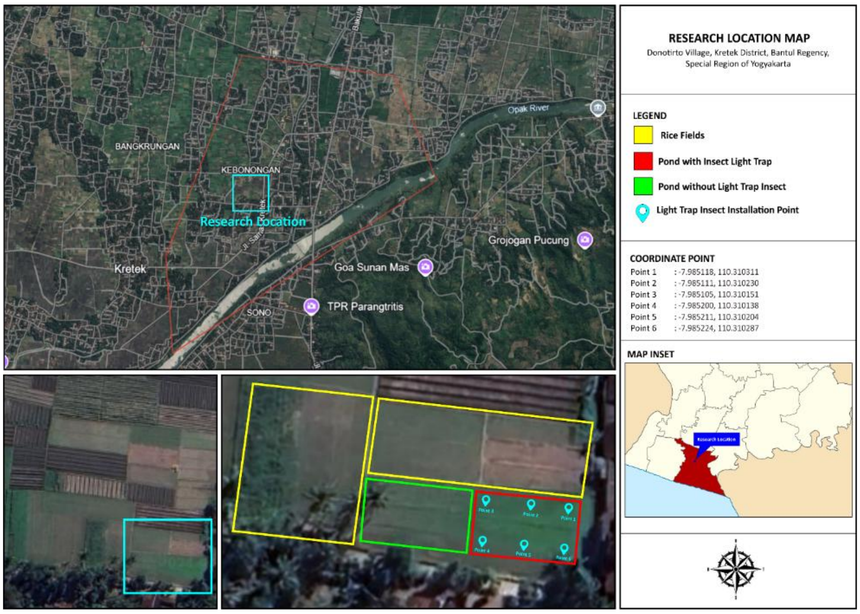


**Figure 1.** Research Location Map, situated in a rice field area. It also illustrates the layout of the research design applied in the field. The yellow box marks the rice field area, while the red and green boxes represent catfish ponds used during the study.

**Experimental Design**

This experimental study was conducted within an integrated rice-pond ecosystem. The setup included three paddy plots: Plots A and B were identical in size (6 x 12 m), while Plot C was larger (12 x 12 m). The system also incorporated two ponds of similar dimensions. The key experimental manipulation was applied to Pond A, which was equipped with a light trap; Pond B served as an untreated control. Both ponds received identical management, including daily feeding with pellets at 3–5% of the total estimated biomass.

The plots and ponds were paired to test the light trap's efficacy. Rice Field A, paired with the treated Pond A, was used to assess the impact of the light trap on insect pest populations. Rice Field B, paired with the untreated Pond B, served as the comparative treatment group. Rice Field C functioned as a negative control, isolated from the pond system to establish a baseline. Research Layout can be seen in Figure 2.

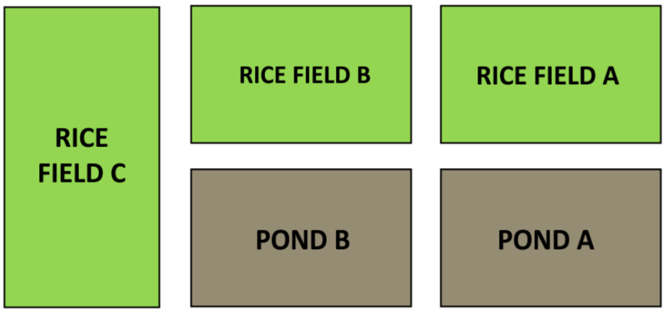


**Figure 2.** Research Layout. Descriptions: Pond A: treatment with pellets and given an insect trap (light trap); Pond B: treatment with pellets without an insect trap (light trap). The area of each pond was 5 × 10 $m^2$ with a depth of each pond of 1.5 m. The area of rice field plots A and B was the same, namely 6 × 12 $m^2$ while rice field plot C had an area of 12 × 12 $m^2$.

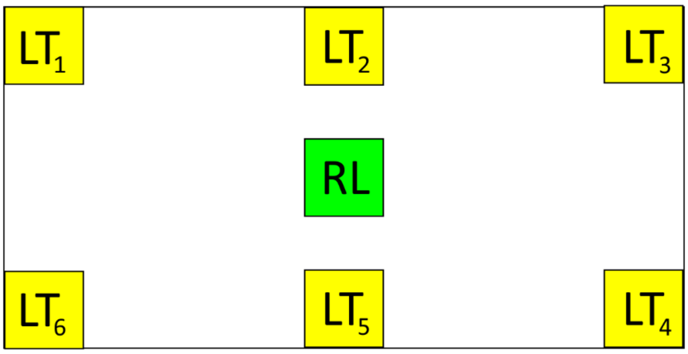


**Figure 3.** Insect light trap installation layout; LT: light trap, RL: regular lamp. Six light traps (LT, yellow box with numbers 1 to 6) were placed at the corners and edges of the pond. A regular lamp (RL, green box) was also placed in the center to provide additional illumination, attracting more insects.

Following land clearance and pond excavation (Figure 1), rice planting was conducted. One-month post-planting, one thousand catfish fingerlings (5 to 6 cm in size age 15 to 20 days) were introduced into each pond (Pond A and Pond B). The key experimental intervention involved installing a light trap with a standard insect lamp above Pond A (Figure 2). Pond B served as the comparative treatment, where fish received a standard daily pellet feed ration equivalent to 3–5% of the estimated biomass. Throughout the study, all rice fields were maintained using conventional practices, with the explicit exclusion of insecticides for pest control.

**Sampling of Insect Abundance and Diversity**

The primary objectives were to quantify the abundance and diversity of insect pests in the rice ecosystem as a potential natural feed for catfish and to monitor catfish growth within the integrated Minapadi system. Accordingly, data were collected on insect populations from all experimental rice plots and pond areas, alongside regular measurements of catfish development.

Insect sampling occurred every two weeks, from one-week post-fish-stocking until rice harvest (one month after rice were planted. Diurnal insects were collected using sweep nets, and nocturnal insects were captured with light traps. All collected insects were identified and categorized as pests or natural enemies. The average daily insect abundance was calculated to estimate the seasonal potential feed biomass. Diversity was quantified using the Shannon-Wiener index (H’).

**Catfish Productivity**

A partial harvest of catfish commenced 2.5 months after stocking, followed by a final harvest at three months. At each harvest event, individual growth data (total length and body weight) were recorded for all captured fish. Additionally, protein content was analyzed for catfish from both treatment ponds.

