Turk. J. Fish.& Aquat. Sci. 25(6), TRJFAS25337
https://doi.org/10.4194/TRJFAS25337

Turkish Journal of FISHERIES and AQUATIC SCIENCES

RESEARCH PAPER

Coexistence of Native and Alien Fish: Food Overlap and Feeding Strategies of *Pseudosphromenus dayi* (Köhler, 1908) and *Trichopodus trichopterus* (Pallas, 1770) in a Tropical Coastal Wetland, India

Suvarna S. Devi[1], Sruthi S. Retnan[1], Giri Bhavan Sreekanth[2], Smrithy Raj[1], Appukuttannair Biju Kumar[1,*]

[1]Faculty of Science, Department of Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram 695581, India.
[2]ICAR-Central Coastal Agricultural Research Institute, Goa 403402, India

How to Cite

Devi, S.S., Retnan, S.S., Sreekanth, G.B., Raj, S., Biju Kumar, A. (2025). Coexistence of Native and Alien Fish: Food Overlap and Feeding Strategies of *Pseudosphromenus dayi* (Köhler, 1908) and *Trichopodus trichopterus* (Pallas, 1770) in a Tropical Coastal Wetland, India. *Turkish Journal of Fisheries and Aquatic Sciences*, *25(6)*, *TRJFAS25337.* https://doi.org/10.4194/TRJFAS25337

Article History
Received 24 December 2024
Accepted 14 January 2025
First Online 20 January 2025

Corresponding Author
E-mail: bijukumar@keralauniversity.ac.in

Keywords
Invasive fish
Microplastics
Food spectrum
Niche overlap

Abstract

Understanding the dynamics between native and invasive species in aquatic ecosystems is crucial for effective conservation and management. This study investigates the diet composition and niche overlap of the native paradise fish (*Pseudosphromenus dayi*) and the introduced three-spot gourami (*Trichopodus trichopterus*) in a coastal wetland in Kerala, India. Through a comprehensive diet analysis, the study aims to reveal trophic dynamics and potential competition between these coexisting species. A substantial diet overlap of 0.73 indicates significant resource sharing, particularly in detritus, plant matter, Chlorophyta, insect remains, Cyanophyta, and Crustacea, highlighting a pronounced interaction between the paradise fish and three-spot gourami. Abundant resources in the wetland likely alleviate interspecific competition, facilitating the coexistence of both species. The presence of microplastics in the gut of both species signals increased human intervention and plastic pollution in the watershed and the wetland. These findings underscore the importance of considering dietary preferences and ecological behaviours in assessing interactions between native and invasive species. Effective management strategies are crucial to mitigate potential competition and maintain the ecological integrity of wetland habitats. Continuous monitoring of invasive fishes is recommended for early detection and the implementation of management plans to address potential threats.

Introduction

Biological invasions facilitated by human beings have merged the biota worldwide and led to irreparable changes in several native ecosystems (Barnosky *et al.,* 2012; Simberloff *et al.,* 2013), including significant loss of biodiversity at wide geographical scales and corresponding changes in function and the supply of ecosystem services (Ehrenfeld, 2010; Murphy & Romanuk, 2014); effects on genetic diversity, and the facilitation of additional invasions through invasion meltdown (Strayer, 2012; Simberloff *et al.,* 2013; Murphy & Romanuk, 2014). This is especially true for freshwater ecosystems, which are susceptible to biological invasions because of the close nexus between humans and aquatic ecosystems, not to speak of the interconnectedness of water bodies, which results in greater dispersal of species compared to terrestrial ecosystems (Selge *et al.,* 2011; Tricarico et al., 2016). As a result, several invasive alien species (IAS) frequently predominate in freshwater habitats, coexisting and interacting with one another (Kiesecker & Blaustein, 1998; Haubrock *et al.,* 2020; Dieleman *et al.,* 2021; Raj *et al.,* 2021a).

The distribution, abundance, and stability of invaded freshwater communities are known to be impacted by invasive alien species across many trophic levels (Strayer, 2010). Closely related species, when compared for feeding biology and diet breadth, will provide valuable insights into the critical characters conferring invasiveness (Mack 1996; Rejmanek & Richardson 1996); the niche breadth of the invasive species is closely related to the impact they have on the invaded communities (Shea & Chesson, 2002). Comparably, the dietary overlap with the endemic species can also determine the consequence of the invasive ones (Jackson *et al.,* 2012), affecting the native communities (Woodford *et al.,* 2005). Those invasive species with broader ecological niches will associate with more species (Goodell *et al.,* 2000). When structuring ecological communities, the interspecific relationship comes to the forefront (McGill, 2010; Razgour *et al.,* 2011). Fishes coming under the Families Salmonidae (Crowl *et al.,* 1992), Cyprinidae (Weber & Brown, 2011), Cichlidae (Martin *et al.,* 2010), etc., coming under various feeding guilds were reported to have negative conflicts from invasive species. Even though some of the non-natives have mastered the situation of resource partitioning with native species effectively (Kakareko *et al.,* 2013), some are known to minimize their competition with endemic ones by occupying empty dietary niches (Shea & Chesson 2002; Jackson & Britton, 2014). A well-established model of invasive ecology in freshwater proves that the intense interspecific competition for food resources among the endemic and invasive fishes frequently impacts the ecosystem (Gozlan *et al.,* 2010; Cucherousset *et al.,* 2012).

The Western Ghats biodiversity hotspot, a centre of endemism of freshwater fish, harbours about 28 species of alien fish in its southern region, and the significant pathways of introduction are ornamental fish trade and aquarium keeping (Raj *et al.,* 2021b). *Trichopodus trichopterus* (native to China and Southeast Asia) is a non-native ornamental fish bred by aquarium traders and hobbyists (Anna Mercy et al., 2007), and *Pseudosphromenus dayi*, a native ornamental fish is used primarily as a larvivorous fish (Anna Mercy *et al.,* 2007; Gopalakrishnan & Ponnaiah, 2000). Feeding biology of *Trichogaster fasciata* (Das & Moitra, 1963; Dasgupta, 2004; Mitra *et al.,* 2007; Gupta, 2015) and *Trichopodus trichopterus* (Pethiyagoda, 1991; Degani, 2001; Talde *et al.,* 2004) has been studied extensively in the past. Most of the studies regarding *Pseudosphromenus dayi* are concerned with its larvivorous potential (Jacob & Nair, 1983a; Jayasree & Paniker, 1992; Chandra *et al.,* 2008; Sarwar, 2015) and a few studies on reproduction (Jacob & Nair, 1983b) and gastric digestion (Jacob & and Nair, 1981).

Accurate prediction of the impacts of invasive fish is imperative for determining optimal management strategies to prevent adverse effects of biological invasions. As global invasion rates escalate (Seebens *et al.,* 2017), understanding and mitigating invasion consequences become paramount. Around one-fifth of the 100 most detrimental invasive species worldwide inhabit aquatic environments, showcasing visible effects on their recipient systems (Kulhanek *et al.,* 2011). Coastal wetlands, crucial for supporting diverse aquatic communities and providing essential ecosystem services, are particularly vulnerable to the introduction of invasive species, particularly from upland habitats, disrupting the ecological balance. This study delves into the diet composition and niche overlap of the indigenous paradise fish (*Pseudosphromenus dayi*) and the exotic three-spot gourami (*Trichopodus trichopterus*) in a tropical coastal wetland in Kerala, South India. By examining these interactions, the aim is to contribute to a better understanding of the potential impacts of invasive species on coastal wetland ecosystems, facilitating effective management practices to safeguard their ecological integrity.

Material and Methods

Fish Species and Sampling

Samples of non-native *Trichopodus trichopterus* (N=95) and native *Pseudosphromenus dayi* (N=95) were collected randomly from the coastal wetland in Thaikkal fishing village (Figure 1), Cherthala, Allapuzha district of Kerala. The fishes were collected using cast nets of mesh sizes 7 mm to 10 mm. Sampling was conducted over a span of twelve months (2021), during which both species were collected from various sites within the coastal wetland.

Three spot gourami, *Trichopodus trichopterus* (Pallas, 1770) (Anabantiformes, Osphronemidae, Trichogastrinae) (Figure 2 A) is a freshwater ornamental fish native to Southeast Asia. This fish has been introduced in various parts of the world for multiple purposes, including fisheries (as food fish), aquaculture, pet trade and research and has been reported from over 17 countries (CABI, 2021). The Brown Spike-tailed Paradise Fish *Pseudosphromenus dayi* (Köhler, 1908), (Figure 2 B), a close cousin of three spot gourami (Anabantiformes, Osphronemidae, Macropodusinae), occurs naturally in the inland water bodies of Kerala, in both fresh and brackish waters (Froese and Pauly, 2023).

