Faculty of Resource Science and Technology

The Invasion of Alien Fish Species in Batang Kerang, Balai Ringin, Sarawak

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Aquatic Resource Sciences

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List of Abbreviations

BOD	Biochemical Oxygen Demand
cm	Centimetre
COD	Chemical Oxygen Demand
D’’	Margalef’s Richness Index
DO	Dissolved oxygen
g	gram
H’	Shannon-Weiner Diversity Index
J’	Pielou’s Evenness Index
m	Metre
mm/L	Millimetre per litre
NH_3-N	Ammonia nitrogen
NO_3-N	Nitrate
NO_2-N	Nitrite
SL	Standard Length
Spp.	species
ST	Station
TL	Total Length
W	Weight

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ABSTRACT

The purpose of this study is to identify alien fish species and their conjunctions that inhabit in Batang Kerang river in Balai Ringin, Sarawak. This research collected ten alien fish individuals from four distinct species, including *Trichopodus pectoralis, Pterygoplichthys pardalis, Helostoma temminckii*, and *Clarias gariepinus*. Another 16 indigenous species were found. Among the species are *Cyclocheilichthys apogon, Hampala microlepidota, Osteochilus vittatus, Puntius orchoides, Rasbora arudinata,* and *Leptobarbus rubripinna*. *Cyclocheilichthys apogon* was the most prevalent native species, whereas *Pterygoplichthys pardalis* was the most prominent alien species. There is no significant different in the composition of native and invasive species ($P \geq 0.05$), indicating that alien species have increased in those habitats even if local species continue to dominate.
Keywords: Batang Kerang, alien, conjunctions, native, invasive

ABSTRAK

Tujuan kajian ini adalah untuk mengenal pasti spesies ikan asing dan hubungkait antara spesies ikan yang mendiami sungai Batang Kerang di Balai Ringin, Sarawak. Penyelidikan ini telah mengumpul sepuluh individu ikan asing daripada empat spesies berbeza, termasuk Trichopodus pectoralis, Pterygoplichthys pardalis, Helostoma temminckii, dan Clarias gariepinus. 16 lagi spesies asli yang lain ditemui. Antara spesies tersebut ialah Cyclocheilichthys apogon, Hampala microlepidota, Osteochilus vittatus, Puntius orchoides, Rasbora arudinata, dan Leptobarbus rubripinna. Spesies asli yang paling dominan ialah Cyclocheilichthys apogon, manakala spesies asing yang paling banyak ditemui ialah Pterygoplichthys pardalis. Tiada perbezaan yang ketara dalam komposisi antara spesies asli dan invasif ($P \geqslant 0.05$*), menunjukkan bahawa spesies asing telah meningkat di habitat tersebut walaupun spesies tempatan terus mendominasi.*
Kata kunci: Batang Kerang, asing, hubungkait, asli, invasif

CHAPTER 1

INTRODUCTION

Freshwater fishes' regional and temporal patterns of diversity, distribution, and species composition can be used to explore the variables that determine fish community structure (Belliard *et al.*, 1997; Galactosa *et al.*, 2004). According to Harris (1995), food availability, breeding sites, water current, depth, terrain, and water physicochemical qualities all had a significant impact on the distribution and composition of fish species in each environment. Alien fish species have both a negative impact on ecological processes and a significant economic impact (Vilà *et al.*, 2010; Cook *et al.*, 2007). Humans have imported a vast number of species that are not native to their bio-geographic range, making fish species important invaders (Strayer, 2010). The expansion of invasive alien fish has resulted in predation, habitat degradation, resource rivalry, hybridization, and disease transmission among native species (Gozlan *et al.*, 2010a). Species translocation into new habitats or across natural geographic ranges may result in conflict between alien and native species. In terms of competitiveness, alien species outnumber native species. Invasive species have the potential to proliferate and disturb ecological processes, particularly if the new location lacks native predators (Ahmad *et al.,* 2020).

Many invasive ornamental and fish species have become critical challenges in Malaysia, including gar species, arapaima, sturgeon, and tilapia. These species have been observed developing in small river systems and gradually overtaking the environment. Alien species reduce native species' capacity to gather food, and they can effectively replace native species, eventually eliminating them from the ecosystem. Invasive predators, on the other hand, may be so adept at prey capture that prey populations decline and many prey species become extinct in impacted areas.