**Rice Field Productivity**

This study incorporated a comprehensive assessment of rice plant productivity to evaluate the experimental outcomes. Key agronomic parameters—including plant height, panicle length, the number of filled and unfilled grains, and grain diameter—were meticulously measured for each plot. These quantitative measurements enabled a direct and comparative analysis of productivity differences between the various treatment plots. The data collected provides critical insight into the yield components and overall performance of the rice cultivars under the studied conditions.

**Abiotic Factors Measurements**

Abiotic factors were measured in rice field plots and treatment ponds. All measurements were done in the morning starting from 8.30 to 10.30 AM. The abiotic factors measured in rice field plots include air temperature, humidity, soil temperature, soil pH and light intensity. Measurements of abiotic pond factors include dissolved oxygen (DO), temperature, and water pH, which are conducted every two weeks with three replications of each parameter.

**Data Analysis**

Statistical analysis was performed as follows: The diversity of insect pest populations was compared between treatment ponds using the Shannon-Wiener Index. Differences in diversity indices for insect pests and natural enemies were assessed for significance using One-Way ANOVA (SPSS v25). Catfish productivity was evaluated through two metrics: protein content was compared using an independent t-test, and average harvested fish weight was compared using the Kruskal-Wallis test (both in SPSS v25). Rice productivity was analyzed descriptively by comparing the means of morphological features including plant height, panicle length, filled grains, unfilled grains, and grain diameter.

## Results and Discussion

**Results**

***Insect Abundance and Diversity***

Based on the research conducted, the results showed that there was a total of 29 insect species in the rice fields and experimental pond areas. These insects were then grouped based on their ecological role in the agricultural area, namely insect pests and natural predator insects. Based on Table 1, the insect community was consistently dominated by a single species, *Leptocorisa acuta,* which maintained its presence from the initial to the final observation period. In contrast, several other pest species appeared only during the later stages of the experiment, coinciding with the reproductive phase of the rice plants when specific resources like developing grains become available. This shift in species composition suggests that the rice crop's phenological stage is a critical factor structuring the pest community.

The calculated Shannon-Wiener diversity index, presented in Figure 4, reflects this ecological dynamic; a lower index value is expected given the overwhelming dominance of *L. acuta*, which reduces overall community evenness. Consequently, the index trend likely shows minimal fluctuation or a slight increase only if the late-arriving species introduced marginal additional diversity without disrupting the established dominance. The diversity index showed variations in species diversity in each plot and observation time. The highest diversity index was found at the 4th observation time, especially in the rice field plot 1, while the lowest diversity index was found in the rice field plot 3 at the fourth observation time. In addition to the diversity of insect pests, calculations were also carried out for groups of natural enemy insects. Table 2 shows the abundance and diversity of natural enemy insects in the experimental area.

**Table 1.** Inventory of insect pest taxa in the experimental minapadi plots, showing relative abundance and frequency across observational weeks. This table classifies and quantifies insect pest species collected from the rice field ecosystem during the study period. It presents the observed abundance for each pest type, facilitating a comparison of insect populations across the different experimental periods. The data allows for analysis of pest dynamics and the potential impact of the Minapadi system and light traps on pest prevalence.

| Types of pests | Observation | | | | Number |
|---|---|---|---|---|---|
| | I | II | III | IV | |
| *Leptocorisa acuta* | 19 | 39 | 56 | 188 | 302 |
| *Scirpophaga innotata* | 13 | 3 | 6 | 5 | 27 |
| *Nymphula depunctalis* | 5 | 0 | 0 | 0 | 5 |
| *Atherigona exigua* | 9 | 5 | 4 | 3 | 21 |
| *Oxya spp.* | 5 | 17 | 13 | 7 | 42 |
| *Nezara viridula* | 0 | 0 | 3 | 0 | 3 |
| *Leptispa pygmaea* | 0 | 0 | 0 | 5 | 5 |
| *Nilaparvata lugens* | 0 | 0 | 0 | 4 | 4 |
| *Leptocorisa acuta* | 0 | 0 | 0 | 3 | 3 |
| *Hemiptera sp.* | 0 | 0 | 0 | 3 | 3 |
| *Phlaeoba fumosa* | 0 | 0 | 0 | 3 | 3 |
| *Scirpopaga incertulas* | 0 | 0 | 0 | 3 | 3 |
| Total | 51 | 64 | 82 | 224 | 421 |

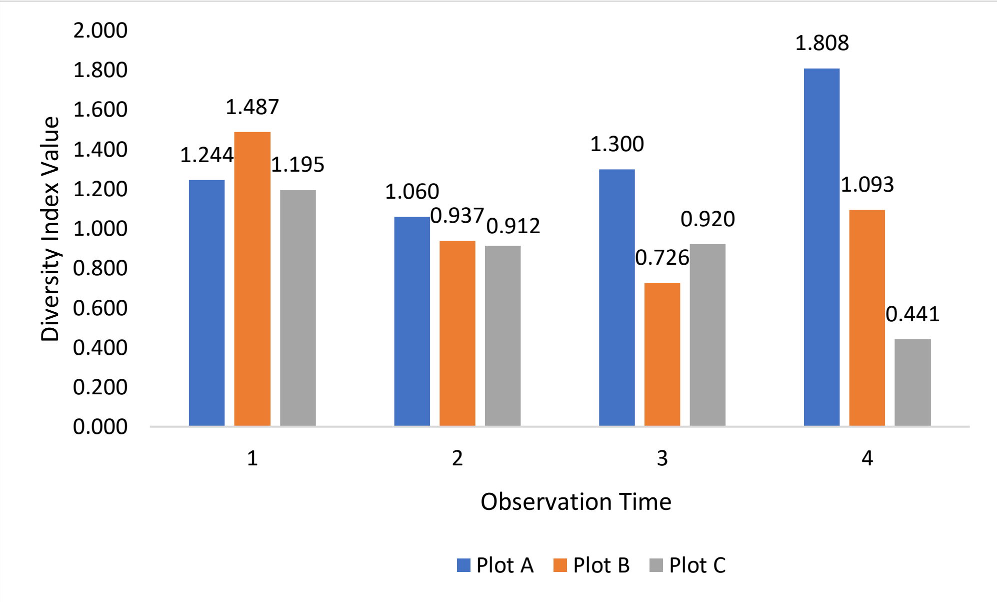


**Figure 4**. Shannon Wiener Diversity Index of insect pests based on observation time and rice field plots. Observation time 1 - Two weeks post fish stocking; 2 - Four weeks post fish stocking; 3 - Six week post fish stocking; 4 - Eight weeks post fish stocking.

