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Species diversity and feeding habits of fish in organic rice fields, Nakhon Phanom Province, Northeast Thailand

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Abstract A total of 1,039 fish individuals was collected from organic rice fields in Nakhon Phanom Province, northeast Thailand. The samples comprised 35 species, 28 genera, and 15 families. The community was dominated by cyprinids, which contributed 13 species and formed the largest share of total species richness. Of the recorded taxa, 15 species were considered dominant, with *Esomus metallicus* being the most abundant (13.28%). Only one non-native fish species recorded in the sampled area, namely *Oreochromis niloticus*. Most species (94.29%) were classified as Least Concern in terms of conservation status. However, *Boraras urophthalmoides* is listed as Near Threatened, while *Betta smaragdina* remains data deficient. The diversity indices suggested a relatively balanced community structure, with a Shannon-Wiener diversity index (H') of 2.93, species richness (R) of 4.20, and evenness (E) of 0.91. In the feeding ecology, the dominant species were grouped into different trophic levels. *Clupeichthys aesarnensis* was mainly found to feed on zooplankton, while *Parambassis siamensis* showed a carnivorous feeding habit. Most of the remaining dominant species were classified as omnivores with mixed diets. The results indicated that organic rice fields are found to be capable of supporting fish communities with a range of feeding strategies. It suggested that these habitats may help to maintain local fish diversity and have some role in supporting biodiversity within agricultural landscapes.

Keywords: Feeding habits, Fish diversity, Fish ecology, Organic rice fields, Northeast Thailand

Introduction

Rice fields in Southeast Asia have long been recognized as important agroecosystems that support a wide range of freshwater organisms, particularly fish (Bambaradeniya and Amerasinghe, 2004; Freed *et al*., 2020; Saikia, 2024). They often serve multiple ecological functions, acting as both feeding and breeding habitats, especially for early life stages that are more vulnerable to environmental changes. As a result, rice fields are associated with the recruitment and maintenance of fish populations (Katano *et al*., 2003; Yamazaki *et al*., 2004;

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Halwart, 2008). In some cases, they may also function as temporary floodplain-like habitats, providing alternative spawning and nursery grounds where natural floodplains have been reduced (Lawler, 2001; Iwata *et al*., 2003; Natuhara, 2013).

Rice production is one of the primary agriculture enterprises in Thailand and can be categorized broadly as either an organic or a conventional type (Thongphak and Iwai, 2016). Organic rice fields lack chemical inputs and, as a result, exhibit highly unpredictable environmental conditions. However, this variability can contribute to habitat heterogeneity and support higher richness of freshwater organisms (Tuck *et al*., 2014; Thongphak and Iwai, 2016; Pérez-Méndez *et al*., 2023). However, farming itself is only one factor influencing fish diversity; local environmental dynamics, such as changes in water chemistry, connectivity, and the availability of food resources, also play equally important roles in shaping fish communities (Khoa *et al*., 2005; Shah *et al*., 2010; Freed *et al*., 2020). Thus, relying solely on species inventories may be insufficient for understanding these ecological phenomena. In order to analyze fish community structure in rice fields, it is necessary to go beyond species richness and consider both species composition and feeding habits (Katano *et al*., 2003; Halwart and Bartley, 2007; Samanta *et al*., 2020).

Fish assemblages in rice-based ecosystems have been fairly well documented (Iguchi *et al*., 2003; Yamazaki *et al*., 2004; Natuhara, 2013; Ibrahim *et al*., 2023; Saikia, 2024). However, organic rice fields in Northeast Thailand have received far less attention. This is especially true in Nakhon Phanom Province, which lies within the Mekong River Basin and is known for relatively high aquatic biodiversity. A clearer understanding of fish diversity and feeding ecology in this area would not only improve knowledge of local biodiversity, but may also help inform more sustainable management of organic rice farming systems.

The research findings aimed to provide the first investigation of the species diversity and feeding habits of fish in organic rice fields in Nakhon Phanom Province, Northeast Thailand.

Materials and methods

Study area and fish sampling

The study was conducted in an organic rice field ecosystem covering 17,600 m² with four sampling stations, located in Ban Tong Phon Sawang, That Phanom District, Nakhon Phanom Province, northeast Thailand (16°54'36.0"N, 104°41'10.3"E), within the Mekong River Basin. Fish samples were collected monthly from May to September 2024, covering a single rice cultivation cycle. Sampling was carried out using fine-mesh drag nets (3 m × 1 m; mesh size: 1 mm × 1 mm) and scoop nets (mesh size: 1 mm × 1 mm), with three randomized replicates at each station. Specimens were preserved in 10% formalin for one month and subsequently transferred to 75% ethyl alcohol for long-term storage. Species identification was conducted at the Fisheries Research Laboratory, Faculty of Agriculture and Technology, Nakhon Phanom University, following Smith (1945), Rainboth (1996), Kottelat (2001), Vidthayanon (2008), and Taki *et al*. (2021). Standard length (SL) was measured to the nearest 0.1 cm. Species were classified system following Nelson *et al*. (2016).

Analysis of diversity fish community

Fish community diversity was evaluated using three commonly used ecological indices: the Shannon-Wiener diversity index (H'), the Margalef richness index (R), and Pielou's evenness index (E).