One factor that contributes to the monitoring of alien species in newly introduced environments is food (Ahmad *et al.*, 2020).

Malaysia is vulnerable to fish introductions caused by human activity, whether intentional or unintentional (Khairul Adha *et al.*, 2013). Aliens fish species have been identified in natural and other freshwater environments throughout the country, including streams, marshes, rivers, lakes, reservoirs, paddy fields, drainage zones, and mining pools (Samat *et al.*, 2008; Khairul Adha *et al.,* 2012). The distribution of this alien fish is crucial for anticipating any ecological problems that may arise as a result of its introduction, mitigating the impacts of its introduction, and preventing its expansion. Information on the introduction of alien fish species may aid in the prevention of biodiversity loss, such as species extinction, in naturally varied tropical systems. Thus, the purpose of this research is to determine the distribution and occurrences of alien fish species in the Batang Kerang floodplain, followed by a comparison of the water quality characteristics between the sampling stations in Batang Kerang waters.

CHAPTER TWO

LITERATURE REVIEW

2.1 The history of fish introduction to Malaysia

As early as the seventeenth century, southern Chinese immigrants brought foreign fish species to Malaysia (DOF, 2007). Aquaculture in Malaysia began with the introduction of Chinese carps such as bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), and grass carp (*Ctenopharyngodon idella*) (Welcomme, 1989; Mazuki, 2008). Welcomme (1989) also stated that following the 1950s, several foreign fish species were imported by governmental and semi-governmental organisations, as well as the commercial and private sectors, for aquaculture, recreation, and the aquarium fish trade (DOF, 2007).

The most common source of dissemination was discovered to be cultural introduction, with additional pathways including stocking to improve fisheries, aquarium business, sport fishing, and biological control (DOF, 2007; Chong *et al.*, 2010). According to Khairul (2013), the number of invasive fish species in Malaysia is increasing, owing to the continuous rapid expansion of the aquaculture, aquarium, and recreational fish sectors, as well as the growing interest in fishing and the growing demand for fish as a protein source. Invasive species invasion includes several stages, beginning with the initial introduction and continuing with local diffusion by transmission from one location to another (Yeo and Chia, 2010). They also stated that the vast majority of the animals died throughout the journey. However, between 10% and 50% of the species successfully adapt to the relevant stages of emergence, development, and invasiveness (Khairul Adha, 2012; Hashim *et al.*, 2012; Rahim *et al.,* 2013).

2.2 Studies on the alien fish species

Invasive alien species have a detrimental effect on both biodiversity and the economy. As more non-native (foreign, alien) species establish themselves in new places, the repercussions of invading species are expected to be severe across all ecosystems. Invasive species limit biological diversity in two ways: they lower the variety and quantity of species in one location, as well as the distinctness of assemblages in other locations. When invading species cause the extinction of native species or diminish the number of local populations, the former occurs (Deacon *et al.*, 2011).

Since the mid-twentieth century, ecological research has focused increasingly on the problem of invading alien species. Early biological invasion research concentrated on ecological concerns such as invasion process principles (Sakai *et al.,* 2001; Keane and Crawley 2002; Pyek *et al.*, 2008, Vaz *et al.,* 2017) and the consequences of invasive fish species on ecosystems (Sakai *et al.*, 2001). Recent research has focused on the economic costs of biological invasions (van Wilgen *et al.,* 2001; Pimentel *et al.*, 2005; Brunson and Tanaka, 2011).

Malaysian biodiversity scientists focused their attention on the arrival and impact of general invasive species (Khairul Adha, 2012; Hashim *et al.*, 2012; Rahim *et al.*, 2013). Furthermore, the effects of a certain invasive species, particularly those impacting freshwater ecosystems, were disregarded in that study.