Diet Analysis

The captured fish were washed thoroughly with deionised water and later preserved in 5 % formalin; total length (TL) was measured using a digital calliper to the nearest mm and weight using an electronic balance to the nearest milligrammes. Later, the gut was dissected, and diet composition was studied using the point's method (Hynes, 1950; Hyslop, 1980). The gut contents were viewed and sorted under a stereomicroscope (EZ4, Leica, Germany) and compound microscope (BX43, Olympus, Japan). They were identified up to their lowest taxa possible, and points were given for gut (Windel & Bowen, 1974) and food items (Kow, 1950). Percentage composition was determined for each food item, and it is expressed as numerical abundance (%N), percentage frequency of occurrence (%F) and percentage volume (%V). The important food items consumed by both the species were identified using the Index of Relative Importance (IRI) (Pinkas *et al.,* 1971): IRI = %F × (%N+%V); where F is the percentage frequency of occurrence, N is the percentage of numerical abundance, and V is the percentage volume of each prey item. Gastrosomatic Index (GaSI) was also determined following Khan *et al.* (1998) using the formula: GaSI = weight of gut /Weight of fish x 100.

Trophic Niche Breadth and Feeding Overlap

Levin's measure (Krebs, 1999) was computed using volume data to calculate the diet breadth of both the species. To standardise the trophic niche measure (scale from 0 to 1), Hurlbert's formula (1978) was applied, which is as follows:

$$B_A = [(\sum_{i}^{n} = {}_1P_{ij}^2)^{-1} - 1]\,(n-1)^{-1}$$

Where B_A is the standardised trophic niche breadth, P_{ij} is the proportion of food category j in the diet of species i, and n is the total number of food categories. Trophic niche breadth was considered low when the values lie between 0-0.39, intermediate (0.4-0.6) and high (0.61 - 1) (modified method of Grossman, 1986).

Diet overlap between two species was calculated using the Schoener Index (Cx), as follows:

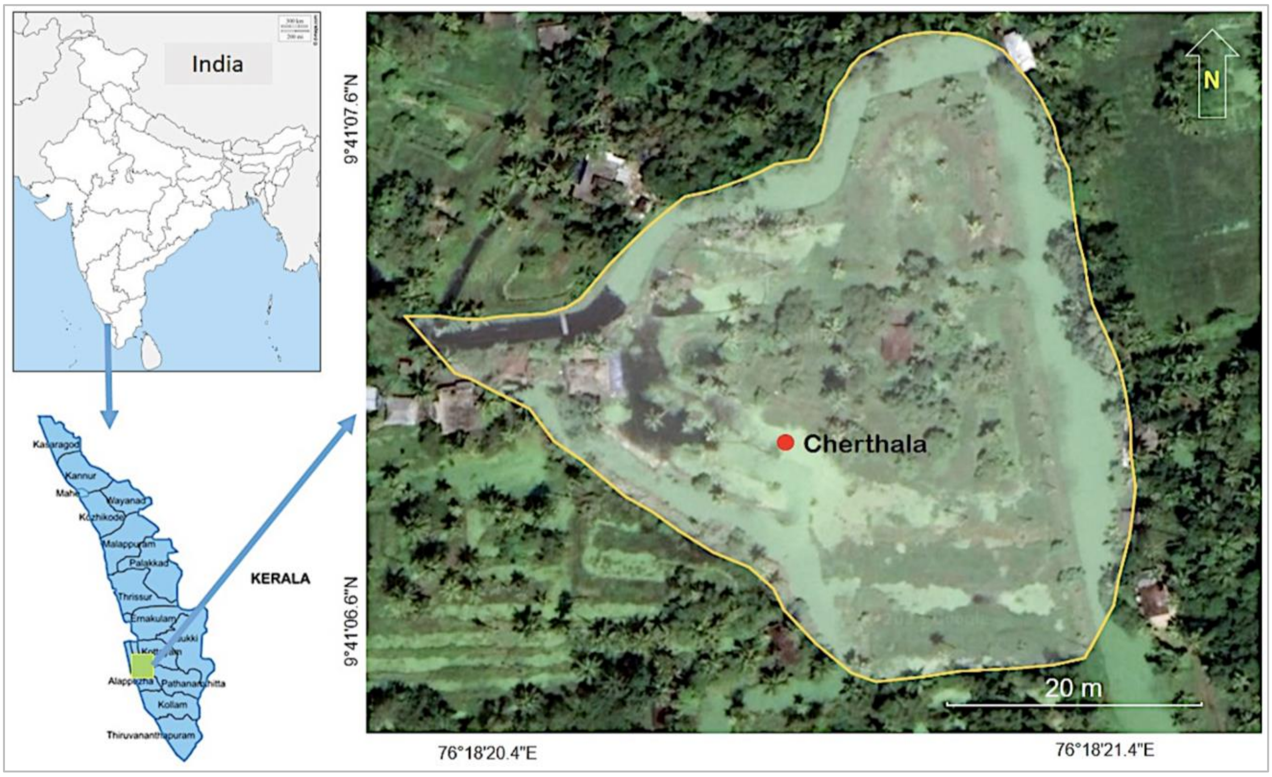

Figure 1. Map showing the location of the sampling site in Thaikkal Fishing village, Cherthala, Kerala, India

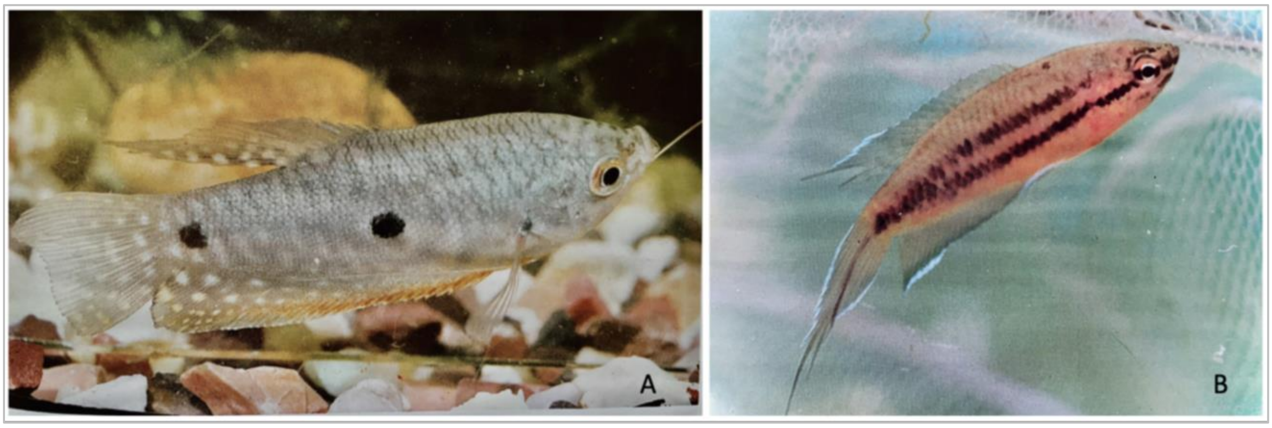

Figure 2. A. *Trichopodus trichopterus* (Pallas, 1770); B. *Pseudosphromenus dayi* (Kohler, 1908)

$$C_x = 1 - \frac{1}{2}\sum(P_{xi}\text{-}P_{yi})$$

where P_{yi} and P_{xi} are the proportion of the 'I' type of food organism used by the y-fish and the x-fish group (Moyle & Senanayake, 1984; Grossman, 1986).

Dietary overlap values were assessed using Pianka's symmetric index (1974), ranging from 0 to 1, where the value 1 indicates complete overlap and is considered low (0 - 0.39), intermediate (0.4 - 0.6) or high (0.61 - 1) (modified from Grossman, 1986). The trophic level of each species was gathered from Froese and Pauly (2023).

Microplastics Analysis

While analysed for diet spectrum, the gut contents of *T. trichopterus* and *P. dayi* showed the presence of plastic particles. Hence, after identifying the stomach contents and points given, the contents in the petri dish were transferred to glass bottles with metal forceps, treated with 10% KOH solution and incubated at 60°C for 48 hours to digest the organic matter present in it (Dehaut *et al.,* 2016). The digested contents were filtered through a vacuum pressure pump using Whatman filter paper of pore size 1.2µm; later air-dried, and observed under a stereo zoom microscope (Leica EZ4D), microphotographs and measurements were taken using software (Leica Application Suit). The fibers and fragments were collected using metal forceps under a stereoscope microscope and stored in glass vials for spectroscopic analysis.

After taking from the ice box, the procured fish were thoroughly cleaned with deionized water. The instruments, glassware, and metal forceps were washed with 75% ethanol. Nitrile gloves were used while dissecting and also for the entire procedure. Procedural blanks were kept during the study to ensure no contamination.

The samples were analysed using an ATR FT-IR spectrometer (Thermo Fisher Scientific NICOLET IS50) with a scan range of 400-4000 cm^{-1} for polymer analysis at the Central Laboratory for Instrumentation and Facilitation (CLIF), University of Kerala. The result was compared with Bruker FTIR spectral library samples of natural and synthetic fibres, polymers and natural compounds (Mecozzi *et al.,* 2016). The fragments were subjected to scanning electron microscopy (SEM) (Carl Zeiss Evo-18) to analyse the surface morphology of the microplastic particles.