**Table 2.** Statistical analysis of insect pest diversity across experimental conditions and time. This table presents the results of a One-Way ANOVA performed to determine if there are statistically significant differences in the insect pest diversity index. The presented statistics include F-values, degrees of freedom, and p-values to assess the significance of variations attributed to each factor. The results indicate whether pest diversity significantly changed over time or differed meaningfully between the distinct agricultural management systems tested in this study.

| Means comparison of insects pest diversity | Sum of squares | df | Mean square | F | Sig. |
|---|---|---|---|---|---|
| Between groups | .479 | 2 | .239 | 2.364 | .150 |
| Within groups | .912 | 9 | .101 | | |
| Total | 1.390 | 11 | | | |

The finding that plot location did not significantly influence the insect pest diversity index (p = 0.150) suggests a degree of homogeneity in the ecological conditions across the study area. This could be due to several factors: (1) consistent crop management practices (e.g., irrigation, pesticide use) applied uniformly to all plots, (2) a dominant landscape matrix that overrides small-scale locational differences, or (3) the pest community having reached a stable equilibrium unaffected by the specific plot gradients measured (Table 3). While this result negates our initial hypothesis that location would be a key driver, it redirects focus to other potential factors controlling pest diversity, such as microclimate, soil health, or the presence of natural enemies. Future studies should investigate these variables to better understand the primary determinants of pest assemblage structure in this system. Importantly, the lack of significant difference may inform integrated pest management (IPM) strategies, suggesting that broad-scale, rather than plot-specific, interventions could be equally effective across similar locations.

**Table 3.** List of insects categorized as natural enemy in the Minapadi Plots. This table provides an inventory of the predatory and parasitic insect species, collectively termed natural enemies, identified within the experimental rice field ecosystem. It details the specific taxa found and quantifies their respective abundances across the different observational periods. The data captures population levels at specified observation intervals, allowing for analysis of how each agricultural management approach influences the community of beneficial insects. This inventory is crucial for assessing the biological control potential within each experimental condition.

| Types of natural enemies | Observation | | | | Number | Percentage (%) |
|---|---|---|---|---|---|---|
| | I | II | III | IV | | |
| Coccinelid beetles (*Synharmonia* sp.) | 13 | 10 | 5 | 8 | 36 | 17.3 |
| Four-jawed spiders (*Tetragnatha* sp.) | 5 | 0 | 4 | 0 | 9 | 4.3 |
| Dragonflies (*Anisoptera* sp.) | 3 | 0 | 10 | 0 | 13 | 6.3 |
| Tomcats (*Paederus fuscipes*) | 6 | 8 | 4 | 5 | 23 | 11.1 |
| Striped-eyed spiders (*Oxyopes javanus*) | 4 | 3 | 8 | 5 | 20 | 9.6 |
| Black ladybugs (*Paraeucosmetus pallicornis*) | 3 | 4 | 3 | 0 | 10 | 4.8 |
| Black ants (*Lasius niger*) | 3 | 5 | 11 | 6 | 25 | 12.0 |
| Fire ants (*Solenopsis geminata*) | 0 | 4 | 0 | 0 | 4 | 1.9 |
| Long-horned grasshoppers (*Conocephalus longipennis*) | 0 | 13 | 3 | 0 | 16 | 7.7 |
| Dragonflies (*Anisoptera* sp.) | 0 | 15 | 0 | 0 | 15 | 7.2 |
| Needle dragonflies (*Agriocnemis* spp.) | 0 | 3 | 0 | 0 | 3 | 1.4 |
| Klanceng bee (*Trigona* sp.) | 0 | 5 | 3 | 4 | 12 | 5.8 |
| Praying mantises (*Mantis* sp.) | 0 | 3 | 0 | 0 | 3 | 1.4 |
| Wolf spiders (*Lycosa pseudoanulata*) | 0 | 0 | 3 | 0 | 3 | 1.4 |
| Striped lynx spiders (*Oxyopes salticus*) | 0 | 0 | 0 | 3 | 3 | 1.4 |
| Telenomus bees (*Telenomus* sp.) | 0 | 0 | 0 | 5 | 5 | 2.4 |
| Argiops spiders (*Argiope aurantoa*) | 0 | 0 | 0 | 8 | 8 | 3.8 |
| Number | 37 | 73 | 54 | 44 | 208 | |
| Percentage (%) | 17.8 | 35.1 | 26.0 | 21.2 | | |

The analysis of natural enemy arthropod diversity is quantified in Figure 5 using the H' Index. This metric provides a standardized measure that reflects both the species richness (the number of different species) and their relative abundance (how evenly individuals are distributed among those species) within the sampled community. The results presented in the figure allow for a comparative assessment of arthropod predator and parasitoid communities across the different experimental treatments—specifically, between the integrated Minapadi plots and the control rice monoculture. A higher index value indicates a more complex and stable natural enemy community, which is a key indicator of robust biological control potential within the agroecosystem.

Based on the results of the analysis, the H’ index for the natural enemy insect community exhibited notable variation across the observation periods and experimental plots (Table 4). The peak in species diversity, indicating the most complex and balanced community of predators and parasitoids, occurred during the second week of observation. Conversely, the lowest recorded diversity index value was identified in Plot C at the initial observation point. However, this initial advantage observed in the integrated Minapadi systems was not sustained linearly throughout the study. The notable shift during the final observation period, where Plot C exhibited the highest diversity index, suggests a potential lag effect or a divergent ecological trajectory. This reversal implies that the relationship between cultivation practice and natural enemy diversity is dynamic and phase-dependent, warranting further investigation into the long-term seasonal dynamics and specific environmental drivers at play in each system.