2.3 Ecology, distribution and the establishment of alien fish species in Malaysia

Various research has shown that native fish populations in Malaysian tropical streams and rivers are distributed and impacted by a diverse range of bio-geographic zones (Inger and Chin, 1990; Choy *et al.*, 1996; Martin-Smith, 1998; Zakaria *et al.*, 1999; Samat *et al.*, 2002; Amir Shah *et al.*, 2009). The proliferation of invasive alien species is linked to global climate change, which complicates infection (Frank and Julian, 2008). Climate change has a significant impact on fish species distribution and phenology, which is responsible for the establishment of invasive fish species and the consequences they have on the systems (Poff *et al.,* 2002).

Because of species multiplication and transit over the world, the introduction rates and volume of new invasive species have been growing every year since the 1950s. By filling unfilled ecological niches and competing with local fish species, established foreign fish populations have altered the energy flow and trophic compositions under these conditions, resulting in a variety of negative consequences for native fish biodiversity conservation and restoration (Scott *et al.*, 2003). The species' global distribution was aided by strong predation pressure, abundance in its natural environment, the capacity to acquire and consume a diverse range of food, rapid growth, great genetic diversity, and reproductive potential. Furthermore, the species was extremely adaptable to a broad variety of physical and chemical conditions.

A total of 42 foreign fishes from 12 families have been detected in Malaysia, according to a thorough review from Khairul Adha. Cichlidae and Cyprinidae had the most species, with seven and six, respectively, followed by Xenocyprididae, which had five. There were also 173 non-native freshwater ornamental fish species found from 40 families. The Cichlidae family has the most species (67), followed by the Characidae (27) and the Cyprinidae (22). Every other family contained one to seven species, and some of them had several variations, up to 30 in certain cases (DOF, 2007). The list includes ornamental, recreational, and biological-control fishes. The great majority of ornamental fishes are said to have been produced in Malaysia, with just a handful being released into public waters (DOF, 2007; NCIAS, 2018).

2.4 Impact of alien fish species on native species

The introduction of organisms outside of their natural range by humans (referred to here as invasive species) causes changes in the ecosystems to which they are introduced. In certain cases, these alterations are significant enough to result in the extinction of native species or drastic changes in ecosystem functioning; however, for the great majority of invasive species, no quantitative information on the repercussions of such invasions is available (Kulhanek *et al.*, 2011; Larson *et al.,* 2013; Simberloff *et al.*, 2013). Freshwater habitats and biotas are facing extinction on a global scale (Olson *et al.,* 1998; Ricciardi *et al.,* 1999). Freshwater biodiversity, on the other hand, has gotten less attention (Allan and Flecker 1993; Leidy and Moyle 1998; Saunders *et al.*, 2002).

Conservation biology has mostly focused on terrestrial biodiversity, which is more visible and well-known to the general public (Olson *et al.,* 1998). The fate of fish species exemplifies the difficulties of freshwater conservation. Furthermore, fish account for half of all vertebrates, or around 24,600 species, with 41% totally freshwater (Leidy and Moyle 1998). After amphibians, freshwater fishes are the most endangered animals (Saunders *et al.,* 2002). Indeed, invasive species can have an immediate impact; for example, infections can devastate the health of animals, plants, and other organisms as soon as they arrive in a new region. Because of the range and possible severity of invasive species' repercussions, a better knowledge of them is crucial for prioritising management, conservation, and restoration measures, as well as developing appropriate policy responses to invasions (Welcomme, 1988; Simberloff, 2003; De Silva and Funge-Smith, 2005).

CHAPTER 3

METHODOLOGY

3.1 Study site

Fish were collected from the Batang Kerang floodplain (N 01°04'42.5" E 110°46'00.7") of Balai Ringin, Serian, Sarawak, during March 23 and March 24, 2022 (Figure 1).