Results

A total of 95 specimens each of invasive fish three-spot gourami *T. trichopterus* (size range 7.0 - 11.5 cm) and indigenous paradise fish *P. dayi* (size range 3.50 - 6.40 cm) were analysed for their gut contents. It was observed that both the fish species feed on plant matter and animal origin, and the food items were categorized into Cyanobacteria, Ochrophyta, Chlorophyta, Cryptophyta, Rotifera, Protista, Crustacea, fish eggs and miscellaneous items.

Food Spectrum of *T. trichopterus*

Diet analysis revealed that *T. trichopterus* has a benthic omnivorous feeding habit consuming a variety of invertebrates along with Amoeboza, Euglenophyta, Cyanophyta, Ochrophyta, Chlorophyta, detritus and miscellaneous items. The major component of the food in the fish's gut was comprised of detritus (38%), followed by miscellaneous items containing sand, plastic fragments and fibers (20%). Plant remains (14%) while least was Amoeboza (*Saccamoeba* sp.) and Euglenophyta (*Phacus* sp.) with 1% each (Figure 3a). The frequency of occurrence of various food items also showed higher values for detritus followed by miscellaneous items and plant remains. In comparison, lower values were obtained for Amoeboza and water mites (Figure 4). The GaSI recorded for *T. trichopterus* surprisingly showed lesser values for larger groups of fishes and higher values for smaller ones (Figure 5).

Food Spectrum of *P. dayi*

The diet spectrum of *P. dayi* revealed the omnivorous feeding habits of the fish, consuming a wide array of invertebrates and plant remains. The percentage composition of various food items showed that *P. dayi* mainly fed on detritus (27%), followed by miscellaneous items (16%), Chlorophyta (18%), and plant remains (12.5%) (Figure 3b). Other food items were represented in smaller percentages with the lowest values for Euglenophyta, Protista, Cnidaria and Nematoda (2% each). Similar results were obtained for the frequency of occurrence, in which detritus and Chlorophyta were recorded frequently in the gut of *P. dayi,* followed by miscellaneous items, plant and insect remains, with the least being Cnidaria and Nematoda (Figure 4). Thus, the percentage composition and frequency of food items in the gut proved that the fish prefers benthic food items especially plant matter, to animal matter. The GaSI values of *P. dayi* indicated maximum values for a larger size range of fishes, whereas the rest of the size ranges exhibited more or less fluctuating values (Figure 5).

Trophic Niche Breadth and Feeding Overlap

The diet overlap obtained between the native and non-native species was 0.73, showing a high overlap. Trophic niche breadth (B_A) derived was very low for both species (*T. trichopterus* - 0.16 and *P. dayi* - 0.27) (Table 1). Patterns of resource utilisation showed by *T. trichopterus* and *P. dayi* in the natural wetland suggest that even though resource sharing prevails to a greater extent within these species, it does not hamper the coexistence of the species. The diet breadth (B) of *T. trichopterus* was less (2.77) when compared to that of *P. dayi* (3.92). A high abundance of resources might

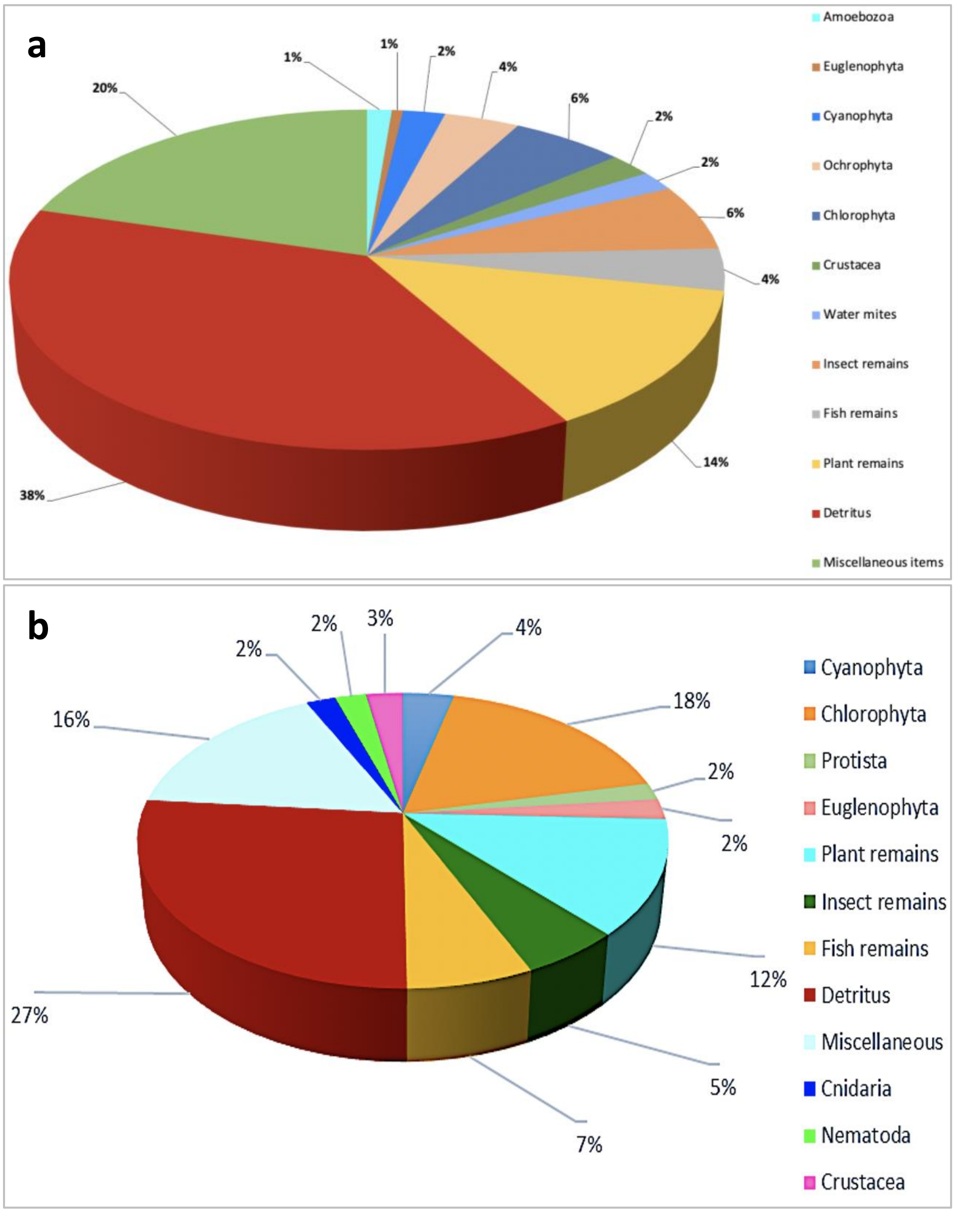

Figure 3. Percentage composition of various food items found in the gut of *T. trichopterus* **(a)** and *P. dayi* **(b)**

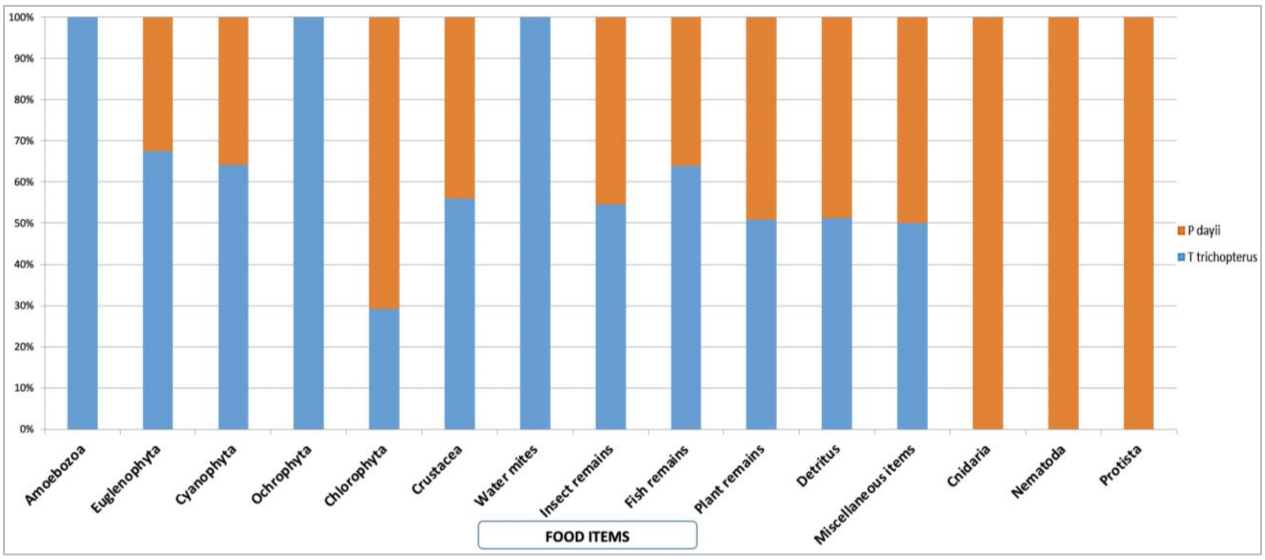

Figure 4. Percentage frequency of occurrence of various food items of *T. trichopterus* and *P. dayi* showing niche overlap

promote relaxation of interspecific competition and facilitate coexistence. Even though both fishes prefer plant matter and detritus, they also consume insect larvae and small zooplankton. Hence, the trophic level calculated for *T. trichopterus* was 2.64, and that of *P. dayi* was 2.45, showing little more than the herbivorous fish.