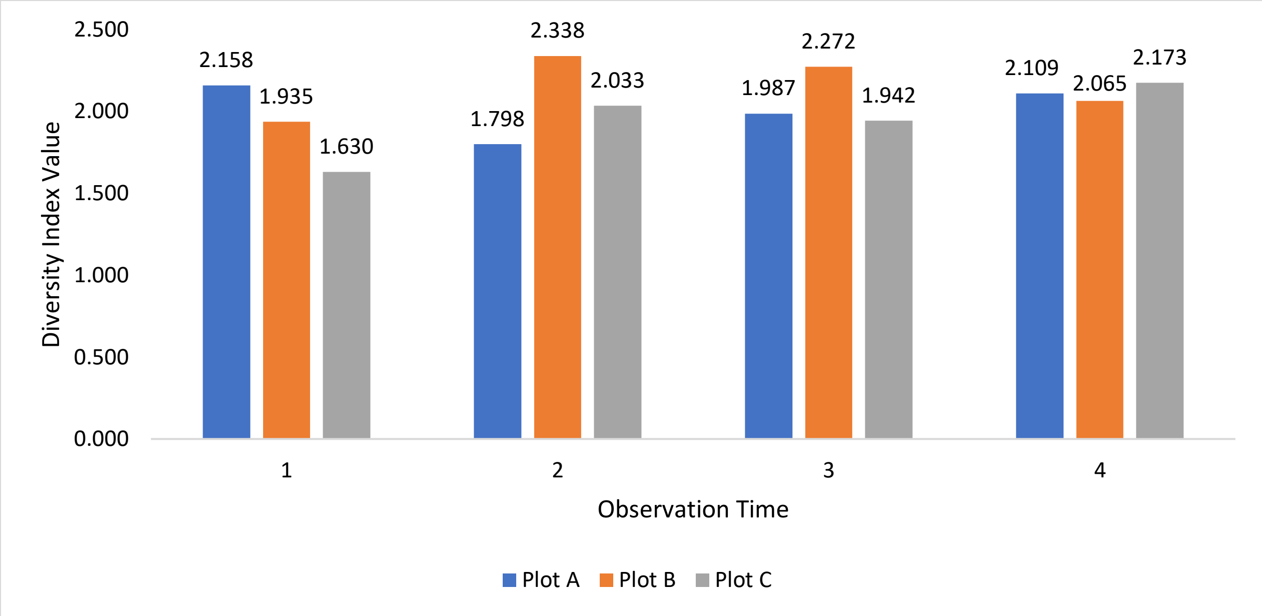


**Figure 5.** Shannon-Wiener (H') Diversity Index of natural enemy arthropods across experimental plots and observation timeline. This figure illustrates the temporal variation in the diversity of beneficial arthropods, including predators and parasitoids, within the rice field ecosystem. The Shannon-Wiener index values are plotted over consecutive observation weeks for three distinct treatments: the integrated Minapadi plot with a light trap (Plot A), the integrated plot without a trap (Plot B), and the conventional rice-only plot (Plot C). Higher index values indicate a community with greater species richness and evenness. The visualization enables a direct comparison of how each cultivation system influences the stability and complexity of the natural enemy community over the course of the growing season.

**Table 4.** Statistical analysis of natural enemy arthropod diversity across temporal and treatment variables. This table presents the results of a one-way analysis of variance (ANOVA) conducted to test for statistically significant differences in the Shannon-Wiener diversity index of natural enemy arthropods. It reports key statistical outputs, including F-values, degrees of freedom, and p-values, for each factor. These results determine whether observed variations in the diversity of beneficial insects—such as predators and parasitoids—are attributable to the progression of the growing season.

| Means comparison of natural enemy insects diversity | Sum of squares | df | Mean square | F | Sig. |
|---|---|---|---|---|---|
| Between groups | .090 | 2 | .045 | 1.191 | .348 |
| Within groups | .340 | 9 | .038 | | |
| Total | .430 | 11 | | | |

The One-Way ANOVA indicated no significant difference in the natural enemy arthropod diversity index among Plots A, B, and C (p = 0.348). This suggests that plot location did not significantly affect the diversity of natural enemies in the study area. The absence of significant differences in natural enemy arthropod diversity across the study plots (p = 0.348) is a noteworthy finding. It implies a degree of functional homogeneity in the habitats provided for predators and parasitoids, which could be attributed to consistent landscape features, uniform agricultural practices (e.g., pesticide regimes or crop diversity), or sufficient connectivity between plots allowing for free movement of these arthropods. This result has significant implications for IPM. A stable and evenly distributed natural enemy community across a field or farm is highly advantageous, as it suggests the potential for broad-scale, consistent biocontrol pressure on pest populations. However, this finding also prompts further questions. It would be valuable to investigate whether the composition (specific species present) or abundance of natural enemies varied despite the similar diversity indices, as these factors also critically impact pest suppression. Future work should examine how specific local factors (e.g., floral resource strips, soil management) might be enhanced to not only maintain but increase this baseline level of natural enemy diversity for more resilient agroecosystems.

***Rice Field Plot Productivity***

Observations were made on the productivity of rice field plots and catfish ponds to determine the productivity of Minapadi agricultural land, Figure 6 shows the results of the calculation of the five parameters of rice field plot productivity that have been determined. Based on the results, rice plants from rice field C have lower productivity in three morphological features namely plant height, panicle length, filled grains.

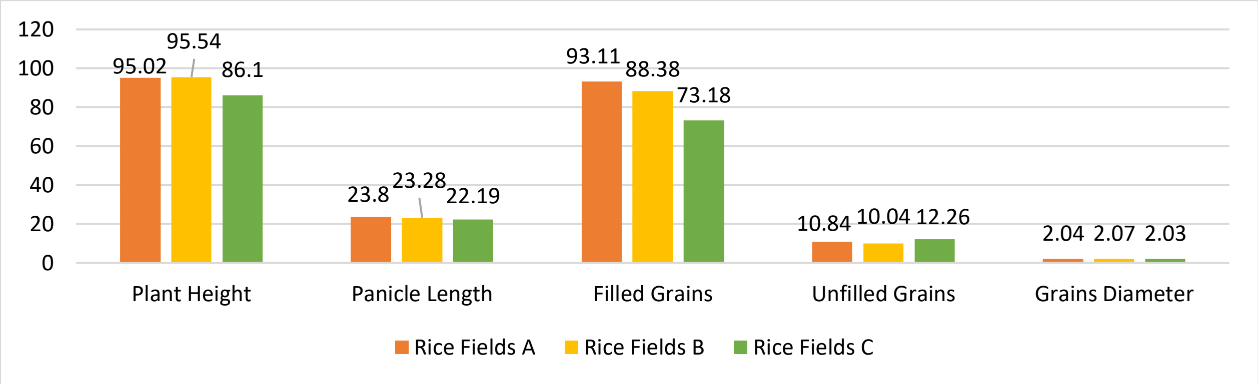


**Figure 6.** Comparative analysis of rice productivity across five yield parameters in different agricultural systems. This figure presents a side-by-side comparison of key productivity metrics for the three experimental plots: the integrated Minapadi system with a light trap (Plot A), the Minapadi system without a trap (Plot B), and the conventional rice monoculture control (Plot C). By visualizing these data collectively, the figure allows for a direct assessment of how each cultivation method—particularly the integration of fish and the use of a light trap—influences various components of rice crop performance. This integrated comparison highlights trade-offs and advantages among the systems, providing a holistic view of agricultural productivity beyond a single metric.