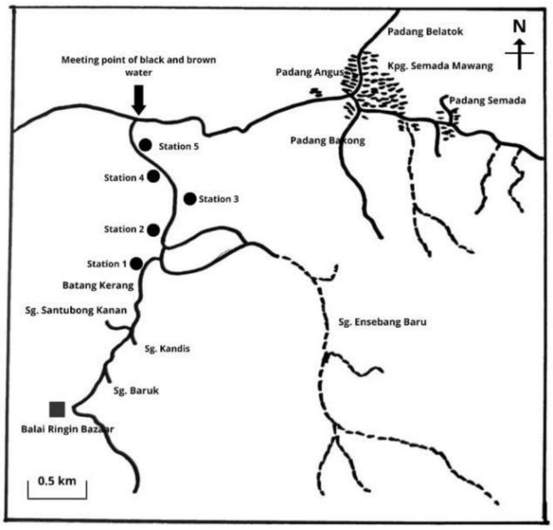

Figure 1: Sampling stations of Batang Kerang floodplain

3.2 Fish sampling

Fish species were sampled in the Batang Kerang floodplain using two types of monofilament gill nets with varied mesh sizes (single layer gill nets and three-layer gill nets). The mesh sizes for single layer gill nets were 1.5cm, 2.5cm, and 4cm, while the mesh sizes for triple layer gill nets were 3.5cm (inner layer) and 14cm (outer layer). During high-water seasons, both nets were employed at four locations in brown water zones. Gill nets were put at appropriate depths at the chosen locations and left overnight. Samples were also collected using a traditional fishing method known locally as 'Selambau.'

3.3 Fish identification

Except for the unknown fish samples, all captured fish were counted and validated in situ before being kept in 10% formalin, followed by 70% alcohol for further identification in the laboratory, as well as to authenticate their scientific names and species (Zakaria Ismail et al., 2019). The fish sample were all identified to their species level, the Total length (TL), Standard length (SL) were measured using the ruler to nearest centimetres and the weight (W) were measured in gram using weighing scale and recorded (Figure 2). Fish identifications were based on the morphological characteristics and the fish taxonomy. The total number of fish in each species were documented during the fish sample procedures as well as the status of whether the fishes were native or introduced (Froese *et al.*, 2018). The conservation evaluation was used in this study to evaluate the status of each collected fish species is The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species (IUCN, 2019).

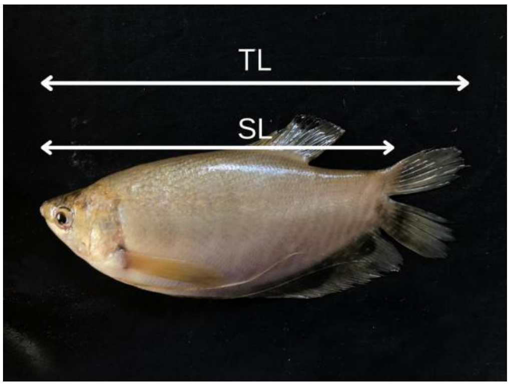

Figure 2: The measurement of fish (*Trichopodus pectoralis*)

3.4 Water physicochemical analyses

Water qualities were measured three times from the sampling status where the fish were collected, specifically after the fishing gear was deployed for fish capture. The Aquaread Water Quality Multiprobe Model AP 2000 was used to monitor water temperature (°C), pH (1-14), dissolved oxygen (DO), biochemical demand (BOD), and turbidity (NTU) in situ (Aquaread Water Monitoring Instrument, UK). Meanwhile, the river's depth (m) and width (m) were measured in situ with a depth finder and a range finder. Standard Method 8038, based on Nessler Methods Model DR1900, was used to determine the total ammonium nitrogen concentration (HACH, 2000). Nitrate and nitrite contents were determined in the laboratory using Standard Methods 8039 and 8153, respectively, using a Spectrophotometer model HACH DR 3900. (HACH, 2000). The chemical oxygen demand (COD) was determined using HACH DR 3900 and Standard Method 8000.

3.5 Data Analysis

Fish diversities were analysed using Shannon-Wiener diversity index, Pielou's evenness index and Margalef species richness by following the formula.