Microplastics Analysis

Microscopic examination of particulates obtained from the gut contents of *T. trichopterus* and *P. dayii* showed the presence of microplastic fragments and fibers (Figure 6). Out of the 95 each of the fish examined, 31 MPs were obtained from 26 fishes (*T. trichopterus*) and 22 MPs from 17 fishes (*P dayi*). Fragments (transparent-6; yellow-1; n=4) and fibers of red (n=13), blue (n=18), violet (n=12), purple (n=2) and green (n=1) were obtained which indicates the dominance of fibres. Characterisation of microplastic fragments and fibres using ATR-FTIR spectroscopy showed that fragments of polyamide (PA), and fibers constituted polypropylene (PP), polyamide (PA) and polyethylene (PE) (Figure 7). Further, scanning electron microscopy (SEM) images of microplastic fragments obtained from gut contents of *T.*

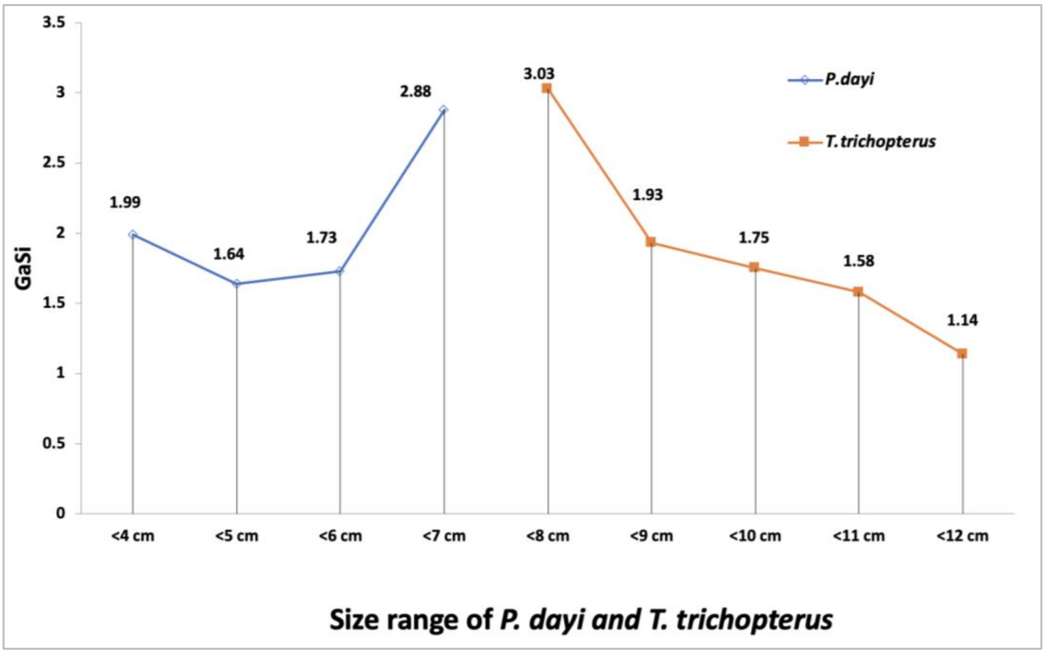

Figure 5. Gastro-somatic index **(**GaSI) of *T. trichopterus* and *P. dayi*

Table 1. The diet composition and feeding indices for *Trichopodus trichopterus* and *Pseudosphromenus dayi* in a tropical coastal wetland, Cherthala, Kerala State, India

Prey items		*T. trichopterus*	*P. dayi*
Proportion of prey items	AM	0.000141981	0
	EG	0.000487464	0.000896
	CY	0.004395052	0.002561
	OC	0.008894162	0
	CH	0.01663951	0.277831
	CR	0.001027104	0.000701
	WM	0.000313963	0
	IR	0.028106332	0.017594
	FR	0.011403379	0.019317
	PR	0.181927126	0.182106
	DE	0.52594154	0.347962
	MI	0.220722386	0.14961
	CN	0	0.000277
	NE	0	0.000901
	PT	0	0.000244
Diet breadth		1.78	2.93
Trophic niche breadth		0.16	0.27
Trophic level		2.64	2.46
Diet overlap		0.73	

trichopterus showed pits, corrosions and cracks which is an indication of mechanical weathering (Figure 8).

Discussion

One of the leading causes of biodiversity loss in freshwater ecosystems is non-native species (Dudgeon *et al.,* 2006). They compete with indigenous species for food resources (Zambrano *et al.,* 2010a), resulting in diet shifts of the native species (Sharma & Borgstrøm, 2008) and trophic cascade by elevating nitrogen and phosphorous levels in the water, thereby promoting algal growth (Figueredo & Giani, 2005). One of the prerequisites to developing management decisions and action plans for non-native species is to understand their ecological niche (Townsend, 2002). The feeding analysis showed the sharing of food between the alien *T. trichopterus* and the native *P. dayi,* but with a well-defined resource partitioning. The diet composition results in both species are in corroboration with previous studies (Conlu, 1986; Chung *et al.,* 1994; Rainboth, 1996; Talde *et al.,* 2004), with detritus, miscellaneous items and plant remains forming the major food of *T. trichopterus,* and detritus, miscellaneous items, Chlorophyta and plant remains representing the predominant food of *P. dayi.* This shows the omnivorous feeding nature of both species. *T. pectoralis* was indicated as a plankton feeder, and their leading food was crustaceans and insects (Diniya *et al.,* 2014). The GaSI obtained for *T. trichopterus* was lesser for the larger-size grouped individuals, whereas the case was vice versa for *P. dayi*. Month-wise, GaSI reported that the banded gourami, *C. fasciata,* had low

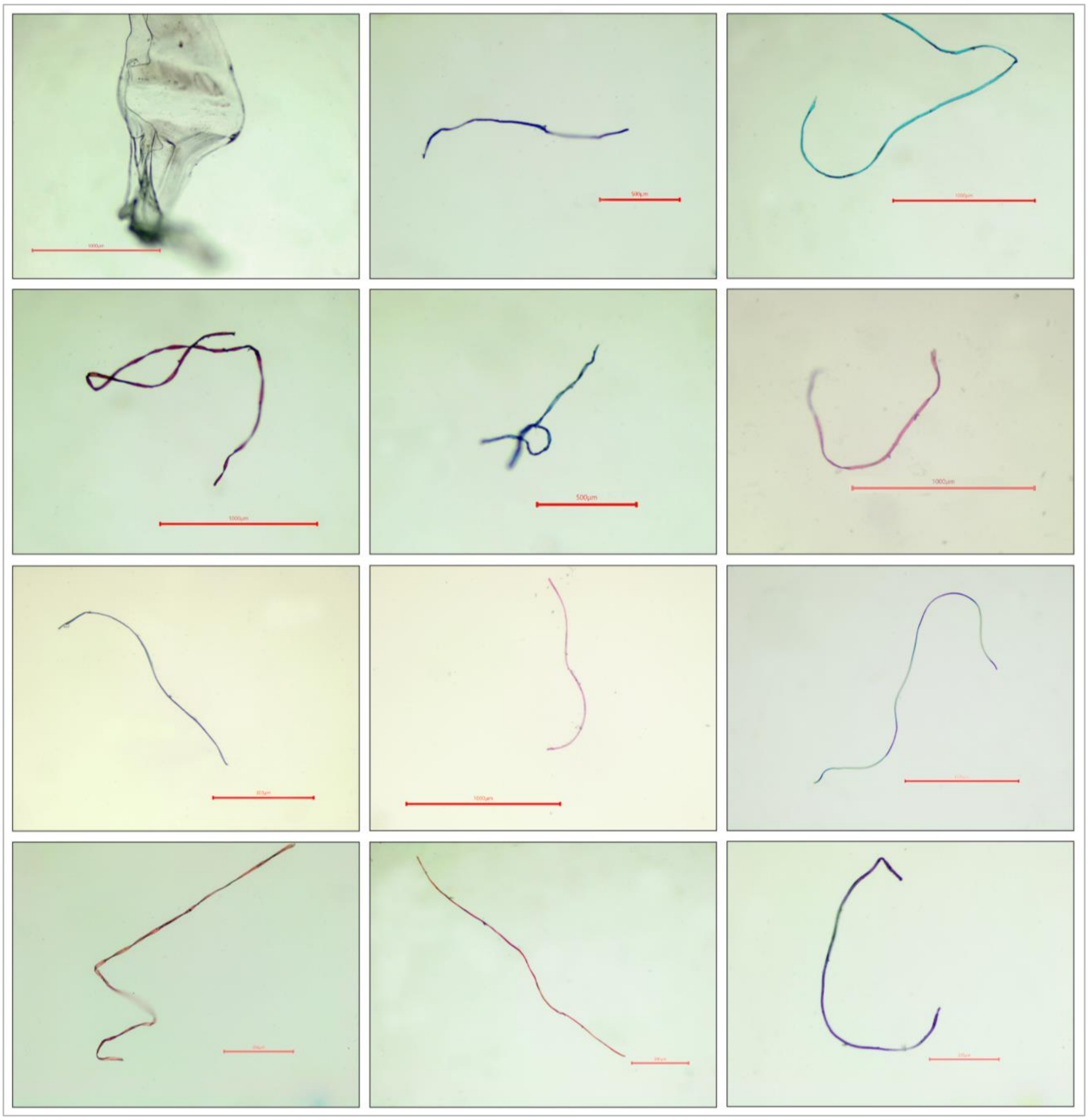

Figure 6. Microplastic fragments and fibers obtained from gut contents of *Trichopodus trichopterus and Pseudosphromenus dayi*

values from May to July, peaking in October (Mitra *et al.,* 2007).