The Shannon-Wiener diversity index (H') was calculated based on Shannon and Weaver (1963), using the following formula:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where s is the total number of species, $p_i = n_i/N$, n_i is the number of individuals in species i, and N is the total number of individuals.

The Margalef species richness index (R) was calculated following Margalef (1958), using the formula:

$$R = (S - 1) / \ln N$$

where S is the number of species and N is the total number of individuals.

Pielou's evenness index (E) was calculated to evaluate the uniformity of species distribution at each station (Pielou, 1969), using the formula:

$$E = H' / H'_{max}$$

where H' is the observed Shannon-Wiener diversity index and H'_{max} is the maximum possible value of H'

Stomach content analysis

After measuring standard length, the fish were dissected along the ventrolateral side using fine scissors. The alimentary canal was removed and extended to measure its length. Stomachs were then separated and examined individually to assess diet composition. In addition, the presence or absence of stomach contents (empty) was recorded. If food items were presented, all contents were transferred into a clean petri dish. Food items were examined under a stereomicroscope and identified to the general taxonomic level, where possible, using references from Gillott (2005), Barnes *et al*. (2009), and Maitland (2013). Stomach contents were analyzed using the frequency of occurrence method as described by Hyslop (1980). The relative length of the alimentary canal (RLA) was calculated following Taki (1978).

Data analysis

The data were analyzed using standard statistical procedures. The Shannon-Wiener diversity index, species richness index, and evenness index obtained from each sampling station during the survey period in the organic rice fields were compared using one-way ANOVA, followed by Tukey's HSD (Honestly Significant Difference) test at a significance level of $p = 0.05$. All analyses were performed using SPSS software version 24.0 (IBM SPSS Inc.).

Ethics statement

The research project had been carefully reviewed and approved according to the Ethical Principles and Guidelines for the Use of Animals (No. ACNPU67-002) provided by Nakhon Phanom University, Thailand.

Results

Species diversity

During the study period, a total of 1,039 fish specimens were collected from four sampling stations in organic rice fields. These specimens represented 35 species, belonging to 15 families and 28 genera (Table 1). The most species-rich family was Cyprinidae, with 13 species (37.14%), followed by Osphronemidae (6 species, 17.14%), Bagridae (3 species, 8.57%), and Cobitidae (2 species, 5.71%). The remaining families were each represented by a single species (2.86% each) (Figure 1).

Among all collected specimens, 15 species were dominant across all sampling stations. The most abundant species was *Esomus metallicus* (13.28%), followed by *Oryzias mekongensis* (11.26%), *Rasbora borapetensis* (7.22%), and *R. rubrodorsalis* (6.64%). Other notable species included *Amblypharyngodon chulabhornae* (4.91%), *Trichopsis vittata* (4.81%), *Clupeichthys aesarnensis* (4.33%), *Parambassis siamensis* (4.23%), *Trichopodus trichopterus* (3.95%), *Lepidocephalichthys hasselti* (3.66%), *Anabas testudineus* (3.46%), *T. pumila* (3.46%), *Oreochromis niloticus* (3.37%), *R. trilineata* (3.27%), and *R. spilocerca* (3.08%) (Table 1). The remaining species each accounted for less than 3% of the total sample. Notably, only one non-native fish species, *O. niloticus*, was recorded in the study area.

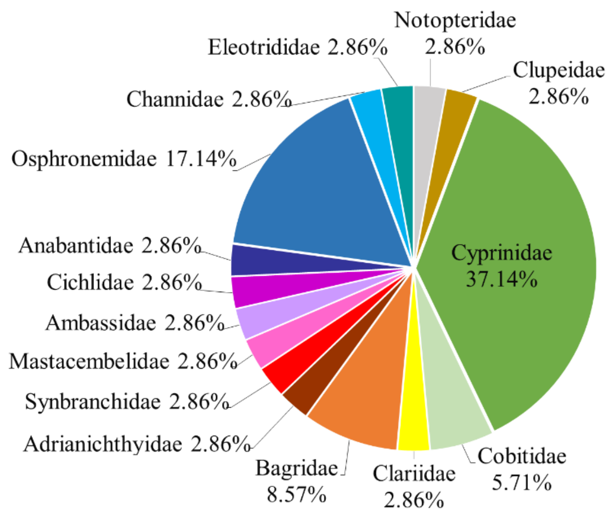

Figure 1. Composition of fish families in organic rice fields, Nakhon Phanom Province, Northeast Thailand

In this survey of an organic rice field in Nakhon Phanom Province, the ichthyofauna was predominantly composed of species classified as Least Concern (LC) according to the IUCN Red List (2025), accounting for 94.29% of the 35 recorded species. In addition, two species of conservation concern were recorded, namely *Boraras urophthalmoides* (Near Threatened, 2.86%) and *Betta smaragdina* (Data Deficient, 2.86%) (Table 1).

Differences in species composition were observed among sampling stations, particularly in terms of species richness. The highest species number (77.14%) occurred at Station 4, which contained 27 species, while Station 1 had the lowest richness at only 21 species (60.00%). Similar trends could be observed for biodiversity indices, with no significant differences found between stations ($p>0.05$). However, Station 4 had the highest Shannon-Wiener index (H'), which was 3.10, while Station 3 (3.04) and Station 2 (2.82) scored lower than Station 1 (2.76). Similarly, there was also no significant difference in species richness (R) found among stations, with the average score of 4.20 and range from 4.51 to 3.84. The evenness (E) was the only index that showed significant difference among stations ($p<0.05$). Station 4 had the highest evenness score at 0.94, followed by

Station 3 and Station 2 (both 0.91), and Station 1 had the lowest score at 0.89 (Table 2).