3.5.1 Shannon-Wiener Diversity Index (Shannon-Weaner, 1963)

The Shannon-Weiner Index (H') was used to calculate the variety of fish species based on the number of species and individuals in each species (Muchlisin and Siti Azizah, 2009).

$$\mathbf{H' = -\sum[(p_i) \times \ln(p_i)]}$$

Where-

- p_i = proportion of total sample represented by species
- S = number of species, = species richness
- H_{max}=ln(S)H_{max}=ln(S) = Maximum diversity possible

3.5.2 Pielou's Species Evenness Index (Pielou, 1966)

$$\mathbf{J = H'/\ln(S)}$$

Where-

- H' is Shannon Weiner diversity
- S is the total number of species in a sample

3.5.3 Margalef Species Richness Index (Margalef, 1958)

$$\mathbf{D'' = (S - 1) / Log\ (n)}$$

Where-

- S = Total Number of Species
- n = Total Number of Individuals in the Sample

3.5.4 One-way ANOVA

To compare the water physicochemical parameters data between stations, a one-way ANOVA test with a 95 percent confidence level ($\alpha = 0.05$) was performed. If the probability p-value is less than 0.05, it indicates that there are significant differences in the data for water parameters.

Null hypothesis: There is no significant difference between the mean of the water physicochemical data between the three stations.

Alternate hypothesis: There is a significant difference between the mean of the water physicochemical parameters data between the three stations.

Critical value: $\alpha=0.05$

CHAPTER 4

RESULTS

4.1 Native and Invasive Fish Composition

In Batang Kerang, Balai Ringin, Serian, Sarawak this study has collected 106 fish (native and invasive species) from four station, represented by 10 families and 16 species. The Cyprinidae fish family accounted for 72.64 percent of all fish taken. Other families that recorded are: Anabantidae (3.77%), Belontiidae (2.83%), Cyprinidae (72.64%), Clariidae (0.94%), Bagridae (1.89%), Channidae (1.89%), Siluridae (2.83%), Loricariidae (2.83%), Helostomatidae (2.83%), and Clupeidae (6.6%). Their families and species composition are presented in Figure 3.

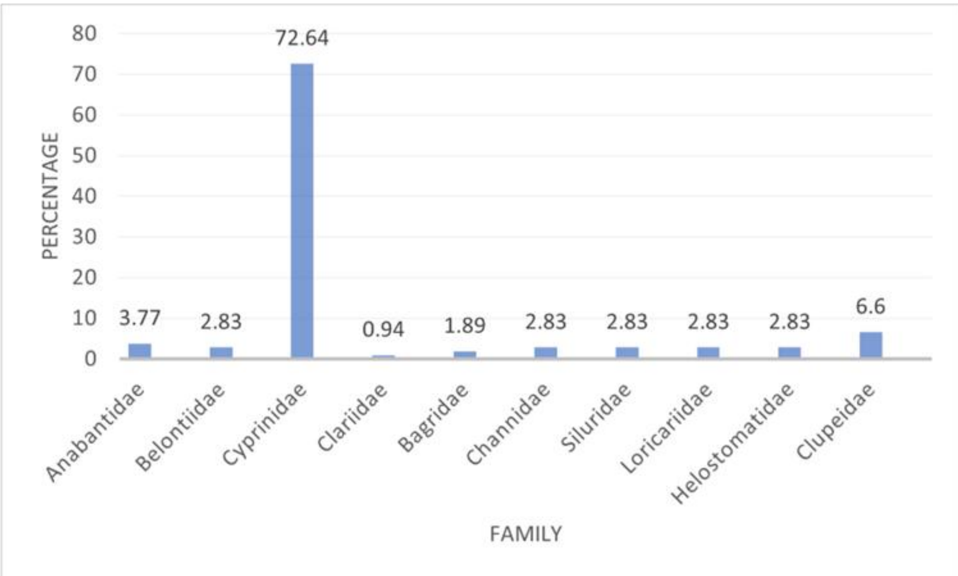

Figure 3: The percentage (%) of fish family collected in Batang Kerang, Balai Ringin, Serian, Sarawak.

From 16 species recorded (Figure 3), four are invasive species to Malaysia namely *Trichopodus pectoralis, Clarias gariepinus, Helostoma temminckii* and *Pterygoplichthys pardalis*. Those alien species represent 9.43% of total species recorded. Four of the 16 species identified (Figure 3) are invasive to Malaysia:

Trichopodus pectoralis, Clarias gariepinus, Helostoma temminckii, and *Pterygoplichthys pardalis*. These alien species account for 9.43 percent of all species documented. Amongst invasive species captured (Figure 4), *Pterygoplichthys pardalis* was the most dominant species collected (3 individuals).