Observed harvest data revealed distinct differences in yield and plant characteristics among the three rice fields (A, B, and C). Field B achieved the greatest average plant height (95.54 cm), while Field A produced the longest panicles (23.8 cm) and the highest average number of filled grains per panicle (93.11). In contrast, Field C consistently showed lower averages across all measured parameters: plant height (86.1 cm), panicle length (22.19 cm), and filled grains (73.16). Notably, Field C also exhibited the highest percentage of empty grains. The average grain diameter was similar across all fields (2.03–2.07 mm). Final productivity, measured as the wet and dry weight of harvested grain, is presented in Figure 7.

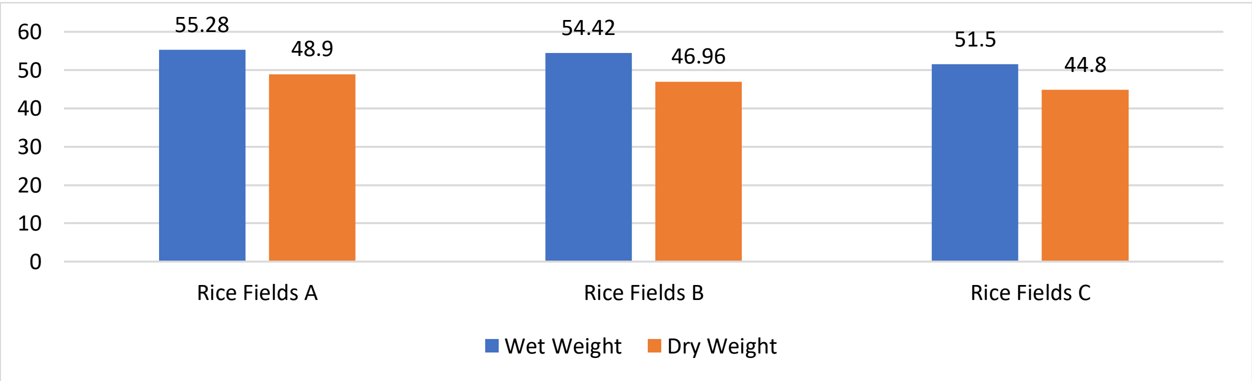


**Figure 7.** Comparison of rice productivity metrics: post-harvest wet weight versus dry weight yield. This figure illustrates the comparative yield output from the three experimental plots—Plot A (Minapadi with light trap), Plot B (Minapadi without trap), and Plot C (rice monoculture)—using two fundamental measures: wet weight and dry weight of harvested rice. Wet weight represents the total fresh biomass at harvest, while dry weight reflects the grain mass after moisture removal, providing a more accurate indicator of actual grain yield and economic value. Displaying both measures allows for an assessment of moisture content differences among the plots, which can be influenced by cultivation practices and microclimate. This direct comparison highlights how each agricultural system impacts not only total biomass production but also the final, storable grain yield, offering insight into both biological productivity and practical harvest outcomes.

***Catfish Pond Productivity***

In addition to evaluating rice field productivity, the study concurrently assessed the aquaculture component by measuring catfish productivity within the Minapadi system. The yield from the catfish ponds was quantified using two key parameters: the final harvested body weight of the fish and the protein content within the fish muscle tissue. Figure 8 presents the comparative results of the average catfish body weight harvested from the two integrated plots—Plot A (equipped with a light trap) and Plot B (without a trap). Figure 9 complements this by displaying the corresponding analysis of protein content measured in the catfish from these same treatments. Together, these figures allow for a holistic evaluation of how the different Minapadi management practices influence not only the biomass yield but also the nutritional quality of the cultivated catfish.

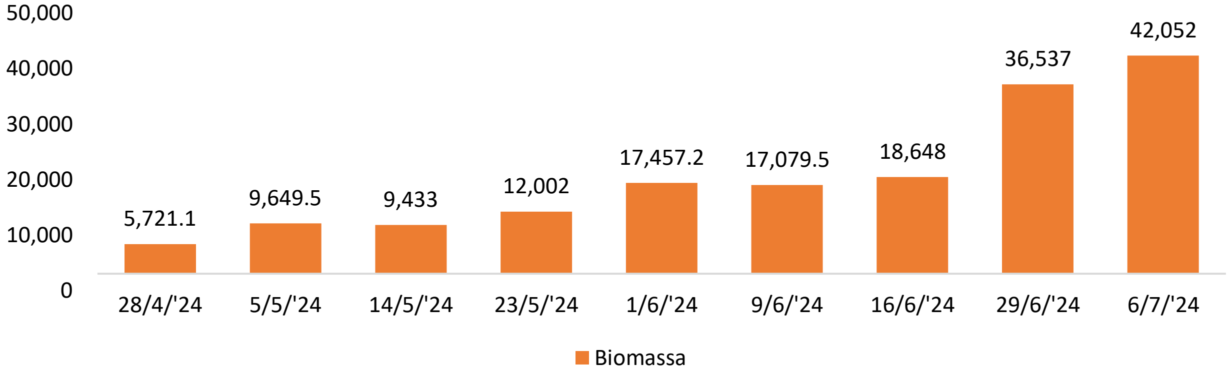


**Figure 8.** Average weight gain (g) of catfish during the maintenance period in pond A (Pond with light trap treatment) The diagram above explains the increase in the weight of catfish in pond A (pond accompanied by a light trap) which shows an increase in each observation.

