International Journal of Design & Nature and Ecodynamics
Vol. 20, No. 4, April, 2025, pp. 933-944
Journal homepage: http://iieta.org/journals/ijdne

Food Habits and Growth Patterns of Native and Invasive Fish in Lake Aneuk Laot Sabang, Indonesia

Nurfadillah Nurfadillah[1,2], Nur Fadli[3*], Zulkarnain Jalil[4], Noor Adelyna Mohammed Akib[5]

[1] Graduate School of Mathematics and Applied Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
[2] Department of Aquaculture, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
[3] Department of Marine Science, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
[4] Physics Department, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
[5] School of Biological Sciences, Universiti Sains Malaysia, Gelugor 11800, Malaysia

Corresponding Author Email: nurfadli@usk.ac.id

https://doi.org/10.18280/ijdne.200422

Received: 6 February 2025
Revised: 15 March 2025
Accepted: 20 March 2025
Available online: 30 April 2025

Keywords:
aquatic resources management, indigenous fish, length-weight relationships (LWRs), niche breadth, trophic ecology

ABSTRACT

Feeding habits and growth patterns of fish in lake ecosystems are influenced by food availability, competition, predation, and environmental conditions. This study aimed to analyze the feeding habits and length-weight relationships of native and invasive fish species in Aneuk Laot Lake, Sabang, Indonesia. Fish were sampled using traps and gill nets with mesh sizes of 0.5, 0.75, and 1 inch. A total of 483 fish were collected: 98 *Rasbora* sp., 104 *Barbodes* sp., and 218 *Amphilophus trimaculatus*. Feeding habits were examined using the digestive tract dissection method, and the data were analyzed based on the volumetric index, frequency of occurrence, index of preponderance, niche breadth, and niche overlap. Growth patterns were assessed through length-weight relationship analysis using linear regression and t-test analysis. Results indicated that *Rasbora* sp. is herbivorous, primarily consuming *Cosmarium* sp. (84.4%), whereas *Barbodes* sp. preferred *Daphnia* sp. (45.1%). *A. trimaculatus* primarily preys on small fish (62.5%). Both *Barbodes* sp. and *A. trimaculatus* are omnivorous. There was a high dietary overlap (0.96) between *Rasbora* sp. and *Barbodes* sp., indicating strong interspecific competition. *A. trimaculatus* preys on Rasbora sp., demonstrating its impact as an invasive predator. All species exhibited negative allometric growth ($b < 3$), suggesting environmental stress or food limitations. These findings highlight the need for managing invasive species to conserve native fish populations and maintain ecological balance.

1. INTRODUCTION

Food is a critical biological factor that determines the survival of a fish [1, 2]. The feeding habits of fish serve as a basis for assessing their role and position in the food chain [3-5]. Additionally, information on diet is essential for managing sustainable fisheries and plays a vital role in selecting suitable species for aquaculture [6, 7]. The utilization of identical food sources by fish in the wild leads to direct competition [8-11].

Each species has a unique ecological niche, encompassing how it utilizes resources and interacts with its environment. This niche includes aspects such as diet composition, feeding time, habitat, and interactions with other species [12-14]. These complex interactions shape a species' realized niche, which is often narrower than its fundamental niche due to competition and other ecological constraints [15, 16]. If two species occupy highly similar niches, intense competition for limited resources is likely to occur. This competition can reduce the availability of resources for native fish, ultimately leading to a decline in population size and local fish species diversity. Additionally, invasive fish that act as efficient predators and prey on native fish, including juveniles and eggs, can cause a drastic decline in native fish populations.

The presence of invasive fish species can disrupt the existence of native fish species [17-23]. Similarly, concerns arise regarding the presence of non-native fish species, which affect competition for food and habitat [22, 24-26]. As one of the main doctrines in ecological theory, this principle states that two species competing for the same limited resources cannot coexist stably [15]. This principle, first formally formulated by G.F. Gause, highlights the instability of ecological systems in which multiple species compete for the same resources [27, 28]. The Competitive Exclusion Principle states that the species that utilizes resources more efficiently will outcompete and eventually eliminate the other species from its habitat [27].

This situation occurs in Aneuk Laot Lake. Aneuk Laot Lake is the second-largest lake in Aceh Province [29]. This lake provides significant benefits to the community in Sabang City, including its use as a fishing area for residents around the lake [30, 31]. The supply of fish for consumption in Aneuk Laot Lake has primarily relied on the catches from local fishermen operating within its waters. Intensive fishing by the community is believed to cause high fishing pressure, which could lead to a decline in fish resources. The decline in fish species composition is suspected to be caused by several issues, including increasing activities along the lake's riparian zone each year, contributing to the pollution load entering the lake's water body. The rise in anthropogenic waste loads disrupts the fish habitats in the lake. Environmental degradation, in turn, affects fish production [30, 32-34].

Research on the feeding habits of fish in Aneuk Laot Lake is particularly important, as the lake serves as a vital habitat for various species, including some that may be endemic [35]. Research on the feeding habits of fish in the waters of Aneuk Laot Lake has been previously conducted, but it was limited to invasive fish species that were caught. In contrast, the feeding habits of native fish in this lake have never been studied. This report represents the first documented study on the feeding habits and growth patterns of native fish species in Aneuk Laot Lake. This study is an essential strategic step for ensuring the survival of species and the sustainability of their ecosystems. Understanding habitats as feeding grounds is crucial for gaining insights into the ecological processes within the lake and how different species interact within the ecosystem [36-38].

Continuous fluctuations in the Aneuk Laot Lake ecosystem pose a serious threat to the survival of aquatic organisms. These threats include potential habitat loss and biodiversity loss within the lake environment. Therefore, although fish resources are fundamentally renewable, they are limited, necessitating proper utilization, protection, and management to ensure their long-term availability and ecological balance [39, 40]. As a result, empirical research consistently demonstrates that coexisting species tend to differentiate in at least one key aspect of their ecological niche, thereby reducing direct competition and enabling resource partitioning. This mechanism allows multiple species to exploit different resources or utilize the same resources in slightly different ways, thereby minimizing interspecific competition.