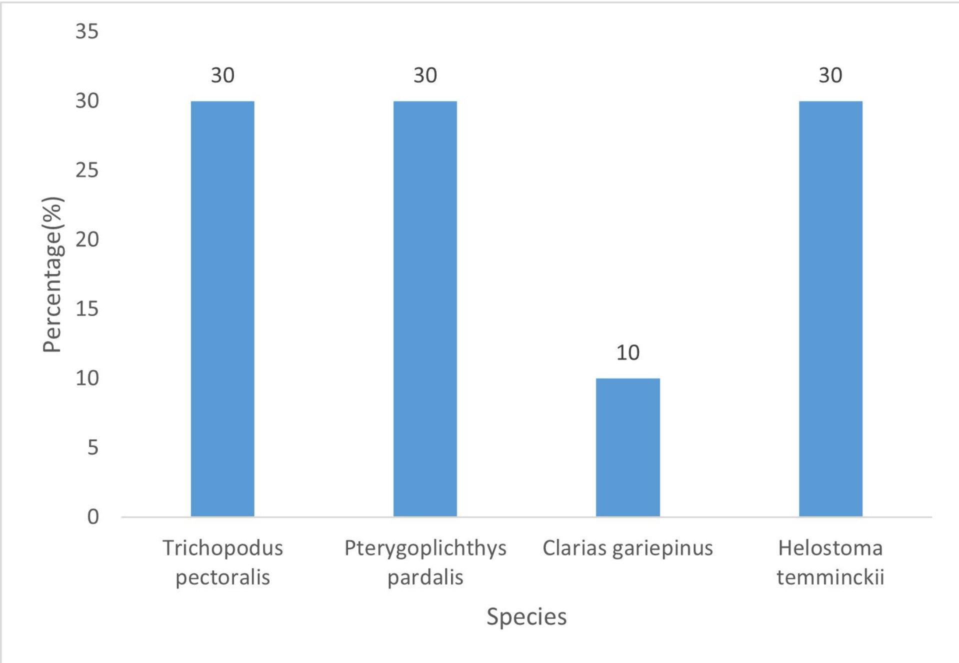

Figure 4: Percentage of four invasive fish species collected from Batang Kerang, Balai Ringin, Sarawak.

In Figure 5, *Cyclocheilichthys apogon* was numerous, accounting for 81.8 percent of the fish collection, with a mean weight of 41.71±17.68 gm and a standard length of 11.30±1.41 cm. *Hampala microlepidota* and *Osteochilus spp*. accounted for 5.9 percent of the fish collection, respectively. *Cyclocheilichthys apogon* was also detected in greater abundance at station 1, followed by *Clupeoides borneensis* (Clupeidae) and *Anabas testudineus* (Anabantidae), which accounted for 6.6 percent and 3.77 percent of the total fish captured, respectively.