Table 1. Checklist of fish species and standard-length data from sampling stations in organic rice fields, Nakhon Phanom Province, Northeast Thailand

Scientific name	IUCN status	Station S1	S2	S3	S4	Total	Size range (cm SL)
Family Notopteridae							
Notopterus notopterus	LC		+	+	+	8 (0.77)	5.2-6.5
Family Clupeidae							
Clupeichthys aesarnensis	LC	+	+	+	+	45 (4.33)	2.6-3.0
Family Cyprinidae							
Esomus metallicus	LC	+	+	+	+	138 (13.28)	2.0-5.5
Boraras urophthalmoides	NT			+	+	11 (1.06)	1.0-1.4
Rasbora borapetensis	LC	+	+	+	+	75 (7.22)	1.6-4.1
Rasbora rubrodorsalis	LC	+	+	+	+	69 (6.64)	1.1-3.3
Rasbora spilocerca	LC	+	+	+	+	32 (3.08)	1.8-2.6
Rasbora trilineata	LC	+	+	+	+	34 (3.27)	2.5-3.9
Amblypharyngodon chulabhornae	LC	+	+	+	+	51 (4.91)	1.7-3.5
Barbonymus gonionotus	LC			+	+	16 (1.54)	9.5-10.2
Hampala dispar	LC				+	3 (0.29)	11.4-13.5
Puntius brevis	LC				+	29 (2.79)	2.2-6.4
Cyclocheilichthys apogon	LC		+	+	+	8 (0.77)	6.1-6.2
Labiobarbus siamensis	LC				+	4 (0.38)	5.7-6.0
Henicorhynchus siamensis	LC				+	5 (0.48)	8.4-9.1
Family Cobitidae							
Lepidocephalichthys hasselti	LC	+	+	+	+	38 (3.66)	1.6-2.5
Aperioptus hapalias	LC			+		12 (1.15)	2.3-3.0
Family Clariidae							
Clarias batrachus	LC	+				4 (0.38)	9.2-14.8
Family Bagridae							
Mystus atrifasciatus	LC	+				2 (0.19)	10.2-10.6
Mystus mysticetus	LC		+	+	+	6 (0.58)	5.4-7.3
Hemibagrus nemurus	LC		+			1 (0.10)	12.4
Family Adrianichthyidae							
Oryzias mekongensis	LC	+	+	+	+	117 (11.26)	0.9-1.5
Family Synbranchidae							
Monopterus albus	LC	+	+			3 (0.29)	12.4-18.9
Family Mastacembelidae							
Macrognathus siamensis	LC		+			2 (0.19)	6.7
Family Ambassidae							
Parambassis siamensis	LC	+	+	+	+	44 (4.23)	2.1-3.0
Family Cichlidae							
Oreochromis niloticus	LC	+	+	+	+	35 (3.37)	5.7-10.3
Family Anabantidae							
Anabas testudineus	LC	+	+	+	+	36 (3.46)	2.2-7.6

Scientific name	IUCN status	Station S1	S2	S3	S4	Total	Size range (cm SL)
Family Osphronemidae							
Trichopodus trichopterus	LC	+	+	+	+	41 (3.95)	2.0-6.5
Trichopodus microlepis	LC		+	+	+	23 (2.21)	1.9-6.2
Trichopodus pectoralis	LC	+		+	+	18 (1.73)	2.1-9.4
Trichopsis vittata	LC	+	+	+	+	50 (4.81)	1.7-3.6
Trichopsis pumila	LC	+	+	+	+	36 (3.46)	1.5-3.3
Betta smaragdina	DD	+	+			9 (0.87)	3.9-4.2
Family Channidae							
Channa striata	LC	+		+	+	26 (2.50)	5.1-7.5
Family Eleotrididae							
Oxyeleotris marmorata	LC		+	+		8 (0.77)	6.9
Total		21	24	25	27	1,039 (100)	

Note: S1-S4 = Sampling stations for collecting fish; IUCN Red List status: LC = Least Concern, NT = Near Threatened, DD = Data Deficient

Table 2. Diversity, species richness, and evenness indices of fish communities by station in organic rice fields, Nakhon Phanom Province, Northeast Thailand

Parameters	S1	S2	S3	S4	Mean
Shannon-Wiener diversity index (H')	2.76	2.82	3.04	3.10	2.93
Species richness index (R)	3.84	4.18	4.25	4.51	4.20
Evenness index (E)	0.89^{b}	0.91^{ab}	0.91^{ab}	0.94^{a}	0.91

Note: Means in a row with different superscript letters are significantly different ($p<0.05$)

Food composition and feeding habits of studied fish species

To map out feeding patterns, stomach contents were analyzed in 450 specimens across 15 dominant fish species. Along with stomach fullness (Figure 2) and diet composition (Figure 3), standard length (SL), alimentary canal length (ACL), and relative length of alimentary canal (RLA) were tracked for each species (Table 3). The combined dietary and RLA data then served to interpret their overall feeding habits.