In this context, species can avoid direct competition by utilizing resources differently or occupying different spatial and temporal niches within the ecosystem [27]. Therefore, this principle highlights the dynamic interaction between competition and niche differentiation in shaping community structure and biodiversity [41]. Quantifying a species' niche is a complex task that often requires an in-depth analysis of resource use patterns, habitat preferences, and activity over a given time frame [15]. A comprehensive understanding of species niches is crucial for predicting community assembly dynamics, forecasting species responses to environmental disturbances such as climate change and habitat loss, and anticipating the ecological consequences of species introductions and removals. All these aspects play a vital role in effective conservation management and ecosystem restoration. Therefore, our hypothesis in this study is that the non-native fish *Amphilophus trimaculatus* has a broad niche breadth, which may disrupt the presence of native fish species in Lake Aneuk Laot, specifically *Rasbora* sp. and *Barbodes* sp.

This research can provide the necessary data to formulate adaptation and mitigation strategies and serve as a basis for developing conservation and ecosystem management policies. Accurate and up-to-date data are essential for effective policies and appropriate interventions [42, 43]. One of the approaches to support the conservation and sustainability of native fish resources in Aneuk Laot Lake is through studies on feeding habits, fish growth, and the factors influencing habitat availability for aquatic biota. These studies are crucial as a foundation for sustainable management, particularly for Aneuk Laot Lake, which is classified as a productive water body. The presence of native fish species is crucial for the sustainability of fisheries in this lake and serves as a biological indicator of the aquatic ecosystem through the analysis of fish length and weight. This provides a foundation for implementing protective measures to mitigate the impacts of invasive fish species [44-47].

2. METHOD

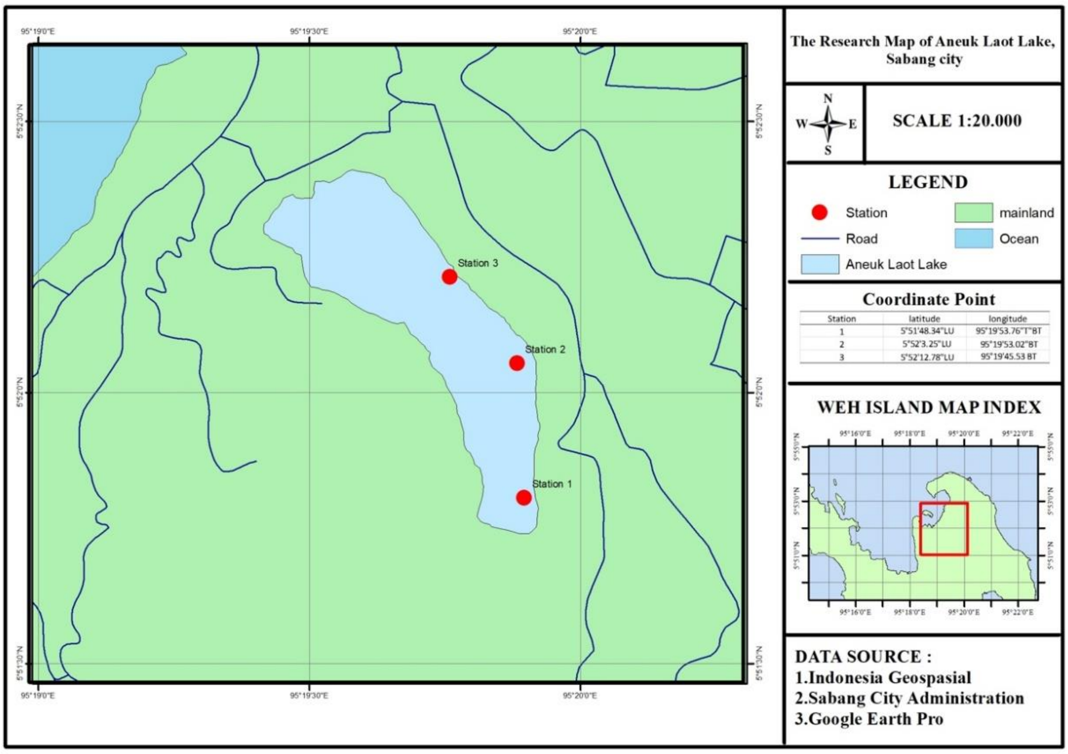


Figure 1. The research location map of Aneuk Laot Lake

This study was conducted from March to November 2024 in Aneuk Laot Lake, Sabang City, Weh Island, Indonesia. Fish sampling was carried out every two months over nine months at three observation stations selected based on habitat characteristics. Aneuk Laot Lake is a unique lake as it has no inlet or outlet [29, 48]. It is relatively small, covering an area of approximately ±39.86 hectares, with a maximum length of 1,419 meters, an average width of 250 meters, and a maximum depth of 22 meters [29].

Fish collection was conducted through direct capture using traps and gill nets. The gill nets used varied in size, with mesh sizes of 0.5-inch, 0.75 inch, and 1 inch. The deployment of traps and nets was performed twice daily: the first deployment occurred at 07:00 WIB and was retrieved at 17:00 WIB, while the second deployment occurred at 18:00 WIB and was retrieved at 06:00 WIB. The research location map is presented in Figure 1.

A total of 483 fish individuals were sampled for analysis of feeding habits and growth patterns, consisting of 98 *Rasbora* sp., 104 *Barbodes* sp., and 218 *Amphilophus trimaculatus.* Observations indicated that *Rasbora* sp. was more frequently captured in calm areas with greater depths (Station 1). In contrast, *Barbodes* sp. and *Amphilophus trimaculatus* were predominantly captured in areas densely populated with aquatic vegetation (Stations 2 and 3).

Fish length was measured as the total length (from the tip of the mouth to the tip of the caudal fin) using a caliper with a precision of 0.1 cm. Total fish weight was measured using a digital scale with a precision of 0.01 grams.

The analysis of fish feeding habits involved dissection using surgical scissors, starting from the anus toward the upper abdomen below the lateral line and along the lateral line to the posterior of the operculum, then ventrally toward the abdominal cavity. After dissection, the fish's digestive organs (stomach and intestines) were preserved in 4% formalin [8, 49]. Subsequent observations of the digestive tract contents were conducted at the Marine Biology Laboratory, Faculty of Marine and Fisheries, Syiah Kuala University, Banda Aceh.