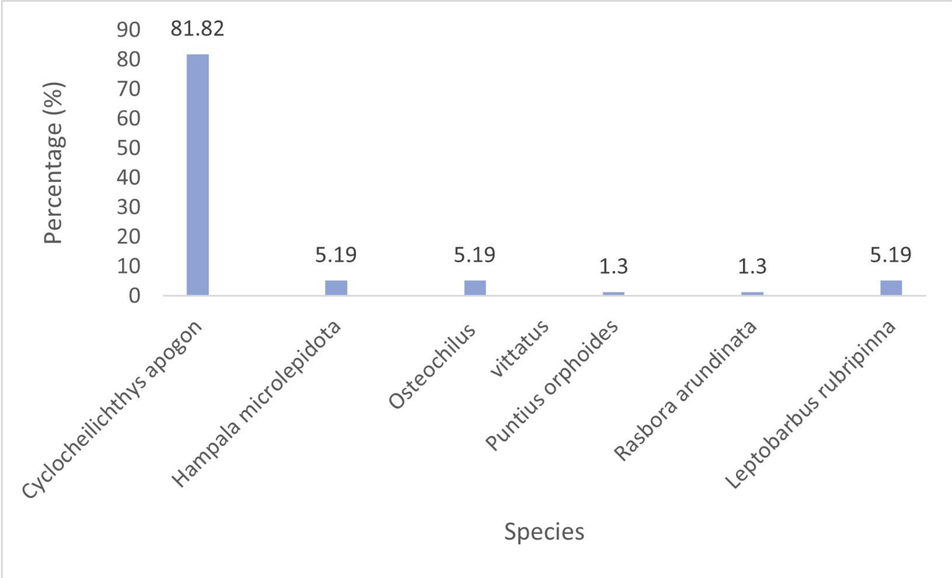

Figure 5: Percentage of Cyprinidae fish species collected from Batang Kerang, Balai Ringin, Sarawak.

Six fish of four different species were captured at station 2. The *Helostoma temminckii* (Helostomatidae) was the most numerous fish found in station 2, accounting for 2.83 percent of all fish taken. *Helostoma temminckii*, with a mean standard length of 18.8±11.8 cm, was detected mainly at stations 2 and 4. *Trichopodus pectoralis* accounted for 2.83 percent of the total fish taken at this station, whereas *Pterygoplichthys pardalis* and *Hampala microlepidota* accounted for 0.94 percent. Station 2 was the only one with the fewest number of fish captured.

Next, a total of 16 fish from eight species were collected from station 3. The most abundant species in this station were *Cyclocheilichthys apogon* which represented 37.5% of the total fish caught. The other species that were also collected from this station were *Trichopodus pectoralis, Hampala microlepidota, Osteochilus vittatus, Puntius orphoides, Leptobarbus rubripinna, Hemibagrus nemurus* and *Phalacronotus apogon.* Station 3 has the most fish diversity compared to the other stations.

In the last station, there were 17 fish from 11 species were caught. The common fish collected from this station were *Cyclocheilichthys apogon* which contribute to 17.65% from the fish collection. This includes *Leptobarbus rubripinna, Channa striata, Phalacronotus apagon* and *Pterygoplichthys pardalis*. Followed by *Anabas testudineus, Hampala microlepidota, Rasbora arundinata, Clarias gariepinus, Hemibagrus nemurus* and *Helostoma temminckii.*

In particular, Cyclocheilichthys *apogon, Osteochilus vittatus, Clupeoides borneensis, Anabas testudineus, Hampala microlepidota, Pterygoplichthys pardalis, Phalacronotus apogon* and *Hemibagrus nemurus* were mostly caught in both days. However, other species such as *Trichopodus pectoralis, Helostoma temminckii, Channa striata, Rasbora arundinata,* and *Clarias gariepinus* were only found during the first caught. During the second day, only *Puntius orphoides* and *Channa Lucius* were collected. The list of the fish collected were recorded in Table 1.

Table 1: Fish species composition and diversity in Batang Kerang floodplain.

Family	Station				No. of fish	Native/Invasive
	1	2	3	4		
Anabantidae						
Anabas testudineus	3	-	-	1	4	Native
Belontiidae						
Trichopodus pectoralis	-	2	1	-	3	Invasive
Cyprinidae						
Cyclocheilichthys apogon	54	-	6	3	63	Native
Hampala microlepidota	-	1	2	1	4	Native
Osteochilus vittatus	2	-	2	-	4	Native
Puntius orphoides	-	-	1	-	1	Native
Rasbora arundinata	-	-	-	1	1	Native
Leptobarbus rubripinna	-	-	2	2	4	Native
Clariidae						
Clarias gariepinus	-	-	-	1	1	Invasive
Bagridae						
Hemibagrus nemurus	-	-	1	1	2	Native
Channidae						
Channa lucius	-	-	-	1	1	Native
Channa striata	-	-	-	2	2	Native
Siluridae						
Phalacronotus apogon	-	-	1	2	3	Native
Loricariidae						
Pterygoplichthys pardalis	-	1	-	2	3	Invasive
Helostomatidae						
Helostoma temminckii	-	2	-	1	3	Invasive
Clupeidae						
Clupeoides borneensis	7	-	-	-	7	Native
Total	66	6	16	18	106	

Note: (-) indicates absence