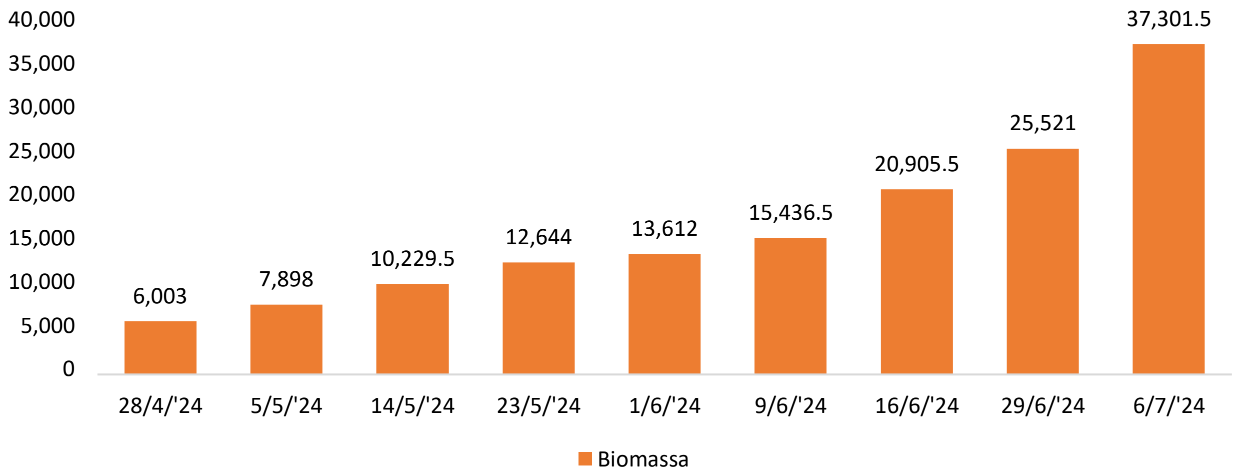


**Figure 9.** Average weight gain (g) of catfish during the maintenance period in pond B (Pond without light trap treatment). The diagram above explains the increase in the weight of catfish in pond B (ponds that are not accompanied by light traps) which shows an increase in each observation.

Weekly weight measurements confirmed that catfish in both treatment groups (Pond A with a light trap, and Pond B without a light trap) grew over the course of the experiment. By the end of the study 635 fish from pond A and 577 fish from pond B were harvested out of 1,000 of initial fish stocking. A statistical comparison of the two groups showed no significant difference in growth ($p = 0.55$). This result indicates that the presence of the light trap did not have a significant effect on final catfish weight. The final harvest weights for both groups at the end of the experiment are presented in Figure 10.

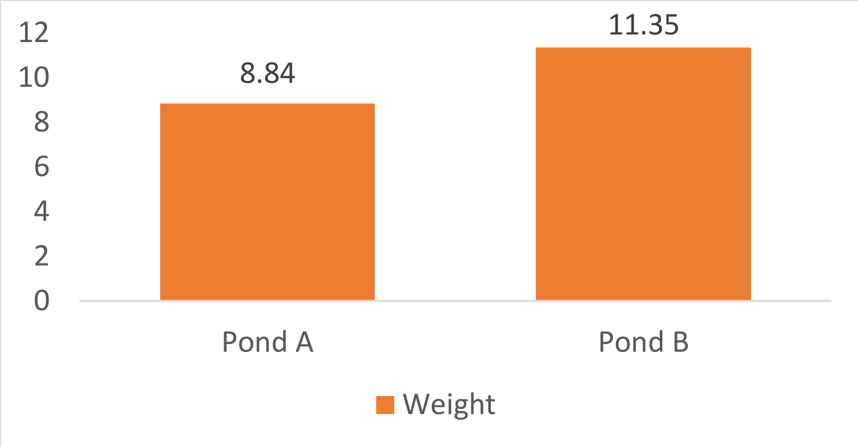


**Figure 10.** Comparison of average harvest weight of catfish cultivated in integrated minapadi ponds. This diagram illustrates the comparative aquaculture yield from the two integrated rice-fish systems, specifically measuring the final biomass of catfish at harvest. It presents the mean body weight (in grams) of catfish harvested from Pond A, which was equipped with an insect-attracting light trap, and Pond B, which operated without a light trap. The visual comparison aims to quantify the effect of the supplemental natural feed—provided by insects falling from the light trap into Pond A—on fish growth performance.

Based on the results of the Kruskall-Wallis test related to the average weight of catfish from the harvest period, it shows that there is no significant effect of both pool A (light trap) and pool B (non-light trap), it can be seen from the test results 0.408 > 0.05 (Table 5). In addition to catfish weight, measurements were carried out on protein levels in the catfish's body. Table 6 shows the results of protein level measurements in the two treatment groups and the results of statistical tests. The results of the protein content test in both groups showed that the protein levels in both groups were in the high category [16]. However, the results of the independent T-test showed that there was no significant difference between the two treatment groups.

**Table 5.** Statistical comparison of harvested catfish weights across different Minapadi treatments using the Kruskal-Wallis Test. This table presents the results of a non-parametric Kruskal-Wallis test, which was employed to determine if there were statistically significant differences in the median weight of catfish at harvest. The analysis compares the final fish yields from the key experimental groups: Pond A (the integrated Minapadi system with a light trap) and Pond B (the integrated system without a trap).

| Treatment | Asymp. sig | α |
|---|---|---|
| Average weight of harvested catfish | 0. 408 | 0.05 |

**Table 6.** Analysis of catfish protein content: nutritional yield and statistical analysis between treatments. This table presents the results of protein content analysis performed on catfish harvested from the two integrated Minapadi treatments, alongside the statistical comparison of these results. It details the mean protein percentage measured in fish from Pond A (supplemented with a light trap) and Pond B (without a light trap). The subsequent statistical analysis employs an independent samples T-Test to determine if the difference in mean protein content between the two groups is statistically significant.

| Treatment | Protein content (%) | Sig. (T-test) |
|---|---|---|
| Pond A (with light trap) | 16.17 ± 0.81 | 0.104 |
| Pond B (without light trap) | 16.89 ± 1.05 | |

Measurement of environmental factors (microclimatic) namely in the rice field and pond environments showed that the average microclimatic conditions are in normal range that could be tolerated by rice plants and catfish. The results of measurements for climatic factors and water quality in the rice field and pond environments of the treatment are presented in Tables 7 and 8, respectively. Overall, climatic factors measured in rice field A is lower compared to Field B and C except in the air humidity. Rice field C was exposed to light from the sun higher compared to Field A and B therefore resulting in higher air temperature and soil temperature.