The diet overlap values (0.728) were considerably higher, showing resource sharing of detritus, plant matter, Chlorophyta, fish remains, insect remains, Cyanophyta, Crustacea, Euglenophyta, miscellaneous, indicating that both species are structured in specific trophic guilds. Other than low diversity environments, tropical fish assemblages are patterned in trophic guilds in fixed seasons (Winemiller & Pianka, 1990). The high degree of diet overlap in this study may also reflect the ecosystem's lesser diversity of food resources. The two species share their resources with slight variations without interspecific competition. However, as the species in an aquatic ecosystem are mobile and the prey availability changes in patterns during seasons/years, it is highly unpredictable (Raborn *et al.,* 2004). Sometimes, the data on dietary overlap is not enough to confirm the presence of competition, as low values might result from competition from the past (Colwell & Futuyma,

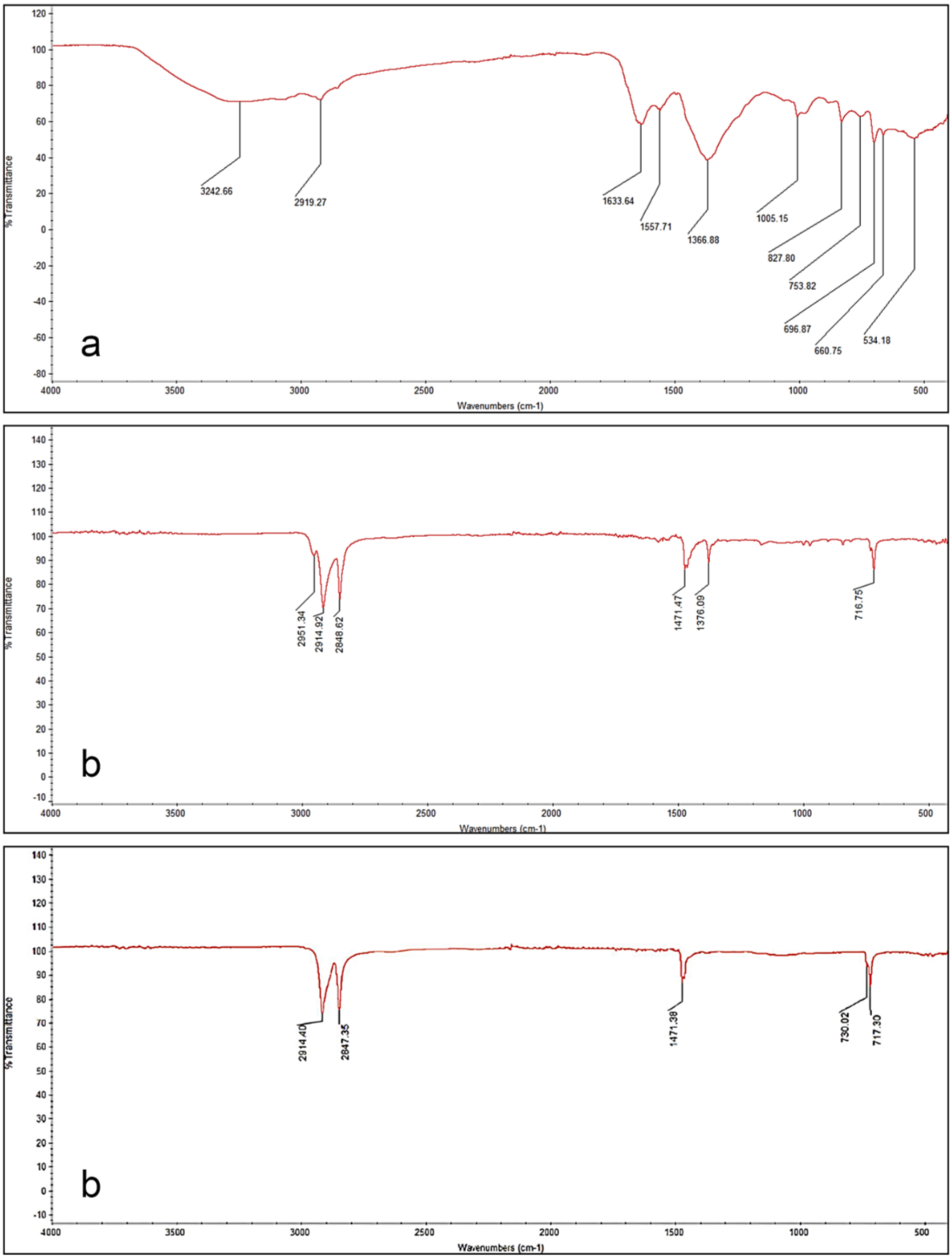

Figure 7. ATR-FTIR spectra of the microplastic fragment with (a) PA (b) PP (c) PE obtained from gut contents of *T. trichopterus* and *P. dayi*

1971) and that too in an evolutionary time scale (Connell, 1980).

When different species co-exist with the same feeding habits, their niches are dependent on the overlap and breadth (Evans, 1983). The dietary level of specialisation can be estimated through niche breadth (Zhang *et al.,* 2019), and its value represents trophic specialisation (Hurlbert, 1978). Hence, niche breadth is used to comprehend adaptation and is considered important for various issues like niche evolution and ecological specialisation (Sexton et al., 2017). In the present study, lower niche breadth values (B_A) (0.161 for *T. trichopterus* and 0.266 for *P. dayi*) indicate that both species are omnivorous in habit with relatively narrow niches and can be considered specialised feeders. Four catfishes from the Cochin estuary showed specialist feeding strategies with low diet breadth values, and high dietary overlap co-exists without interspecific competition (Maitra *et al.,* 2019). Herawati *et al.* (2020) reported similar low niche breadth values on the fish community in the Jatigede reservoir in West Java and Corrêa *et al.* (2011) on the fish fauna of the Cuiabá River basin. Narrow trophic niche breadth points to the fact that even a slight change in the food resource might create a change in the native species. Similar conclusions were also drawn by Cordova-Tapia *et al.* (2015) while studying the trophic niche overlap between native and non-native species at Lake Patzcuaro in Mexico. Wide and narrower diet breadth has been reported for invasive *Pseudorasbora parva* species residing in four different European water bodies with varying trophic impacts at different sites (Rolla *et al.,* 2019). Blue gourami has been reported to be the reason for the decline of native *Puntius semifasciolata* due to competition in Taiwan (Liao & Liu, 1989). Hence, in the present study, it can be concluded that non-native *T. trichopterus* and native *P. dayi* are specialist feeders with a high degree of diet overlap co-existing in a natural wetland. Therefore, they compete with each other for similar food resources.

The trophic level was calculated for T. *trichopterus* and 3.4 ±0.4 for *P. dayi,* indicating that the former species is an omnivore and the latter is a carnivore (Froese & Pauly, 2023). However, the trophic levels of *T. trichopterus* and *P. dayi* calculated from their diet composition in the current study were 2.64 and 2.45, respectively, which revealed the omnivorous feeding habits of both species. The trophic positions of omnivorous species that consume plants, detritus, and animals are between 2.2 and 2.79 (Froese & Pauly, 2023). The lower trophic level values of the native *P. dayi* in this study may be due to resource sharing with the non-native *T. trichopterus* in the natural wetland.