Distinct differences in feeding strategies emerged from one species to the next. The diet of *Clupeichthys aesarnensis* consisted only of zooplanktons, accounting for 100% of the diet, suggesting that *C. aesarnensis* was a specialist feeder. Its length of alimentary canal measured between 2.0 and 2.3 cm, with RLA of alimentary canal measured between 0.7 and 0.8 (mean = 0.75). Since the value of RLA is lower than 1.5, it can be considered as evidence supporting the feeding habit of the fish as a zooplanktivore. *Parambassis siamensis*, on the other hand, mainly preyed on zooplanktons (55%) and insects (45%). Such feeding pattern revealed that *P. siamensis* exhibited flexibility in terms of feeding. Its length of alimentary canal measured between 1.3 and 2.2 cm, and the RLA measured between 0.6 and 0.7 (mean = 0.64). Considering the lower RLA value, *P. siamensis* had a shorter alimentary canal length, which usually applies to carnivorous fish.

The remaining 13 species include *Esomus metallicus*, *Oryzias mekongensis*, *Rasbora borapetensis*, *R. rubrodorsalis*, *Amblypharyngodon chulabhornae*, *Trichopsis vittata*, *Trichopodus trichopterus*, *Lepidocephalichthys hasselti*, *Anabas testudineus*, *T. pumila*, *Oreochromis niloticus*, *R. trilineata*, and *R. spilocerca*, were grouped as omnivores. Their diets included a wide range of food items such as phytoplankton, zooplankton, insects, fish, crustaceans, mollusks, and plant material. Alimentary canal length varied considerably (0.9-46.7 cm), with RLA values ranging from 0.8 to 4.5 (mean = 1.53). Taken together, these results indicate that the fish assemblage is largely dominated by omnivorous feeding strategies.

Table 3. Alimentary canal length (ACL), relative length of alimentary canal (RLA), and feeding habits of fifteen dominant fish species in organic rice fields, Nakhon Phanom Province, Northeast Thailand (n = 30 per species)

Fish species	Size range of fish examined (cm SL)		ACL (cm)		RLA		Feeding habit
	Range	Mean	Range	Mean	Range	Mean	
E. metallicus	2.0-5.5	4.5	5.2-15.3	11.20	2.6-2.8	2.71	OM
O. mekongensis	1.0-1.5	1.3	0.9-1.4	1.20	0.9-0.9	0.90	OM
R. borapetensis	2.0-4.1	3.2	1.6-3.5	2.70	0.8-0.9	0.87	OM
R. rubrodorsalis	1.5-3.3	2.8	1.2-2.9	2.40	0.8-0.9	0.86	OM
A. chulabhornae	1.8-3.5	3.2	2.9-5.8	4.50	1.6-1.7	1.66	OM
T. vittata	1.8-3.6	3.1	1.4-3.1	2.30	0.8-0.9	0.85	OM
C. aesarnensis	2.7-3.0	2.8	2.0-2.3	2.30	0.7-0.8	0.75	ZP
P. siamensis	2.1-3.0	2.6	1.3-2.2	1.75	0.6-0.7	0.64	CA
T. trichopterus	2.5-6.5	5.0	8.9-24.1	16.50	3.6-3.7	3.65	OM
L. hasselti	1.6-2.5	2.2	1.2-2.2	1.70	0.8-0.9	0.83	OM
A. testudineus	2.2-7.6	6.3	1.8-6.9	4.40	0.8-0.9	0.88	OM
T. pumila	1.5-3.3	2.7	1.2-2.9	2.10	0.8-0.9	0.84	OM
O. niloticus	5.7-10.3	9.1	20.4-46.7	33.60	3.6-4.5	4.02	OM
R. trilineata	2.5-3.9	3.3	2.2-3.8	2.90	0.9-1.0	0.93	OM
R. spilocerca	1.8-2.6	2.2	1.5-2.4	2.10	0.8-0.9	0.88	OM

Note: ZP = Zooplanktivore, CA = Carnivore, OM = Omnivore

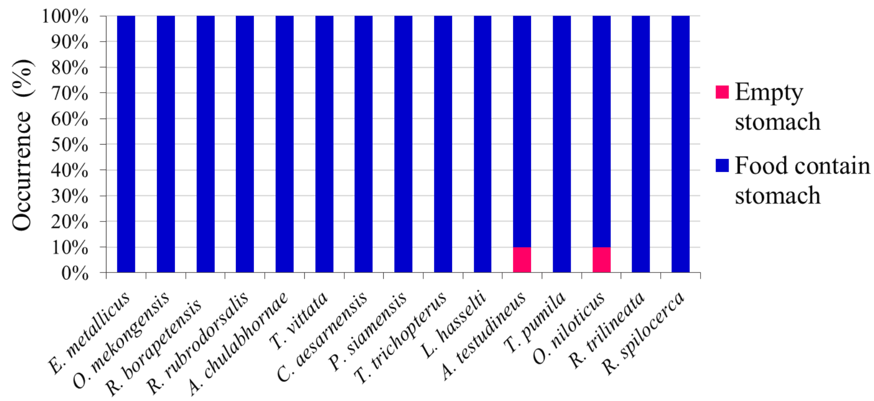

Figure 2. Stomach fullness and emptiness of fifteen dominant fish species in organic rice fields, Nakhon Phanom Province, Northeast Thailand