**Table 7.** Microclimatic conditions recorded in experimental rice plots throughout the study period. This table details the average measurements of key environmental factors taken within the three experimental plots during the observation timeline. It provides the mean values recorded for Plot A (Minapadi with light trap), Plot B (Minapadi without trap), and Plot C (rice monoculture), allowing for a comparison of the microhabitat conditions created by each management system. These abiotic factors are crucial as they directly influence insect ecology, plant physiology, and overall ecosystem dynamics within the rice fields. Presenting this data establishes the environmental context for interpreting observed differences in biological parameters, such as pest and natural enemy populations, rice growth, and fish productivity.

| Rice field plot | Air temperature (°c) | Air humidity (%) | Soil temperature (°c) | Soil ph | Light intensity (lux) |
|---|---|---|---|---|---|
| 1 | 35.89 | 58.51 | 28.73 | 7 | 75,747 |
| 2 | 39.40 | 49.30 | 29.14 | 7 | 81,290 |
| 3 | 38.70 | 48.63 | 30.33 | 7 | 91,348 |
| Average | 37.99 | 52.15 | 29.40 | 7 | 82,795 |

**Table 8.** Average physicochemical water quality parameters in Minapadi fishponds during the experimental period. This table summarizes the mean values for key water quality indicators measured in the two integrated treatment ponds: Pond A (with a light trap) and Pond B (without a light trap). These averages provide a snapshot of the prevailing aquatic environment, which directly impacts fish metabolism, growth, and survival.

| Treatments | | | Threshold [17] |
|---|---|---|---|
| Parameters | A (Ligh Trap) | B (Non-Light Trap) | |
| Temperature (°C) | 28.9–30.1 | 29.1–30.2 | 25–30 |
| DO (mg/L) | 6.73–10.95 | 6.73–11.23 | > 4 |
| pH | 7.5–8.4 | 6.5–8.5 | 6.5–8.5 |

Based on the measurements of water quality, the abiotic factors relating to both the rice field environment and the treatment pond were still within the normal range for the growth of rice plants and catfish. The highest and lowest temperature, dissolved oxygen and pH were within the tolerance of the plant and catfish growth and development. Only small differences can be observed between each treatment pond which were still in the range for normal growth [17].

**Discussion**

***The Effectiveness of The Minapadi System in Controlling the Population of Rice Pest Insects Naturally***

Table 1 show a consistent increase in insect pest populations across each observation interval. In contrast, the population of natural enemies displayed an overall declining trend, particularly after the second observation. The rising pest numbers are attributed to the increasing availability of food resources as the rice crop matured [18]. At the initial observation, the rice was in the early milk stage; by the final observation prior to harvest, the plants had progressed to a more advanced developmental stage, which corresponded with a marked surge in pests. This pattern aligns with findings that pests such as the rice bug (*Leptocorisa* spp.) proliferate in response to abundant food, intensifying their attacks during the milk ripening phase [19].

The data from Table 1 indicate a trend of increasing insect pest abundance over successive observation periods. Concurrently, recorded populations of natural enemy arthropods showed a general decrease, most noticeably following the second observation. This increase in pests coincides with the progression of the rice crop from the early milk stage to a more advanced pre-harvest developmental stage, a period typically associated with greater food resource availability for phytophagous insects [18]. The pattern is consistent with documented population surges in pests like the rice bug (*Leptocorisa* spp.) during the milk ripening phase [19]. The observed trends—rising pest counts alongside declining natural enemy numbers—present a common but critical challenge in agroecology. The pest increase aligns with expected ecological succession in an annual crop system, where a concentrated, high-quality food resource (maturing rice panicles) naturally facilitates herbivore population growth [18–19].

The decline in natural enemies, however, suggests a potential decoupling of predator-prey dynamics within this specific cropping cycle. While this could indicate a failure of biological control to regulate the outbreak, alternative explanations must be considered. The sampling method may have underestimated highly mobile or cryptic natural enemies later in the season. Furthermore, the observed pattern might reflect a temporal lag, where natural enemy populations require more time to numerically respond to increasing pest densities. The data do not rule out other influential factors, such as microclimatic changes within the dense crop canopy or undocumented differences in plot management.

The provision of light traps in rice field locations with the Minapadi cultivation was considered to support the reduction of pest insect populations because of the nature of insect pests that are attracted to light, especially nocturnal insects [20]. Furthermore, according to Gopalakrishnan et al. [21], light has an attractive power and can influence the behavior of pest insects so it can attract insects to gather in the Insect Light Trap. This potential can be utilized as a tool to control the population of beneficial insect pests.

The observed variation in rice yield components between the plots presents an interesting correlation with their proximity to the light trap. The high performance of Plots A and B, coupled with their lower recorded pest pressure compared to the more distant Plot C, suggests the light trap may have contributed to a localized reduction in herbivorous insects. This is a plausible mechanism, as light traps are known to disrupt pest behavior and population dynamics. However, to avoid overinterpretation, it is crucial to acknowledge that this study documents an association rather than definitive causation. The design does not isolate the light trap as the sole variable. The observed differences in yield could also be influenced by unmeasured environmental gradients correlated with distance from the pond, such as subtle variations in soil moisture, fertility, or microclimate. Furthermore, the higher pest numbers in Plot C could be a consequence of the poorer plant health (making plants more susceptible or apparent to pests) rather than its primary cause. Therefore, while the data are consistent with the hypothesis that the light trap provided a protective effect to nearby plots, they do not prove it conclusively. The most parsimonious interpretation is that plot location, encompassing both the potential influence of the light trap and other spatially dependent factors, was a significant determinant of both pest pressure and crop performance in this system. Future controlled experiments, such as randomly assigning replicated light trap treatments across the field, would be necessary to disentangle these effects and directly quantify the efficacy of the trap as a stand-alone pest management tool.

***Potential Abundance and Diversity of Insect Pests in Rice Field Ecosystems as A Source of Natural Food for Catfish***

One of the factors that has the highest influence on fish farming is feed. Quality feed will help catfish grow faster. In this study, both experimental ponds were given pellet feed, but in pond A, light traps were given on the edge and in the middle of the pond, allowing insects trapped in the light trap to fall into the pond and become natural food for catfish.