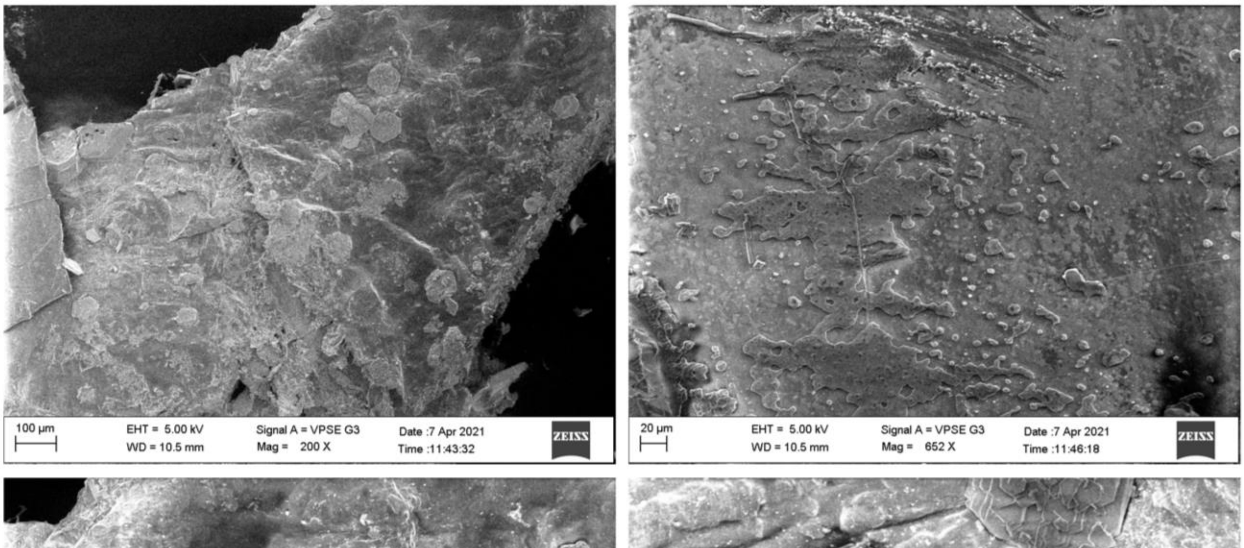

Figure 8. SEM micrographs of fragments obtained from gut contents of *T. trichopterus* showing pits, corrosions and cracks.

Microplastics of fragments and fibres of PA, PP and PE were obtained from the gut of *T. Trichopterus* and P. *dayi*. Polymers like PP, PA, PET and PBT were obtained from invasive fish *Piaractus brachypomus* from Vembanad Lake (Devi *et al.,* 2020). The presence of microplastics, especially microfibers, dominating the gut contents of fish may indicate increasing pollution with plastic debris in the coastal wetlands due to anthropogenic activities. Microplastic contamination in urban coastal wetlands ascribed to human pressure (Ericksen *et al.,* 2013; Lourenço *et al.,* 2017; Su *et al.,* 2019) and its ingestion by fish as well as other aquatic biota is studied limitedly (DeSantiago, 2018; Reynolds & Ryan, 2018; Huang *et al.,* 2020). Parvin *et al.* (2021) reported a similar dominance of microplastic fibres in fishes from the freshwaters of Bangladesh. In Chi River, Thailand, omnivorous fishes were reported to have more microplastics, especially fibers (Kasamesiri & Thaimuangphol, 2020). Commercially valuable food fishes from Cyprinidae and Channidae family in Lucknow, Uttar Pradesh, contained MPs with more fibres (Pandey *et al.,* 2023). Moreover, the SEM images of MP fragments obtained from the gut contents of *T. trichopterus* showed pits, corrosions, and cracks on its surface, which indicates mechanical or oxidative weathering (Zbyszewski *et al.,* 2014; Sathish *et al.,* 2020; Patterson *et al.,* 2021).

Conclusion

The significant dietary overlap observed between the non-native *Trichopodus trichopterus* and the native *Pseudosphromenus dayi* in the tropical coastal wetland of Kerala, as revealed in this study, may not directly indicate competition for food resources. Instead, it likely reflects the abundance of certain food types in the wetland ecosystem. However, the limited dietary diversity of both species highlights a corresponding lack of species diversity in the wetland. This raises concerns about potential competition, as the introduction of *T. trichopterus* could threaten the native *P. dayi* amidst ongoing ecological disruptions on wetlands. Despite this, coexistence is possible when non-native species exhibit minimal ecological or behavioural overlap with native species. To better understand the dynamics of such interactions, it is crucial to adopt a long-term monitoring strategy that accounts for the evolutionary history and behavioural ecology of both native and invasive species. This approach will provide essential insights for designing effective management interventions to maintain ecosystem stability.

Ethical Statement

The fish used in the experiment are collected from the fisherman, and for such cases, ethical committee clearance is not required in India.

Funding Information

The work was internally funded by the University of Kerala.

Author Contribution

SSD: Conceptualisation, data curation, writing first draft and editing; SSR: Collection of data, data curation, invesitation, writing review; GBS: Data curation and statistical analysis, editing; SR: Conceptualisation, field work, data curation; ABK: Funding Acquisition, Project Administration, Resources, editing.

Conflict of Interest

The author(s) declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank University of Kerala for funding support. We thank the Director, Central Laboratory for Instrumentation and Facilitation (CLIF), University of Kerala, for the support on analysis of microplastics.

References

Anna Mercy, A. T. V., Gopalakrishnan, A., Kapoor, D. & Lakra, W.S. (2007). Ornamental Fishes of the Western Ghats of India. National Bureau of Fish Genetic Resources, India.

Barnosky, A.D., Hadly, E.A., Gonzalez, P., Head, J., Polly, P.D., Lawing, A.M., Eronen, J.T., Ackerly, D.D., Alex, K., Biber, E. & Blois, J. (2017). Merging paleobiology with conservation biology to guide the future of terrestrial ecosystems. Science, 355, 6325, http://doi.org.10.1126/science.aah4787

CABI (2021). *Trichopodus trichopterus* (three spot gourami).CABI, current year.Invasive Species Compendium. Wallingford, UK: CAB International.www.cabi.org/isc., downloaded on 29 August 2021.

Chandra, G., Bhattacharjee, I., Chatterjee, S.N. & Ghosh, A. (2008). Mosquito control by larvivorous fish. *Indian Journal of Medical Research* 127, 13-27.

Chung, D.S.L., Ng, P.K.L., Murphy, D.H., 1994. Preliminary studies of the feeding ecology of blackwater Belontiidae of North Selangor, Peninsular Malaysia.In: Proceedings of the 4th Indo-Pacific Fish Conference, Bangkok, Thailand.Bangkok, Thailand: Faculty of Fisheries, Kasetsart University, 76-86

Colwell, R. K. & Futuyma, D. J. (1971). On the measurement of niche breadth and overlap. Ecology, 52, 567 – 576.

Connell, J.H. (1980). Diversity and the coevolution of competitors, or the ghost of competition past. Oikos, 35, 131-138.

Conlu, P.V. (1986). Guide to Philippine Flora and Fauna, Volume IX: Fishes. University of the Philippines, Natural Resources Management Center.

Córdova-Tapia, F., Contreras, M. & Zambrano, L. (2015). Trophic niche overlap between native and non-native fishes. *Hydrobiologia* 746, 291–301. https://doi.org/10.1007/s10750-014-1944-z

Correa C. E., Albrecht, M. P., Hahn N. S. (2011). Patterns of niche breadth and feeding overlap of the fish fauna in the seasonal Brazilian Pantanal, Cuiaba River basin. *Neotropical Ichthyology*, 9(3), 637–646.

Crowl, T. A., Townsend, C. R., McIntosh, A. R. (1992). The impact of introduced brown and rainbow trout on native fish: the case of Australasia. *Reviews in Fish Biology and Fisheries,* 2, 217–241.

Cucherousset, J., Bouletreau, S., Martino, A., Roussel, J. M. & Santoul, F. (2012). Using stable isotope analyses to determine the ecological effects of non-native fishes. *Fisheries Management and Ecology,* 19, 111–119.

Das, S. M. & Moitra, S. K. (1963). Studies on the food and feeding habits of some freshwater fishes of India, Part IV: A review on the food and feeding habits, with general conclusions. *Ichthyologica* 11(1-2), 107-115

Dasgupta, M. (2004). Relative length of gut of some freshwater fishes of West Bengal in relation to food and feeding habits. *Indian Journal of Fisheries* 51(3), 381-384.

Degani, G. (2001). Blue gourami (*Trichogaster trichopterus*) model for labyrinth fish. Tel-Hai College School of Science and Technology, Israel.

Dehaut, A., Cassone, A.L., Frère, L., Hermabessiere, L., Himber, C., Rinnert, E., Rivière, G., Lambert, C., Soudant, P., Huvet, A., Duflos, G. & Paul-Pont, I. (2016). Microplastics in seafood: Benchmark protocol for their extraction and characterization. Environmental Pollution, 215, 223-233, https://doi.org/10.1016/j.envpol.2016.05.018.

DeSantiago, R. (2018). Foraging strategy May predict anthropogenic debris consumption in wetland fishes. Proceedings of the National Conference on Undergraduate Research (NCUR), University of Central Oklahoma, Edmond, Oklahoma, pp. 753-757.

Devi, S. S., Anupama, V. S. and Kumar, A.B. (2020). First report of microplastic ingestion by the alien fish Pirapitinga (*Piaractus brachypomus*) in the Ramsar site Vembanad Lake, south India. *Marine Pollution Bulletin*, 160, 111637., https://doi.org/10.1016/j.marpolbul.2020.111637.