The observations of fish digestive tract contents were analyzed for feeding habits using several parameters, including the volumetric method, index of preponderance, frequency of feeding occurrence [50], niche breadth, and dietary overlap analysis. The volumetric method was applied using the formula referenced from [50].

$$V = \frac{Vi}{Vt} \times 100\% \tag{1}$$

where, *V* represents the percentage of a specific type of food (%), *vi* is the volume of a specific type of food (ml), and *vt* is the total volume of all types of food (ml).

The calculation of the index of preponderance is conducted to determine the types of food consumed by fish. The index of preponderance combines two methods: the frequency of occurrence method and the volumetric method, using the formula equation proposed by study [49].

$$IP = \frac{Vi \times FO}{\Sigma Vi \times FO} \times 100\% \tag{2}$$

where, *IP* represents the index of preponderance (%), *Vi* is the percentage volume of a specific food type (%), *FO* is the percentage frequency of occurrence of a specific food type (%), and *ΣVi × FO* is the total of Vi × FO for all food types.

Subsequently, the identification of all stomach contents was conducted using the frequency of occurrence method, calculated with the following formula [49].

$$FO(\%) = \frac{\text{The total occurrance of a specific food type}}{\text{The total number of stomachs containing food}} \times 100 \tag{3}$$

Testing the difference in feeding habits among fish groups using the Chi-Square (χ^2) statistical test. The food niche breadth indicates the diversity of food types consumed by fish. The determination of niche breadth, according to Levin's Niche Breadth index, is calculated using the following formula:

$$Bi = \frac{1}{\Sigma Pi^2} \tag{4}$$

where, *Bi* represents the food niche breadth, and *Pi* is the proportion of fish species associated with a specific food type.

In this calculation, standardization is required to ensure that the resulting niche breadth values range between 0 and 1, with intervals that are neither too large nor insignificant. Therefore, a formula based on study [51] is applied.

$$BA = \frac{Bi-1}{n-1} \tag{5}$$

where, *BA* is the standardized niche breadth (range 0–1), *Bi* represents the niche breadth, and 'n' is the total number of food organisms utilized.

Subsequently, to calculate the overlap value between fish, the formula proposed by index Pianka [52] can be used. This approach examines the dietary competition based on the contents of the fish intestines, allowing for the identification of similarities or differences in the types of food utilized by the fish.

$$O_{ij} = \frac{\Sigma\,(p_i p_j)}{\sqrt{\Sigma(p_i^2)\Sigma(p_j^2)}} \tag{6}$$

where, O_{ij} represents the overlap between species i and species j, $p_i p_j$ are the proportions of food resources utilized by species i and j, respectively, and $\sum(p_i p_j)$ is the sum of the products of the proportions of the same food resources consumed by both species.

The relative length of the gut (RLG) can be calculated using the formula provided by study [50].

$$RLG\ (\%) = \frac{Gut\ length (mm)}{Total\ body\ length\ (mm)} \tag{7}$$

Gut length refers to the total length of the intestine of the fish, typically measured from the beginning of the digestive tract to the end. It is used in calculating the RLG to assess the feeding habits and dietary classification of the fish species.

Additionally, growth patterns can be analyzed through the calculation of the length-weight relationship of fish, referring to the formula by [53].

$$W = aL^b \tag{8}$$

where, W represents the total weight of the fish (g), and *L* is the total length of the fish (cm). The parameters *a* and *b* are constants. To test whether $b = 3$ or $b \neq 3$, a t-test (partial test) is conducted with the following hypotheses: H0: b=3, indicating that the relationship between length and weight is isometric, and H1: $b \neq 3$, indicating that the relationship between length and weight is allometric. The decision is made by comparing the p-value to the significance level (α=0.05), If the p-value < 0.05, reject the null hypothesis (H0), meaning the difference is statistically significant. If p-value ≥ 0.05, fail to reject the null hypothesis, meaning there is no significant difference.

The value of b characterizes the growth pattern with the following criteria: If b = 3, the growth pattern is isometric, meaning that the fish's length and weight grow at the same rate. If b > 3, the growth pattern is positive allometric, indicating that the weight grows faster than the length. and if b < 3, the growth pattern is negative allometric, meaning that the length grows faster than the weight. Isometric growth signifies balanced growth in length and weight, while negative allometric growth indicates faster length growth compared to weight. Conversely, positive allometric growth means that weight growth outpaces length growth [54, 55].

3. RESULTS AND DISCUSSIONS

3.1 Food habits of native and invasive fish

The feeding habits of native and invasive fish often differ significantly due to their ecological roles and adaptability. Native fish typically feed on food resources available within their natural habitat, maintaining a balanced ecosystem [19, 25]. In contrast, invasive fish often exhibit broader feeding plasticity, allowing them to exploit various food sources, which can lead to competition with native species [56, 57].

The focus of this study is on the feeding habits and growth patterns of three fish species captured in the waters of Aneuk Laot Lake, consisting of two native species (*Rasbora* sp. and *Barbodes* sp.) and one invasive species (*Amphilophus trimaculatus*). The analysis of the feeding habits of the three fish species is presented in Table 1.

Table 1. Feeding habits of *Barbodes* sp., *Rasbor*a sp., and *Amphilophus trimaculatus* based on the volumetric index (V, %), frequency of feeding occurrence (FO, %), and index of preponderance (IP, %)