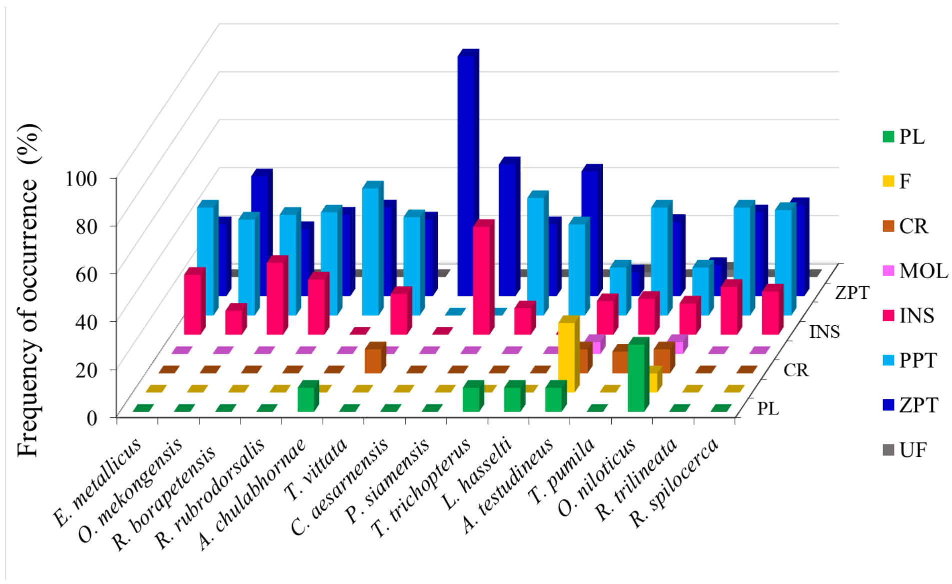

Figure 3. Frequency of occurrence of food items of fifteen dominant fish species in organic rice fields, Nakhon Phanom Province, Northeast Thailand; PL = Plants, F = Fish, CR = Crustaceans, MOL = Molluscs, INS = Insects, PPT = Phytoplankton, ZPT = Zooplankton, UF = Unidentified foods

Discussion

This is study provided important insights and addressed a critical knowledge gap regarding fish communities in organic rice fields in Nakhon Phanom Province, which is located within the Mekong River Basin, Northeast Thailand. To our knowledge, this is the first study to comprehensively document fish species diversity and feeding habits in organic rice fields in Nakhon Phanom Province. A total of 1,039 specimens were collected from four sampling stations, representing 35 species across 15 families and 28 genera. This high species richness reflects the biodiversity characteristic of organic rice field ecosystems, which provide a range of microhabitats that support diverse fish assemblages (Khoa *et al*., 2005; Freed *et al*., 2020; Ibrahim *et al*., 2023). In terms of families, the dominating groups were Cyprinidae, followed by Osphronemidae, and Bagridae. These results are consistent with observations made previously in Southeast Asia, where cyprinids tend to dominate in fish assemblages (Berra, 2001; Nelson *et al*., 2016; Nidsaraporn *et al*., 2017). In general, the domination of cyprinids is explained by their adaptive ability and life history flexibility according to changes in environmental conditions (Iwata *et al*., 2003). Another group that appeared abundant in this investigation was Osphronemidae. Due to the presence of the labyrinth organ, representatives of this family could survive in water with a low oxygen content (Graham, 1997; Norén *et al*., 2017). Such a feature must provide them with certain competitive advantages in rice fields, where oxygen content changes greatly. There was only one non-native fish species in this study, *Oreochromis niloticus*. This species is often intentionally introduced in rice fields to regulate pests (Halwart and Gupta, 2004). The low abundance of Nile tilapia (35 individuals out of 1,039; 3.5%) suggests that it may be less well represented in organic rice field environments compared to native species. Furthermore, the invasive blackchin tilapia (*Sarotherodon melanotheron*) was absent from the current investigation, suggesting that it has not yet become established within the study site.

Fifteen fish species were recorded as dominants in all sampling sites. Out of these species, *Esomus metallicus* accounted for 13.28% of the total fish community. *E. metallicus* is well-known in temporary freshwater ecosystems like flood plains and rice field environments of Indochina (Rainboth, 1996; Iwata *et al*., 2003; Hasan *et al*., 2020). In this study, *E. metallicus* was frequently observed inhabiting the near-surface zone in organic rice fields, and the size of these fish ranged between 2.0 to 5.5 cm in standard length (SL), which comprised both juvenile and adult stages. The existence of different life stages of *E. metallicus* suggested that these habitats could be supporting their recruitment as well as growth.

However, the majority of recorded species (33 out of 35) are currently considered to be of Least Concern status (LC) according to the IUCN Red List (2025). Nevertheless, the inclusion of NT and DD species such as *Boraras urophthalmoides* and *Betta smaragdina* is important for ecological reasons. Despite having been recorded in small numbers, it shows that organic rice fields may still offer favorable living conditions for conservation-sensitive species. These species could also potentially act as indicators for changes within the environment of agricultural wetlands.