Dieleman, J., Cocquyt, C., Nyingi, W. D. & Verschuren, D. (2021). Seasonality in diet and feeding habits of endemic Chala tilapia (*Oreochromis hunteri*) and two introduced tilapiine cichlids in Lake Chala, East Africa. *Hydrobiologia* 848, 3763–3777. http://doi.org.doi:10.1007/ S10750-020-04427-3

Diniya, A., Putra, R.M. & Efizon, D. (2014). Stomach analyse of *Trichogaster pectoralis*. *Journal Universitas Riau* 1, 1–14.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z., Knowler, D. J., Lévêque, C., Naiman, R.J., Prieur-Richard, A. H., Soto, D., Stiassny, M L., & Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews, 81(2), 163 - 182. http://doi.org.10.1017/S1464793105006950.

Ehrenfeld, J.G. (2010). Ecosystem consequences of biological invasions. Annual review of ecology, evolution, and systematics, 41(1), 59-80.

Eriksen, M., Mason, S., Wilson, S., Box, C., Zellers, A., Edwards, W., Farley, H. & Amato, S. (2013). Microplastic pollution in the surface waters of the Laurentian Great Lakes. *Marine Pollution Bulletin, 77*, 177-182. http://doi.org.10.1016/j.marpolbul.2013.10.007

Evans, S. (1983). Production, predation and food niche segregation in a marine shallow soft-bottom community. *Marine Ecology*, 10, 147-157.

Figueredo, C. C. & Giani, A. (2005). Ecological interactions between Nile tilapia (*Oreochromis niloticus*, L.) and the phytoplanktonic community of the Furnas Reservoir (Brazil). *Freshwater Biology* 50, 1391–1403

Froese, R. & Pauly, D. (2023). FishBase. World Wide Web electronic publication. www.fishbase.org, version (06/2023).

Goodell, K., Parker, I. M. & Gilbert, G. S. (2000). Biological impacts of species invasions: implications for policymakers. In National Research Council, ed. Incorporating science, economics, and sociology in developing sanitary and phytosanitary standards in international trade. National Academy Press, Washington, DC, pp. 87–117.

Gopalakrishnan, A and Ponniah, A.G., (2000). Cultivable, food, sport and ornamental fish species endemic to Peninsular India with special reference to the Western Ghats. Pp. 13-32. In: Ponniah, A.G. and Gopalakrishnan, A, (eds.) Endemic fish diversity of the Western Ghats, NBFGR – NATP Publication, No. 1, 347p. National Bureau of Fish Genetic Resources, Lucknow, Uttar Pradesh, India.

Gozlan, R. E., Britton, J. R., Cowx, I. G. and Cowx, I. C. (2010). Current knowledge on non-native freshwater fish introductions. *Journal of Fish Biology*, 76, 751–786.

Grossman, G. D. (1986). Food Resources Partitioning In a rocky intertidal fish assemblage. Journal of Zoology, 1, 317-355.

Gupta, S. (2015). A note on feeding and reproductive biology of banded gourami, *Trichogaster fasciata* (Bloch & Schneider, 1801). *International Journal of Research in Fisheries and Aquaculture*, 5(4), 147-150.

Haubrock, P.J., Bernery, C., Cuthbert, R.N., Liu, C., Kourantidou, M., Leroy, B., Turbelin, A.J., Kramer, A.M., Verbrugge, L.N., Diagne, C. & Courchamp, F. (2022). Knowledge gaps in economic costs of invasive alien fish worldwide. Science of the Total Environment, 803, 149875, https://doi.org/10.1016/j.scitotenv.2021.149875.

Herawati, T., Saputra, R. N., Lili, W., Suryadi, I. B. B., Kurniawati, N., Hedianto, D. A., Herawati, H (2020). The food habits, niche breadth and niche overlap of fish community in Jatigede Reservoir, West Java. Proceedings of the 5th International Conference on Industrial Engineering and Operations Management Detroit, Michigan, USA, August 10 – 14.

Huang, J. S., Koongolla, J. B., Li, H. X., Lin, L., Pan, Y. F., Liu, S., He, W. H., Maharana, D. & Xu, X. R. (2020). Microplastic accumulation in fish from Zhanjiang mangrove wetland, South China. *Science of the Total Environment* 708, 134839. http://doi.org.10.1016/j.scitotenv.2019.134839

Hurlbert, S. H. (1978). The measurements of niche overlap and some relatives. *Ecology* 59, 67-77.

Hynes, H.B.N. (1950). The food of the freshwater sticklebacks (*Gastrosteus aculeatus*) and *Pygosteus pungitius*) with a review of methods used in studies of the food of fishes. *Journal of Animal Ecology,* 19, 36-58.

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

Jackson, M. C. & Britton, J. R. (2014). Divergence in the trophic niche of sympatric freshwater invaders. *Biological Invasions*, 16, 1095–1103

Jackson, M.C., Jackson, A.L., Britton, J.R., Donohoe, I., Harper, D.M. & Grey, J. (2012). Population level metrics of trophic structure based on stable isotopes and their application using invasion ecology. *PLoS ONE*, 7, e31757.

Jacob, S.S. & Nair, N.B. (1981). Rate of gastric digestion in the larvicidal fishes *Aplocheilus lineatus* (Cuv. & Val.) and *Macropodus cupanus* (Cuv. & Val.). *Proceedings of Indian Academy of Science (Animal Science)* 90(4), 407-416.

Jacob, S. S. & Nair, N.B.N. (1983a). Influence of certain environmental factors on the predatory efficiency of the larvivorous fish *Macropodus cupanus*. *Environmental Biology of Fishes* 9, 295-300.

Jacob, S.S. & Nair, N.B.N. (1983b). Reproductive biology of the larvivorous fish *Macropodus cupanus* (Cuv. and Val.) *Proceedings of Indian Academy of Science (Animal Science),* 92, 159–170.

Jayasree, M. & Panicker K.N. (1992). Larvivorous potential of some indigenous fishes of Sherthallai region with special reference to their efficacy in control of mansonioides. *The Indian Journal of Medical Research*, 95, 195-199.

Kakareko, T., Kobak, J., Grabowska, J., Jermancz, K., Przybylski, M., Poznanska, M. et al. (2013). Competitive interactions for food resources between invasive racer goby *Babka gymnotrachelus* and native European bullhead *Cottus gobio*. *Biological Invasions,* 15, 2519–2530.

Kasamesiri, P. & Thaimuangphol, W. (2020). Microplastics ingestion by freshwater fish in the Chi River, Thailand. GEOMATE Journal, 18(67), pp.114-119.

Khan, M.S., M.A. Ambak & A.K.M. Mohsin (1988). Food and feeding biology of a Food and feeding habits of striped spiny eel a tropical catfish, Mystus nemurus with reference to its functional morphology. *Indian Journal of Fisheries* 35, 78-84.

Kiesecker, J.M. & Blaustein, A.R. (1998). Effects of introduced bullfrogs and smallmouth bass on microhabitat use, growth, and survival of native red-legged frogs (*Rana aurora*). *Conservation Biology*, 12(4), 776-787.

Kow, T.A. (1950). Food and feeding relationships of the fishes of the Singapore Straits. Fish. Pub. Land., 1: 1-35.

Krebs, C. J. (1999). Ecological methodology (2nd ed.). Menlo Park, California: Benjamin Cumming.

Kulhanek, S.A., Ricciardi, A. & Leung, B. (2011). Is invasion history a useful tool for predicting the impacts of the world's worst aquatic invasive species? *Ecological Applications*, 21(1), 189-202.

Liao, L. C. & Liu, H. C. (1989). Exotic aquatic species in Taiwan, pp. 101-118. In: de Silva, S.S. (ed.). Exotic Aquatic Organisms in Asia. Asian Fisheries Society, Manila, Philippines, Special Publication 3, 154pp.

Lourenço, P. M., Serra-Gonçalves, C., Ferreira, J. L., Catry, T. & Granadeiro, J. P. (2017). Plastic and other microfibers in sediments, macroinvertebrates and shorebirds from three intertidal wetlands of southern Europe and West Africa. *Environmental Pollution* 231, 123-133. http://doi.org.10.1016/j.envpol.2017.07.103

Maitra, S., Harikrishnan, M. & Nidhin, B. (2019). Feeding strategy, dietary overlap and resource partitioning among four mesopredatory catfishes of a tropical estuary. *Journal of Fish Biology* 96, 130–139. http://doi.org.10.1111/jfb.14194

Mack, R. N. (1996). Predicting the identity and fate of plant invaders: emergent and emerging approaches. *Biological Conservation* 78:,107–121.

Martin, C. W., Valentine, M. M. & Valentine, J.I. (2010). Competitive interactions between invasive Nile Tilapia and native fish: the potential for altered trophic exchange and modification of food webs. PLoS ONE, 5, e14395.

McGill, B. J. (2010). Matters of scale. Science, 328, 575–576.

Mecozzi, M., Pietroletti, M. & Monakhova, Y. B. (2016). FTIR spectroscopy supported 815 by statistical techniques for the structural characterization of plastic debris in the 816 marine environment: Application to monitoring studies. *Marine Pollution Bulletin,* 106(1), 155-161.