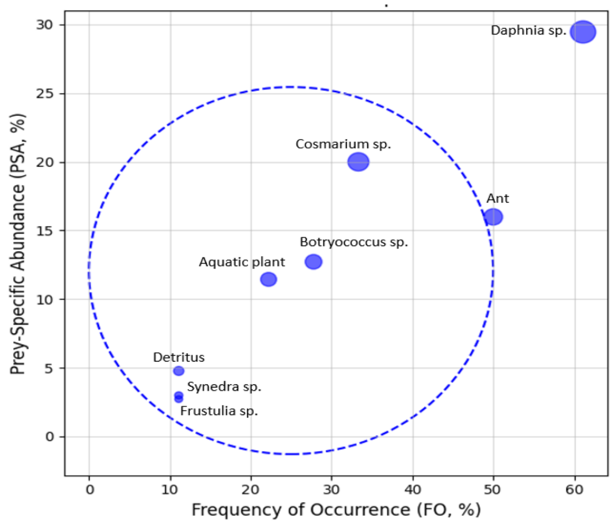
No.	Species of Fish	Organism of Food	V (%)	IP (%)	FO (%)
1	*Barbodes* sp.	*Daphnia* sp.	29.45	45.14	61.1
		Botryococcus sp.	12.71	8.85	27.7
		Cosmarium sp.	19.99	16.70	33.3
		Synedra sp.	2.98	0.83	11.1
		Frustulia sp.	2.71	0.75	11.1
		Aquatic plant	11.43	6.372	22.2
		Ant	15.98	0.03	50.0
		Detritus	4.76	1.33	11.1
2	*Rasbora* sp.	*Scenedesmus* sp.	4.61	0.96	15.0
		Synedra sp.	2.71	0.94	25.0
		Cosmarium sp	63.68	84.4	95.0
		Frustulia sp.	9.16	4.47	35.0
		Skeletonema sp.	5.08	2.48	35.0
		Tabellaria sp.	2.01	0.42	15.0
		Botryococcus sp.	12.74	6.22	35.0
		Pedistrum sp.	0.66	0.09	10.0
3	*Amphilophus trimaculatus*	Fish	35.39	62.59	48.1
		Euphausiacea	4.18	2.28	14.8
		Detritus	5.07	1.38	7.40
		Cosmarium sp.	19.22	18.30	25.9
		Daphnia sp.	7.39	5.03	18.5
		Synedra sp.	7.12	2.90	11.1
		Coscinodiscus sp.	2.25	0.61	7.40
		Skeletonema sp.	1.06	0.14	3.71
		Frustulia sp.	4.36	1.19	7.40
		Botryococcus sp.	10.26	5.58	14.8

Based on the digestive tract contents of the three fish species, various organisms were identified. However, plankton was found in all the fish studied. Differences were observed in the primary food preferences, leading to distinct feeding patterns. According to the index of preponderance, the main food of *Rasbora* sp. was *Cosmarium* sp. at 84.4%, while the primary food of *Barbodes* sp. was *Daphnia* sp. at 45.14%. For *Amphilophus trimaculatus*, the main food identified was fish, accounting for 62.59% (Table 1). This is consistent with the statement by study [6], which classifies an IP% value of ≥45% as a primary food, an IP% of > 4 – 25% as supplementary food, and an IP% of ≤4% as complementary food.

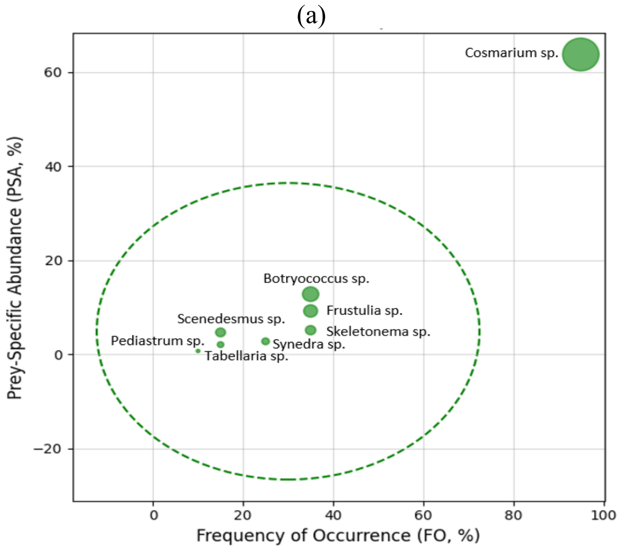
Based on the composition of food types found in the digestive tracts of the fish, it was determined that *Rasbora* sp. belongs to the herbivorous group. The study results show that, according to the index of preponderance (IP), the primary food for *Rasbora* sp. is *Cosmarium* sp. (84%), while *Botryococcus* sp. (6%) and *Frustulia* sp. (4%) serve as complementary foods. Meanwhile, *Scenedesmus* sp., *Synedra* sp., *Skeletonema* sp., *Tabellaria* sp., and *Pediastrum* sp. are supplementary foods.

In contrast, *Barbodes* sp. and *Amphilophus trimaculatus* are classified as omnivorous fish, meaning their digestive tracts contain both animal-based and plant-based food types [6]. For *Barbodes* sp., *Daphnia* sp. (45%) was identified as the primary food, while *Botryococcus* sp., *Cosmarium* sp., insects, and aquatic plants serve as complementary foods, with IP values ranging from 4% to 25%. On the other hand, detritus, *Synedra* sp., and *Frustulia* sp. are only supplementary foods for *Barbodes* sp., with IP values of less than 4%.

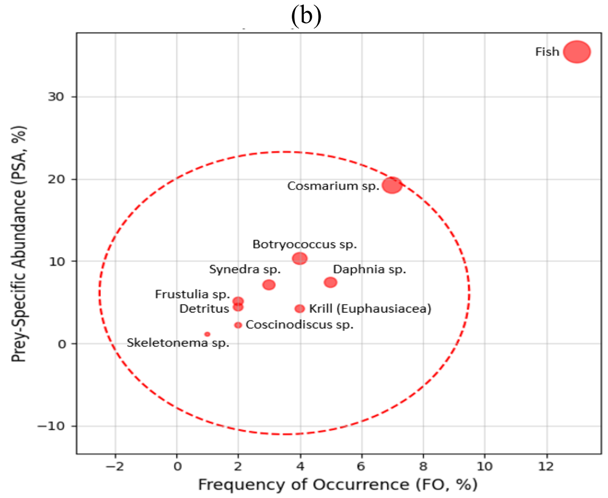
For *Amphilophus trimaculatus*, the primary food is fish fry, accounting for 62.59%. Complementary foods include *Cosmarium* sp. (18%), *Botryococcus* sp. (5%), and *Daphnia* sp. (5%), while supplementary foods are Euphausiacea, *Synedra* sp., *Coscinodiscus* sp., *Skeletonema* sp., *Frustulia* sp., and detritus, all with IP values of less than 4%. *Amphilophus trimaculatus* is an opportunistic feeder, meaning it utilizes any food resources available in its environment. The *Amphilophus trimaculatus*, commonly known as the three-spot cichlid, has a varied diet that mainly includes small fishes, macro-invertebrates, and aquatic and terrestrial insects [58-60].