There were no differences in Shannon-Wiener diversity index (H') and species richness (R) among the sampling stations, meaning that the fish assemblages were fairly consistent across all organic rice field sites (Magurran and McGill, 2011). The H' value equaling 2.93 indicates a relatively high diversity index in this agricultural ecosystem (Magurran, 2013); thus, it can be concluded that these areas still provide a sufficient habitat for various kinds of freshwater fish species. However, certain spatial patterns were noted as well. In particular, Station 4, which was close to an irrigation canal, demonstrated slightly higher H', R, and evenness indices than the other stations. It is reasonable to assume that the mentioned patterns are caused by the increased hydrological connectivity that facilitates the migration of fish from rice fields to canals and vice versa and adds heterogeneity to their habitat (Lawler, 2001; Khoa *et al*., 2005; Freed *et al*., 2020). Consistent results were obtained by Katano *et al*. (2003), who noted higher fish diversity in rice fields connected to irrigation systems. In addition, the higher evenness indices recorded in Station 4 indicate a more stable community and can be considered as evidence of its refugial nature.

Another aspect pointed out in this study was the ecological role played by fish inhabiting organic rice fields in which relatively high diversity levels were observed (H'>2.5). Food analysis showed the presence of a wide variety of food sources, with eight major groups found during the study, consistent with the high trophic diversity typically found in rice-fish agroecosystems (Freed *et al*., 2020). Such variety of diet depends upon not only the availability of resources from the habitat but also on feeding strategies of the fishes under study. Some species seemed to depend on the food resource provided within rice fields, indicating multiple food chains operating in such systems. Diet variation in the 15 dominant species of fish also suggests feeding adaptability based on environmental factors. The fish community was therefore categorized into three different trophic levels, including zooplanktivore, carnivore, and omnivore groups. *Clupeichthys aesarnensis* had the characteristic of being purely zooplanktivorous, with a feeding strategy confined to zooplanktons. This observation agrees with previous findings (Sirimongkonthaworn and Fernando, 1994; Morioka *et al*., 2019), where zooplanktons were found to be their preferred diet. However, *Parambassis* *siamensis* displayed a greater variety in their diet comprising both zooplanktons and insect larvae, thus earning the label carnivorous. The inference is consistent with earlier results by Okutsu *et al*. (2011) stating that *P. siamensis* feeds primarily on small zooplanktons and aquatic insects. It is important to note that the mean RLA is relatively lower at 0.64 as compared to 1.5.

Majority of the dominant species were more generalized feeders and were categorized as omnivores. This is because the stomach contents of the fishes comprised both plants and animals, including insects, small fish, crustaceans, mollusks, phytoplankton, and zooplankton. These findings imply that organic rice fields have a diverse food base, making it easier for fishes to be versatile in their feeding habits. Generalist omnivores exhibit dietary flexibility, allowing them to adapt to temporal and spatial variations in food availability (Saowakoon *et al*., 2021). The value of RLA in this category was between 0.8 and 4.5 (mean = 1.53) and can be compared to the typical range of RLA in omnivorous fishes as described by Taki (1978). However, interspecific variations in this category could be observed, with *Oreochromis niloticus* having high RLA values (greater than 3.0) indicative of a herbivorous tendency while *Rasbora borapetensis* had low values consistent with carnivorous nature. Despite that, the presence of animal and plant foods in one sample suggests that the species were omnivores. It is possible that the heterogeneous resources in organic rice fields make the species adaptable in feeding practices due to the reduction in chemicals used. In addition, the use of chemicals in conventional rice field cultivation may lead to reduced aquatic biodiversity, as indicated by Labe *et al*. (2016) and Fernandez-Zatrate *et al*. (2025).

From the perspective of the local community, the trophic structure found in such organic rice farms demonstrates a highly integrated pattern, which arises from the interaction of multiple parallel feeding relationships. In the present case, zooplanktivores including *C. aesarnensis* are thought to play a regulatory role in controlling the population size of plankton, which would cause a series of indirect impacts on the local nutrient cycle (Morioka *et al*., 2019). Even though their effects may not seem substantial at first glance, especially when examining each individual species, it would become clear once considering the entire food web. As an organism occupying the middle of the trophic chain, *P. siamensis* seems to be serving as an important connection between the lower-level primary consumer and higher trophic level organisms (Okutsu *et al*., 2011). Given the adaptability in their diet, this predator-prey relationship does not seem to be fixed; rather, it tends to vary according to environmental conditions. In contrast to the specialization observed in one type of feeding, the overall community leans towards omnivory and opportunistic feeding strategies. The prevalence of these feeding habits clearly suggests the use of a strategy that enables reduced chances of competitive exclusion, thereby making a variety of fish species inhabit a limited space. Stomach contents provide convincing evidence for this hypothesis insofar as almost all individuals (90-100%) had food items in their stomachs. The abundance of feeding activity in this case indicates that the availability of resources is not a limiting factor. The only exception to this trend was *O. niloticus* and *A. testudineus* with an occasional presence of 10% empty stomachs, which is possibly due to digestive rates or capture timing rather than local food deficiency (Hyslop, 1980; Bowen, 1996; Buckland *et al*., 2017). Overall, organic rice fields can be considered productive and complex habitats capable of supporting multiple food chains and diversity of fish communities.