Mitra, K., Suresh, V. R., Vinci, G. K., Mazumdar, N. N. & Biswas, D. K. (2007). Biology and fishery of banded gourami, *Colisa fasciata* (Bloch and Schneider 1801) in a floodplain wetland of Ganga river basin. *Asian Fisheries Science* 20(4), 409-423.

Moyle, P.B & Senanayake, F.R. (1984). Resource partitioning among the fishes of rainforest streams in Sri Lanka. Journal of Zoology, London 202: 195-223

Murphy, G.E. & Romanuk, T.N. (2014). A meta-analysis of declines in local species richness from human disturbances. Ecology and evolution 4(1), 91-103.

Pandey, N., Verma, R., Patnaik, S. & Anbumani, S. (2023). Abundance, characteristics, and risk assessment of microplastics in indigenous freshwater fishes of India. *Environmental Research* 218, 115011. https://doi.org/10.1016/j.envres.2022.115011.

Parvin, F., Jannat, S. & Tareq, S.M. (2021). Abundance, characteristics and variation of microplastics in different freshwater fish species from Bangladesh*. Science of The Total Environment* 784, 147137. https://doi.org/10.1016/j.scitotenv.2021.147137.

Patterson, J., Jeyasanta, K.I., Laju, R.L. & Edward, J.P., 2021. Microplastic contamination in Indian edible mussels (*Perna perna* and *Perna viridis*) and their environs. Marine Pollution Bulletin, 171, p.112678. https://doi.org/10.1016/j.marpolbul.2021.112678

Pethiyagoda, R. (1991). Freshwater fishes of Sri Lanka. The Wildlife Heritage Trust of Sri Lanka, Colombo.

Pianka, E.R., 1974. Niche overlap and diffuse competition. Proceedings of the National Academy of Sciences, 71(5), pp.2141-2145.

Pinkas, L., Oliphant, M. S. & Iverson, I. L. K. (1971). Food habits of albacore, bluefin tuna, and bonito in Californian waters. *Fish Bulletin* 152, 1-105.

Raborn, S.W., Miranda, L.E. & Driscoll, M.T., 2004. Diet overlap and consumption patterns suggest seasonal flux in the likelihood for exploitative competition among piscivorous fishes. *Ecology of Freshwater Fish*, 13(4), pp.276-284.

Rainboth, W. J. (1996). Fishes of the Cambodian Mekong FAO species identification field guide for fishery purposes. FAO, Rome, 265 - 276 pp.

Raj, S., Kumar, A.B., Tharian, J. & Raghavan, R. (2021a). Illegal and unmanaged aquaculture, unregulated fisheries and extreme climatic events combine to trigger invasions in a global biodiversity hotspot. *Biological Invasions*, *23*, 2373-2380.

Raj, S., Pakash, P., Reghunath, R., Tharian, J.C., Raghavan, R. & Kumar, A.B. (2021b). Distribution of alien invasive species in aquatic ecosystems of the southern Western

Ghats, India. *Aquatic Ecosystem Health & Management*, 24(2), 58–69, 2021 https://doi.org/10.14321/aehm.024.02.09

Razgour, O., Korine, C. & Saltz, D. (2011). Does interspecific competition drive patterns of habitat use in desert bat communities? *Oecologia,* 167, 493–502.

Rejmanek, M. & Richardson, D. M. (1996). What attributes make some plant species more invasive? *Ecology* 77, 1651–1661.

Reynolds, C. & Ryan, P. G. (2018). Micro-plastic ingestion by waterbirds from contaminated wetlands in South Africa. Marine Pollution Bulletin, 126, 330-333. https://doi.org/10.1016/j.marpolbul.2017.11.021

Rolla, M., Consuegra, S. & Garcia de Leaniz, C. (2019). Trophic plasticity of the highly invasive top mouth gudgeon (*Pseudorasbora parva*) inferred from stable isotope analysis. *Frontiers in Ecology and Evolution,* 8, 212. https://doi.org/10.3389/fevo.2020.00212

Sarwar, M. (2015). Control of dengue carrier Aedes mosquitoes (Diptera: Culicidae) larvae by larvivorous fishes and putting it into practice within water bodies. *International Journal of Preventive Medicine Research* 1, 232–237.

Sathish, N., Jeyasanta, I. & Patterson, J. (2020). Occurrence of microplastics in epipelagic and mesopelagic fishes from Tuticorin, Southeast coast of India. *Science of the Total Environment*. doi: https://doi.org/10.1016/j.scitotenv.2020.137614

Seebens, H., Blackburn, T.M., Dyer, E.E., Genovesi, P., Hulme, P.E., Jeschke, J.M., Pagad, S., Pyšek, P., Winter, M., Arianoutsou, M. & Bacher, S. (2017). No saturation in the accumulation of alien species worldwide. Nature communications, 8(1), 14435, https://doi.org/10.1038/ncomms14435

Selge, S., Fischer, A. & van der Wal, R. (2011). Public and professional views on invasive non-native species–A qualitative social scientific investigation. *Biological Conservation*, 144(12), 3089–3097.

Sexton, J. P., Montiel, J., Shay, J. E., Stephens, M. R. & Slatyer, R. A. (2017). Evolution of ecological niche breadth. *The Annual Review of Ecology, Evolution, and Systematics* 48, 183–206. https://doi.org/10.1146/annurev-ecolsys-110316-023003

Sharma, C. M. & Borgstrøm, R. (2008). Shift in density, habitat use, and diet of perch and roach: an effect of changed predation pressure after manipulation of pike. *Fisheries Research* 91, 98–106.

Shea, K. & Chesson, P. (2002). Community ecology theory as a framework for biological invasions. *Trends in Ecology and Evolution* 17, 170–176.

Simberloff, D., Martin, J. L., Genovesi, P., Maris, V., Wardle, D. A., Aronson, J., Courchamp, F., Galil, B., García-Berthou, E., Pascal, M. & Pyšek, P. (2013). Impacts of biological invasions: What's what and the way forward. *Trends in Ecology & Evolution* 28, 58–66. https://doi.org/10.1016/j.tree.2012.07.013

Strayer, D.L. (2010). Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future. *Freshwater Biology,* 55, 152-174.

Su, L., Nan, B., Hassell, K. L., Craig, N. J. & Pettigrove, V. (2019). Microplastics biomonitoring in Australian urban wetlands using a common noxious fish (*Gambusia holbrooki*). Chemosphere, 228, 65-74. https://doi.org/10.1016/j.chemosphere.2019.04.114

Talde, C. M., Mamaril, A. C. & Palomares, M. L. D. (2004). The diet composition of some economically important fishes in the three floodplain lakes in Agusan Marsh wildlife sanctuary in the Philippines. *Sri Lanka Journal of Aquatic Sciences*, 9, 45-56.

Townsend, C. R. (2002). Individual, population, community, and ecosystem consequences of a fish invader in New Zealand streams. *Conservation Biology* 38-47.

Tricarico, E., Junqueira, A.O. & Dudgeon, D. (2016). Alien species in aquatic environments: a selective comparison of coastal and inland waters in tropical and temperate latitudes. *Aquatic Conservation: Marine and Freshwater Ecosystems* 26(5), 872-891.

Weber, M. J. & Brown, M. L. (2011). Relationships among invasive common carp, native fishes and physicochemical characteristics in upper Midwest (USA) lakes. *Ecology of Freshwater Fish*es 20, 270–278.

Windell, J.T. & Bowen, S.H. (1978). Methods of study of fish based on analysis of stomach contents. In T., Benegal (Ed.). Methods Assessment of Fish Production in Freshwaters (pp. 219-226). Oxford: Blackwell Scientific.

Winemiller, K. O. & Pianka, E. R. (1990). Organization in natural assemblages of desert lizards and tropical fishes. Ecological Monographs, 60, 27 – 55.

Woodford, D. J., Impson, N. D., Day, J. A. & Bills, I. R. (2005). The predatory impact of invasive alien smallmouth bass, *Micropterus dolomieu* (Teleostei: Centrarchidae), on indigenous fishes in a Cape Floristic Region mountain stream. *African Journal of Aquatic Science,* 30, 167– 173.

Zambrano, L., Valiente, E. & Vander Zanden, M. J. (2010). Stable isotope variation of a highly heterogeneous shallow freshwater system. *Hydrobiologia* 646, 327–336.

Zbyszewski, M., Corcoran, P. L. & Hockin, A. (2014). Comparison of the distribution and degradation of plastic debris along shorelines of the Great Lakes, North America. *Journal of Great Lakes Research* 40, 288-299. https://doi.org/10.1016/j.jglr.2014.02.012

Zhang, M., Wang, Y., Gu, B., Li, Y., Zhu, W., Zhang, L., Yang, L. & Li. X. (2019). Resources utilisation and trophic niche between silver carp and bighead carp in two mesotrophic deep reservoirs. *Journal of Freshwater Ecology*, 34, 199-212. doi: https://doi.org/10.1080/02705060.2018.1560368