(a)



(b)



(c)

Figure 2. Feeding strategies of (a) *Barbodes* sp., (b) *Rasbora* sp., and (c) *Amphilophus trimaculatus* based on prey frequency of occurrence (FO, %) plotted against prey-specific abundance (PSA, %)

Understanding these feeding habits is essential for assessing ecological interactions, resource competition, and the impact of invasive species on native populations and the overall ecosystem [22, 26]. Observations of feeding habits revealed that *Amphilophus trimaculatus* (Three-spot cichlid) was found to prey on small fish, suspected to be *Rasbora* sp. (Figure 2). This conclusion is based on the discovery of cycloid scales in the stomach contents of *Amphilophus trimaculatus*. A frequency of occurrence of 48% indicates that nearly half of the analyzed *Amphilophus trimaculatus* samples contained cycloid scales in their stomachs. These findings suggest that *Rasbora* sp. constitutes a significant part of the diet of *Amphilophus trimaculatus* in this study, highlighting predatory patterns and interspecies interactions within their habitat. This predation likely influences the distribution and abundance of *Rasbora* sp., a native fish species of Aneuk Laot Lake. Therefore, it is crucial to implement control measures for the invasive species (*Amphilophus trimaculatus*), which damages habitats and disrupts native fish populations. Native species tend to be more sensitive to environmental changes compared to invasive species, which generally have a higher tolerance. In freshwater ecosystems, some top predators exhibit significant overlap in their trophic niches, reflecting similarities in their feeding patterns [61]. The trophic niche space, about the structure of the food web, can change over time. Understanding these changes is crucial for assessing resource utilization and trophic interactions [61]. A species' niche encompasses various relationships it maintains within its ecosystem, including its spatial and temporal positioning, adaptations to the environment, and resource utilization patterns [61].

The invasive species often cause major changes in ecosystems because they dominate resources and outcompete native species. The introduction of non-native fish species has significantly altered freshwater ecosystems, frequently leading to a decline in native species richness and overall functional diversity [62]. The rapid shifts driven by invasive fish highlight the importance of understanding the interaction between environmental characteristics and the ability for native and non-native species to coexist [63]. Invasive fish are especially hard to control because the aquatic environment presents challenges for detection, monitoring, and removal efforts [64]. The findings of this study serve as a fundamental dataset for the management of Aneuk Laot Lake, with a focus on controlling invasive fish populations, conserving native fish habitats, and regulating fisheries to maintain ecosystem balance and ensure optimal fish population growth.

Contrarily, *Rasbora* sp. preys entirely on plankton, with a frequency of occurrence of 100%, indicating that it is a pure planktivore (Figure 2). This means the feeding habits of this fish are exclusively composed of plankton, including phytoplankton and zooplankton. This behavior signifies a specific ecological adaptation to its habitat, making it an important component of the food chain. The availability of plankton directly affects the survival of *Rasbora* sp., thereby supporting its growth and reproduction (Figure 2).

Meanwhile, *Barbodes* sp. utilizes a variety of food resources, including plankton, insects, aquatic plants, and detritus. The highest frequency of food occurrence was recorded for *Daphnia* sp. at 61.1%, followed by insects at 50%. This indicates that the feeding habits of this fish are highly diverse. The strong tendency to consume *Daphnia* sp. highlights its preference for this type of plankton, while the high consumption of insects reflects the fish's adaptation to the available food resources in its habitat. Such feeding patterns contribute to maintaining ecological balance by regulating the populations of their prey species and supporting the integrity of trophic structures within their ecosystem.

3.2 Niche breadth and dietary overlap

The food niche refers to the range of food resources utilized by a species within its ecosystem, reflecting its role in the trophic structure. Dietary overlap occurs when different species exploit similar food resources, potentially leading to competition [65, 66]. Analyzing food niche breadth and dietary overlap helps in understanding interspecific interactions, resource partitioning, and the potential impact of invasive species on native populations [67, 68].

Niche breadth describes the extent of food utilization by a specific fish species and helps determine dietary selectivity within its group [69]. A small niche breadth value indicates that a fish species is selective toward food resources in its environment, whereas a large value suggests a diverse range of consumed food types [70]. Based on fish size, the food niche breadth value for *Barbodes* sp. was 3.64 with a standardized value of 0.66, *Rasbora* sp. had a niche breadth of 1.39 with a standardized value of 0.02, and *Amphilophus trimaculatus* exhibited a niche breadth of 2.31 with a standardized value of 0.03 (Table 2).

Table 2. Food niche breadth of native and invasive fish in Aneuk Laot Lake

Species of Fish	Niche Breadth	Standardized
Barbodes sp.	3.64	0.66
Rasbora sp.	1.39	0.02
Amphilophus trimaculatus	2.31	0.05

Based on the food niche breadth values presented in Table 2, *Barbodes* sp. exhibits a more specific dietary adaptation. The range of values indicates that this species has a more diversified feeding pattern compared to *Rasbora* sp., suggesting that *Rasbora* sp. is more dependent on certain prey types that are consistently available. However, *Amphilophus trimaculatus* demonstrates a higher adaptability to changes in prey availability, indicating that this species has greater dietary flexibility.

Native fish species (*Barbodes* sp. and *Rasbora* sp.) generally exhibit specialized adaptations to utilize locally available food resources. They can consume a variety of food types, including plankton, aquatic invertebrates, aquatic plants, and even other fish, depending on the species and ecological conditions of the lake. The availability of these food resources plays a crucial role in supporting the health and population of native fish while maintaining the ecological balance of the lake. However, the presence of invasive species or environmental changes can disrupt food availability and negatively impact native fish populations.

Invasive fish species, such as *Amphilophus trimaculatus*, often have a broader niche breadth compared to native species, allowing them to compete more effectively and dominate food resources [19, 26]. A large niche breadth in invasive fish enables them to adapt rapidly to new habitats, contributing to their success as invasive species while impacting trophic structure and biodiversity within the ecosystems they inhabit.