In summary, this study represents a first attempt at evaluating the fish diversity and feeding ecology in organic rice fields in the province of Nakhon Phanom, northeast Thailand. Even though being anthropogenic systems, the surveyed agricultural areas contain quite a diverse fish fauna with a number of natural food resources for these organisms. Endangered species of *Boraras urophthalmoides* (NT) and *Betta smaragdina* (DD) have been detected, which makes their presence in the studied areas rather ecologically valuable than scarce numerical abundance. Introduced fish species such as *Oreochromis niloticus* were represented at the survey site, yet in low abundance. An overwhelming majority of individuals observed in organic rice fields were omnivores with quite flexible feeding preferences, a trend characteristic of many rice fields in different geographical locations. Apparently, organic rice fields in the Mekong Basin are operated not only as monoculture production sites, but also as secondary freshwater habitats, providing important ecological roles for local biodiversity. Further research is recommended to conduct additional studies of key species in these ecosystems to ensure sustainable development and protection of aquatic biodiversity in agricultural wetlands.

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Conflicts of interest

The authors declare no conflict of interest.

References

Bambaradeniya, C. N. and Amerasinghe, F. P. (2004). Biodiversity associated with the rice field agroecosystem in Asian countries: a brief review. International Water Management Institute. Colombo, Sri Lanka.

Barnes, R. S. K., Calow, P. P., Olive, P. J., Golding, D. W. and Spicer, J. I. (2009). The invertebrates: a synthesis. John Wiley & Sons, Inc., Hoboken, NJ, USA.

Berra, T. M. (2001). Freshwater fish distribution. Academic press, San Diego, CA, USA.

Bowen, S. H. (1996). Quantitative description of the diet. In: Murphy, B. R. and Willis, D. W. (eds.). Fisheries techniques, 2nd ed. American Fisheries Society. Maryland, USA, pp. 513-532.

Buckland, A., Baker, R., Loneragan, N. and Sheaves, M. (2017). Standardising fish stomach content analysis: The importance of prey condition. Fisheries Research, 196:126-140.

Fernandez-Zatrate, F., Pérez-Delgado, L., Coronel-Bustamante, D., Huanca-Silva, L., Taboada-Mitma, V. H., Quispe-Carhuapoma, M. and Cruz-Luis, J. (2025). Sustainable rice-fish farming systems: a systematic review and meta-analysis. Aquaculture Research, 2025:4029275.

Freed, S., Kura, Y., Sean, V., Mith, S., Cohen, P., Kim, M. and Chhy, S. (2020). Rice field fisheries: Wild aquatic species diversity, food provision services and contribution to inland fisheries. Fisheries Research, 229:105615.

Gillott, C. (2005). Entomology. Springer Science & Business Media, Berlin, Germany.

Graham, J. B. (1997). Air-breathing fishes: evolution, diversity, and adaptation. Elsevier, San Diego, CA, USA.

Halwart, M. and Bartley, D. (2007). Aquatic biodiversity in rice-based ecosystems. In: Jarvis, D. I., Padoch, C. and Cooper, H. D. (eds.). Managing Biodiversity in Agricultural Ecosystems. Columbia University Press, New York, NY, USA, pp.181-199.

Halwart, M. and Gupta, M. V. (2004). Culture of fish in rice fields. FAO; WorldFish Center, Rome, Italy.

Halwart, M. (2008). Biodiversity, nutrition and livelihoods in aquatic rice-based ecosystems. Biodiversity, 9:36-40.

Hasan, V., Widodo, M. S., Faqih, A. R., Mahasri, G., Arief, M., Valen, F. S. and Fitriadi, R. (2020). Presence of striped flying barb *Esomus metallicus* (Teleostei, Cyprinidae) from west Sumatra, Indonesia. Ecology, Environment and Conservation, 26:S73-S75.

Hyslop, E. J. (1980). Stomach contents analysis-a review of methods and their application. Journal of fish biology, 17:411-429.

Ibrahim, L. A., Shaghaleh, H., Abu-Hashim, M., Elsadek, E. A. and Hamoud, Y. A. (2023). Exploring the integration of rice and aquatic species: insights from global and national experiences. Water, 15:2750.

Iguchi, K. I., Yodo, T. and Katano, O. (2003). Habitat conditions for freshwater fishes found in a paddy water system on Iriomote Island. Japanese Journal of Ichthyology, 50:115-121.

International Union for Conservation of Natureand Natural Resources (IUCN). (2025). The IUCN Red List of Theatened Species. Retrieved from: http://www.iucnredlist.org

Iwata, A., Ohnishi, N. and Kiguchi, Y. (2003). Habitat use of fishes and fishing activity in plain area of southern Laos. Asian and African Area Studies, 3:51-86.

Katano, O., Hosoya, K., Iguchi, K. I., Yamaguchi, M., Aonuma, Y. and Kitano, S. (2003). Species diversity and abundance of freshwater fishes in irrigation ditches around rice fields. Environmental Biology of Fishes, 66:107-121.

Khoa, S. N., Lorenzen, K. A. I., Garaway, C., Chamsinhg, B., Siebert, D. and Randone, M. (2005). Impacts of irrigation on fisheries in rain-fed rice-farming landscapes. Journal of Applied Ecology, 42:892-900.

Kottelat, M. (2001). Fishes of Laos. WHT Publications, Colombo, Sri Lanka.

Labe, M. S., Fernado, N. C., and Fiegalan, E. R. (2016). Insects associated with organic and inorganic rice farming. International Journal of Agricultural Technology, 12:1345-1366.

Lawler, S. P. (2001). Rice fields as temporary wetlands: a review. Israel Journal of Zoology, 47:513-528.