The increase in catfish weight (Figures 8 and 9) was influenced by the amount and suitability of food consumed by the fish. In this study, fish in both ponds were given pellet as daily feed amounting to 5% of the total biomass and the amount depended on the weight growth of the fish [22]. The results showed that catfish given pellets supplemented with natural rice plant insects had a greater average weight than catfish that were only given pellet feed. However, the weight gain of catfish that were only given pellet feed every week tended to be more stable compared to the weight gain of catfish that were given pellet feed and rice plant insects. This was because catfish are cannibalistic and there was competition for food between individual catfish due to the lack of food availability and the uneven distribution of insects due to differences in rice planting seasons [23].

Insects have nutritional content that is comparable to or even better than pellet feed. Insects are composed of carbohydrates, proteins, fats, amino acids, and minerals. The most needed element in fish feed is protein. A study conducted by Tran et al. [24] found that several types of insects contained 76.5% protein, 1.01% calcium, 0.79% phosphorus, and 17.3% fat in their body composition. The high protein content showed that insects can match the content of pellet feed for fish.

Figure 10 shows that catfish in pond B had a higher average weight than catfish in pond A. It means that the ability of fish to digest and absorb feed affected the weight gain of catfish. The smoother texture of pellet feed makes it easier for catfish to digest food [25]. In pond A, catfish were given additional feed in the form of natural insects from rice plants. An alternative way to add nutrients to fish feed was to use insects because insects were a natural source having a high protein content. However, the structure of the mouth of catfish could not absorb and digest the natural insects which tended to be hard and rough, thus causing the catfish's ability to digest the insect content of rice plants to be less than optimal [26]. Quality feed was not only determined by its nutritional content but also by the ability of fish seeds to absorb and digest food that entered their bodies [27]. Further research can be done by analyzing the digestive organs of fish to find out what types of insects are eaten by fish. Thus, it can be ascertained whether the abundance of insects in rice plants is effective as natural feed for fish and can replace pellet feed.

***Supporting Environmental Conditions of the Minapadi Ecosystem***

The results of microclimatic measurements showed that light intensity, air humidity, air temperature, and soil temperature had varying values depending on the time and location of measurement. The measurement time started at 08.30 to 10.30 which caused fluctuations in light intensity, air humidity, and air temperature values depending on the position of the sun and atmospheric conditions at the time of measurement. In the morning, light intensity tended to be lower, while air temperature and soil temperature were relatively lower compared to noon. Conversely, when approaching noon, air temperature and soil temperature increased, while air humidity tended to decrease [28]. In general, the air temperature in the three plots was in the range of 30 to 40 °C with air humidity in the range of 40–70%. Higher temperatures and lower humidity tended to support the presence of insect pests, while lower temperatures and higher humidity were more supportive of the survival of natural enemies that can control pest populations. In accordance with the statement by White et al. [29], at higher temperatures, insect pests benefit because reproductive maturity is shorter and there is an increase in food quality due to abiotic stress on cultivated plants. Meanwhile, the results of soil pH measurements in the three plots during the observation period showed the same value, namely 7. This indicated that the acidity of the soil in the three plots was in the neutral range, which generally supported optimal rice plant growth. According to Masum et al. [30], rice plants can grow optimally in soil pH conditions between 4 and 7. Soil with a neutral pH supported better nutrient availability and facilitated nutrient absorption by plants more effectively compared to soil with an acidic or alkaline pH. However, the effect of soil pH on the number of insect pests did not show a significant impact.

Measurement of pond water quality (Table 8) was carried out once a week, with one measurement for 24 hours, using a measurement interval of every 2 hours starting at 19.00 to 17.00. This aimed to obtain data on water quality fluctuations over time, including variables of temperature, pH, and dissolved oxygen levels that can affect environmental conditions in the pond. The pH value in both treatment ponds experienced quite significant fluctuations over time in each observation period, ranging from 6 to 9.5. There was a daily pattern in pH changes. The pH value tended to be higher at night and lower during the day. The pH value was influenced by the activity of fish and other organisms, especially through the respiration process. Supriatna et al. [31] stated that the respiration process produces carbon dioxide ($CO_2$) which can lower the pH value of water, so the pH of the water tends to be lower at night compared to during the day. The optimal pH value to support catfish growth is 6.5 to 9 [32].

Overall, the water temperature in both treatment ponds tended to be stable within a certain range. The pond temperature was generally lowest in the early morning and reached its peak during the day. This was due to the influence of the higher intensity of sunlight during the day that entered the pond and caused an increase in the metabolic process of the fish's body. The optimal temperature range for catfish growth was around 28 to 32 °C [17]. Based on the description of the environmental conditions above, it was known that environmental conditions were not a limiting factor for the growth of rice plants or catfish, because they were still within normal limits for the growth of rice plants or catfish.

## Conclusions

This study assessed the relationship between a Minapadi (rice-fish) system, insect pest dynamics, and crop productivity. The findings suggest that the presence of a catfish pond was associated with spatial variation in insect pest abundance and diversity within the rice plots. In particular, the highest pest counts were recorded in Plot C, which was located farthest from the pond and light trap. Moreover, proximity to the pond equipped with a light trap correlated with a lower relative abundance of pest's insects (14.2% vs. 63.1% in the untreated plot), indicating that the integrated use of a light trap may enhance pest suppression in this system. However, no clear effect of pest availability on catfish protein levels was observed, possibly due to suboptimal fish growth conditions or sampling constraints. Overall, while the Minapadi framework shows promise for integrated pest management, the results indicate that supplementary control measures, such as light traps, may be beneficial for reducing specific pests.

## Author Contributions

**TA:** Conceptualization, Methodology, Investigation, Writing – Original Draft, Writing – Review & Editing; **B:** Writing – Review & Editing; **RAP:** Writing – Review & Editing; **S:** Writing – Review & Editing, Supervision; **AS:** Methodology, Writing – Review & Editing; **FYI:** Investigation, Data Analysis; **HKH:** Investigation, Data Analysis; **GAK:** Investigation, Data Analysis; and **ST:** Investigation, Data Analysis.

## AI Writing Statement

The authors utilized Grammarly to assist with language editing. The authors have thoroughly reviewed and edited the output and take full responsibility for the final content of this publication.

## Conflicts of interest

There are no conflicts to declare.


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