Non-native fish species typically adopt a generalist feeding strategy with adaptable dietary patterns, enabling them to establish themselves and thrive as invasive species. In this study, the invasive fish *Amphilophus trimaculatus* exhibited a mixed and generalized feeding strategy, utilizing the available food resources within the Aneuk Laot Lake habitat. Table 3 illustrates the shared utilization of food resources between *Rasbora* sp. and *Barbodes* sp., with a dietary overlap value of 0.96, which is close to 1. In contrast, the invasive fish *Amphilophus trimaculatus* showed a lower dietary overlap with native fish species, ranging from 0.47 to 0.49. According to study [71], invasive species influence the demographics of native species through predation and competition for food resources. In this study, *Amphilophus trimaculatus* was found to have the potential to impact the population of the native fish species *Rasbora* sp. through predation, as evidenced by the presence of *Rasbora* sp. scales in its stomach contents. This impact extends beyond economic consequences, affecting the balance of the food chain and potentially triggering cascading effects within the ecosystem. In general, invasive fish tend to adopt an opportunistic feeding strategy, meaning they do not rely on specific food types but instead adjust their diet based on the availability of food in their environment. Fish species with this strategy exhibit flexibility in prey selection and can utilize a wide range of food resources depending on habitat conditions and seasonal variations.

Table 3. Dietary overlap values of *Barbodes* sp., *Rasbora* sp., and *Amphilophus trimaculatus* captured in Aneuk Laot Lake, Sabang City, Aceh

	***Rasbora* sp.**	***Barbodes* sp.**	***Amphilophus trimaculatus***
Rasbora sp.	-	0.96	0.49
Barbodes sp.	0.96	-	0.47
Amphilophus trimaculatus	0.49	0.47	-

Figure 3 illustrates the shared utilization of food resources between native and invasive fish species. Native fish in Aneuk Laot Lake exhibit a specialist-stenophagic feeding strategy, whereas invasive fish demonstrate a generalist-opportunistic feeding behavior. Native fish populations with a specialist and stenophagic-monophagic feeding strategy are less likely to expand, making them more vulnerable to environmental changes and competition. A similar situation is observed with the presence of flowerhorn fish (*Amphilophus trimaculatus*) in Aneuk Laot Lake, where its population continues to grow, posing a threat to the declining native fish populations. The presence of flowerhorn fish was first reported by researcher [8], whereas previous research [72] did not identify *Amphilophus trimaculatus* in the lake, suggesting that its introduction occurred after that period.

The interplay between niche overlap and competitive differences significantly shapes the evolutionary trajectory of ecological communities [73]. While an increase in the number of competing species doesn't necessarily decrease tolerable niche overlap due to environmental variability, it does highlight the relationship between overlap and diffuse competition [52]. The degree of niche overlap and the magnitude of competitive differences are intricately governed by a network of complex ecological processes, consequently opening diverse avenues for species to coexist within a shared environment [73, 74]. Species can coexist by differentiating resource use, thereby minimizing direct interactions, or by maintaining partially overlapping resource use alongside near-equivalent average competitive abilities. The initial conditions of a community, including factors such as resource availability, environmental stability, and the existing species composition, play a crucial role in determining whether evolutionary shifts in niche overlap or competitive abilities will foster or hinder species coexistence [74].

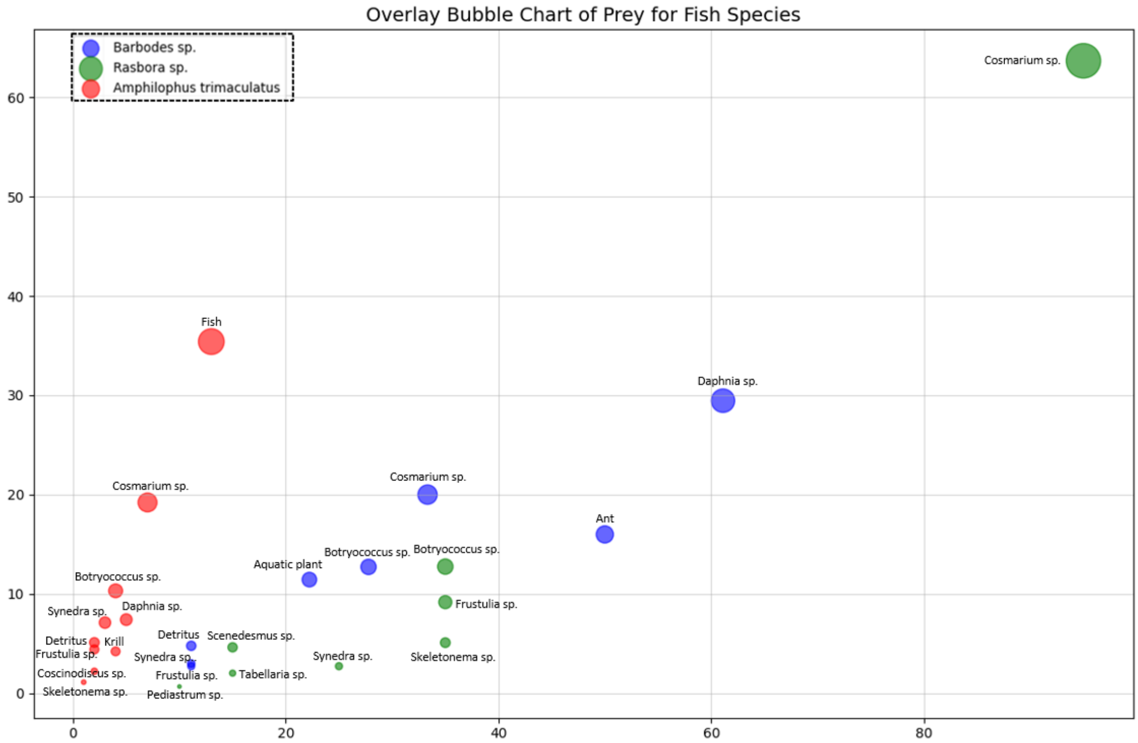


Figure 3. Variations in food types of native and invasive fish in Aneuk Laot Lake, with *Barbodes* sp. represented by the blue label, *Rasbora* sp. by the green label, and *Amphilophus trimaculatus* by the red label