Magurran, A. E. and McGill, B. J. (2011). Biological diversity: frontiers in measurement and assessment. Oxford University Press, Oxford, UK.

Magurran, A. E. (2013). Ecological diversity and its measurement. Springer Science & Business Media, Dordrecht, Netherlands.

Maitland, P. S. (2013). Biology of fresh waters. Springer Science & Business Media, Dordrecht, Netherlands.

Margalef, R. (1958). Information theory in ecology. General Systems. 3:36-71.

Morioka, S., Vongvichith, B., Marui, J., Okutsu, T., Phomikong, P., Avakul, P. and Jutagate, T. (2019). Characteristics of two populations of Thai river sprat *Clupeichthys aesarnensis* from man-made reservoirs in Thailand and Laos, with aspects of gonad development. Fisheries Science, 85:667-675.

Natuhara, Y. (2013). Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. Ecological engineering, 56:97-106.

Nelson, J. S., Grande, T. C. and Wilson, M. V. H. (2016). Fishes of the World, 5th ed. John Wiley and Sons, New Jersey, NJ, USA.

Nidsaraporn, P., Sitthi, K. and Jirawaeth, P. (2017). Species diversity and distribution of fishes in Pranburi river, Phetchaburi province and Prachuap Khirikhan province. International Journal of Agricultural Technology, 13:671-682.

Norén, M., Kullander, S., Rahman, M. M. and Mollah, A. R. (2017). First records of Croaking Gourami, *Trichopsis vittata* (Cuvier, 1831) (Teleostei: Osphronemidae), from Myanmar and Bangladesh. Check List, 13:81-85.

Okutsu, T., Morioka, S., Shinji, J. and Chanthasone, P. (2011). Growth and reproduction of the glassperch *Parambassis siamensis* (Teleostei: Ambassidae) in Central Laos. Ichthyological Exploration of Freshwaters, 22:97-106.

Pérez-Méndez, N., Martínez-Eixarch, M., Llevat, R., Mateu, D., Marrero, H. J., Cid, N. and Catala-Forner, M. (2023). Enhanced diversity of aquatic macroinvertebrate predators and biological pest control but reduced crop establishment in organic rice farming. Agriculture, Ecosystems & Environment, 357:108691.

Pielou, E. C. (1969). An introduction to mathematical ecology. Wiley-Interscience, New York. NY, USA.

Rainboth, W. J. (1996). FAO species identification field guide for fishery purpose. Fish of the Cambodian Mekong. Rome, Italy.

Saikia, S. K. (2024). Aquatic resources and feed diversification: Reviewing three case studies from South East Asia with a viewpoint of trophic intensification in rice fish culture. Aquaculture and Fisheries, 9:501-510.

Samanta, D., Samanta, C. and Bhargava, D. (2020). Diversity analysis of freshwater fishes in paddy field ichthyofauna in Sutahata and Haldia block of Purba Medinipur, West Bengal, India. International Journal of Fisheries and Aquatic Studies, 8:18-23.

Saowakoon, S., Saowakoon, K., Jutagate, A., Hiroki, M., Fukushima, M. and Jutagate, T. (2021). Growth and feeding behavior of fishes in organic rice-fish systems with various species combinations. Aquaculture Reports, 20:100663.

Shah, A. S. R. M., Ismail, B. S., Mansor, M. and Othman, R. (2010). Diversity and distribution of fish in irrigation water derived from recycled and uncontrolled flow water sources in the Muda ricefields. Pertanika Journal of Tropical Agricultural Science, 33:213-222.

Shannon, C. E. and Weaver, W. (1963). The mathematical theory of communication. University. of Illinois Press, Urbana, IL, USA.

Sirimongkonthaworn, R. and Fernando, C. H. (1994). Biology of *Clupeichthys aesarnensis* (Clupeidae) in Ubolratana Reservoir, Thailand, with special reference to food and feeding habits. Internationale Revue der gesamten Hydrobiologie und Hydrographie, 79:95-112.

Smith, H. M. (1945). The fresh-water fishes of Siam, or Thailand. Bulletin of the United States National Museum, 188:1-622.

Taki, Y. (1978). An analytical study of the fish fauna of the Mekong basin as a biological production system in nature. Research Institute of Evolutionary Biology, 1:1-77.

Taki, Y., Ohtsuka, R., Komoda, M., Natori, Y., Utsugi, K., Shibukawa, K. and Tran, L. X. (2021). Fishes of the Indochinese Mekong. Nagao Natural Environment Foundation, Tokyo, Japan.

Thongphak, D. and Iwai, C. B. (2016). Diversity of aquatic insects in the organic and conventional rice fields in Khon Kaen Thailand. International Journal of Environmental and Rural Development, 7:57-62.

Tuck, S. L., Winqvist, C., Mota, F., Ahnström, J., Turnbull, L. A. and Bengtsson, J. (2014). Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis. Journal of applied ecology, 51:746-755.

Vidthayanon, C. (2008). Field guide to fishes of the Mekong Delta. Mekong River Commission, Vientiane, Lao PDR.

Yamazaki, M., Hamada, Y., Kamimoto, N., Momii, T. and Kimura, M. (2004). Composition and structure of aquatic organism communities in various water conditions of a paddy field. Ecological research, 19:645-653.

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