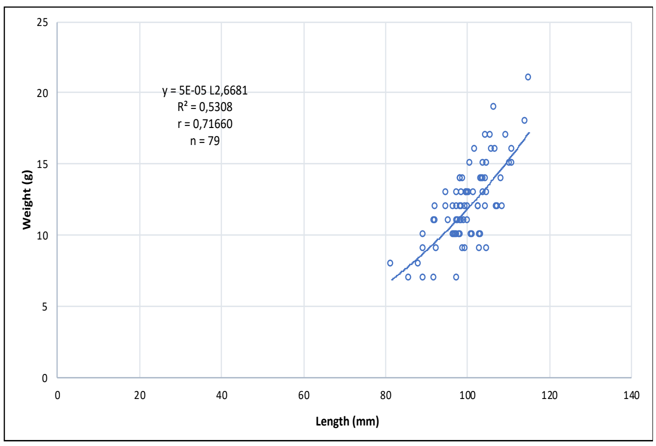
Study [50] stated that fish species capable of adapting their feeding habits can significantly influence their population dynamics in natural habitats. A similar phenomenon was observed in Lake Matano, where the flowerhorn fish exhibited strong adaptability, leading to a population increase [75]. A precautionary approach is necessary when introducing new fish species into Aneuk Laot Lake, as the establishment of new species can alter the food chain structure within the fish community. High ecological pressure in the form of niche competition from introduced fish populations may threaten the existence of native fish species [76].

3.3 Growth patterns of native and invasive fish

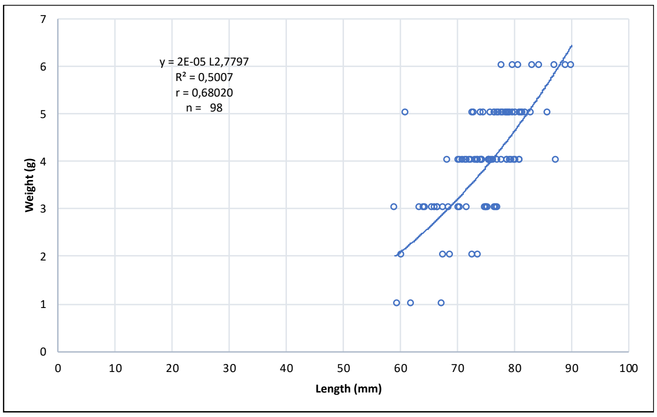
The length-weight relationship of fish is a crucial biological parameter for understanding growth, body condition, and the ecology of a species. Fish feeding habits play a significant role in determining growth patterns [77, 78]. In this study, *Barbodes* sp. exhibited a negative allometric growth pattern, meaning that the proportional increase in length was faster than in weight. This finding aligns with the study [79], which reported that the growth pattern of *Barbodes* sp. identified in Krueng Simpoe also followed a negative allometric pattern. Similarly, study [80] stated that the growth pattern of *Barbodes lateristriga* in the Tebudak River, Pisak Village, Bengkayang Regency, was negative allometric for both male and female fish. In contrast, a study conducted in a national park in northern Vietnam found that *Barbodes semifasciolatus* exhibited a positive allometric growth pattern [81]. Study [35] stated that fish growth and fluctuations in food resources in aquatic environments are influenced by seasonal variations.

A similar pattern was observed in *Rasbora* sp. from Aneuk Laot Lake, which exhibited a negative allometric growth pattern with a b value of 2.77 (Figure 4). Referring to [53], fish growth patterns are determined based on the b value, where growth is classified as isometric ($b = 3$), negative allometric ($b<3$), or positive allometric ($b>3$). The length-weight relationship of fish is an important indicator of their overall health and condition [82, 83].

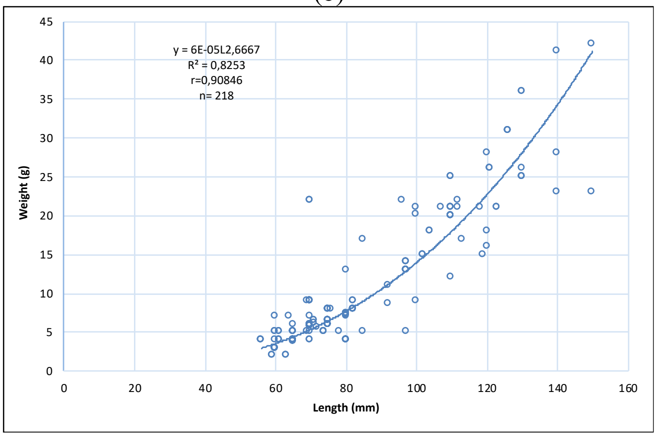
In fish species experiencing high predation pressure, individuals tend to grow longer before increasing their body weight. This phenomenon is evident in the native fish of Aneuk Laot Lake (*Rasbora* sp. and *Barbodes* sp.), which serve as prey for *Amphilophus trimaculatu*s. The growth pattern of *Amphilophus trimaculatus* also follows a negative allometric trend. This is likely due to numerous predators in a shared habitat, leading to competition among these fish for the same prey resources. As a result, individual predators may not obtain sufficient food to adequately increase their body mass.



(a)



(b)



(c)

Figure 4. Length-weight relationship of native and invasive fish in Aneuk Laot Lake, Sabang City, Aceh (a) growth pattern of *Barbodes* sp., (b) growth pattern of *Rasbora* sp., and (c) growth pattern of *Amphilophus trimaculatus*

Interestingly, this study found a similar growth pattern for both native and invasive fish, with a b value of less than 3, indicating a negative allometric growth pattern (Figure 4). This suggests that environmental degradation in the waters of Aneuk Laot Lake, such as pollution, sedimentation, and temperature fluctuations, may be causing stress in these fish, leading to inhibited growth. Study [84] reported that Lake Aneuk Laot is classified as heavily polluted, with several water quality parameters exceeding environmental standards, including total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), and total phosphate. Furthermore, study [84] explained that sedimentation disrupts the photosynthesis process and leads to the mortality of aquatic organisms. The TSS concentration in Aneuk Laot Lake was recorded at 102.25 mg/L, exceeding the permissible water quality standards for lakes.

In contrast, studies conducted in Lake Matano, Sulawesi, found that flowerhorn fish in those waters exhibited a positive allometric growth pattern [85]. Meanwhile, other studies reported that flowerhorn fish in the P.B. Soedirman Reservoir, Central Java, demonstrated an isometric growth pattern [86]. These differences indicate that fish growth patterns can vary depending on environmental conditions and other influencing factors. Furthermore, slope values (b) can fluctuate primarily due to diverse environmental, human-induced, and biological factors, including gonadal maturation, dietary intake, stomach fill level, and growth stage [81]. Trophic interactions are crucial in aquatic environments and dictate the flow of energy and nutrients within an ecosystem [87]. Understanding the feeding ecology of fish offers valuable insights into population dynamics, resource partitioning, habitat preferences, and energy transfer, all of which have implications for fisheries management [87].

4. CONCLUSIONS

This study confirms that *Rasbora* sp. and *Barbodes* sp. exhibit significant dietary overlap, leading to competition for food resources, with Pianka's overlap index value of 0.96. Predation by *Amphilophus trimaculatus* further threatens native fish populations. The growth pattern of native fish in Aneuk Laot Lake follows a negative allometric trend ($b < 3$), with a b-value of 2.77, indicating environmental pressure. These findings provide critical insights for ecological management strategies aimed at mitigating the impact of invasive species and preserving biodiversity in Aneuk Laot Lake. The study serves as baseline data for lake management, emphasizing invasive fish population control, native fish habitat conservation, and the implementation of fisheries regulations to maintain ecosystem balance and optimize fish population growth.

ACKNOWLEDGMENT

The authors would like to thank Universitas Syiah Kuala which has funded this research on the Lector Research Scheme in 2024 with contract No.: 353/UN11.2.1/PG.01.03/SPK/PTNBH/2024 on May 3rd, 2024.

REFERENCES

[1] Lall, S.P., Tibbetts, S.M. (2009). Nutrition, feeding, and behavior of fish. Veterinary Clinics of North America: Exotic Animal Practice, 12(2): 361-372. https://doi.org/10.1016/j.cvex.2009.01.005

[2] Siswati, L., Putri, A. (2018). Factors which influence the fish purchasing decision: A study on traditional market in Riau mainland. IOP Conference Series: Earth and Environmental Science, 156: 012064. https://doi.org/10.1088/1755-1315/156/1/012064

[3] Khaing, M.M., Khaing, K.Y.M. (2020). Food and feeding habits of some freshwater fishes from Ayeyarwady river, Mandalay district, Myanmar. IOP Conference Series: Earth and Environmental Science, 416: 012005. https://doi.org/10.1088/1755-1315/416/1/012005

[4] Pujiyati, S., Hamuna, B., Hisyam, M., Azzah, A., Sunarwati, E., Pasaribu, R. (2021). Distributions of environmental parameters and fish at Humbold Bay, Jayapura. IOP Conference Series: Earth and Environmental Science, 944: 012003. https://doi.org/10.1088/1755-1315/944/1/012003

[5] Nisak, L., Agustono., Budi, D.S. (2022). The effects of different feeding rates on the growth of silver Rasbora (*Rasbora argyrotaenia*). IOP Conference Series: Earth and Environmental Science, 1036: 12069. https://doi.org/10.1088/1755-1315/1036/1/012069

[6] Damora, A., Nur, F., Batubara, A., Nugroho, R., Fadli, N., Muchlisin, Z. (2021). Food and feeding habits of two

species ornamental fishes from Bira Cot, Aceh Besar, Indonesia. IOP Conference Series: Earth and Environmental Science, 674: 012104. https://doi.org/10.1088/1755-1315/674/1/012104

[7] Khan, A., Ahmed, S.M., Sarr, C., Kabore, Y., Kahasha, G., Bangwe, L., Odhiambo, W., Gahunga, N., Mclean, B., Diop, H. (2021). Nourishing nations during pandemics: Why prioritize fish diets and aquatic foods in Africa. Maritime Studies, 20: 487-500. https://doi.org/10.1007/s40152-021-00236-z

[8] Nurfadillah, N., Dewiyanti, I., Maulana, M.A., Sari, S., Hasfiandi, H. (2022). Food habits and niche breadth of three species of fish catchs in Aneuk Laot Lake, Sabang Aceh. Elkawnie: Journal of Islamic Science and Technology, 8(1): 54-64. https://doi.org/10.22373/ekw.v8i1.10536

[9] Schroeder, A., Camatti, E., Pansera, M., Pallavicini, A. (2023). Feeding pressure on meroplankton by the invasive ctenophore *Mnemiopsis Leidyi*. Biological Invasions, 25: 2007-2021. https://doi.org/10.1007/s10530-023-03023-5

[10] Olopade, O.A., Dienye, H.E. (2023). Health status of sciaenid species following mass fish kills in coastal waters of Niger Delta, Nigeria. World Journal of Advanced Research and Reviews, 18(2): 807-813. https://doi.org/10.30574/wjarr.2023.18.2.0837

[11] Roesti, M., Groh, J.S., Blain, S.A., Huss, M., Rassias, P., Bolnick, D.I., Stuart, Y.E., Peichel, C.L., Schluter, D. (2022). Species divergence under competition and shared predation. Ecology Letters, 26(1): 111-123. https://doi.org/10.1111/ele.14138

[12] Takola, E., Schielzeth H., (2022). Hutchinson's ecological niche for individuals. Biology & Philosophy, 37(4): 25. https://doi.org/10.1007/s10539-022-09849-y

[13] Steinmüller, K. (1980). A model of niche overlap and interaction in ecological systems. Biometrical Journal, 22(3): 211. https://doi.org/10.1002/bimj.4710220303

[14] Popielarz, P.A., Neal, Z.P. (2007). The niche as a theoretical tool. Annual Review of Sociology, 33(1): 65. https://doi.org/10.1146/annurev.soc.32.061604.123118

[15] Bandyopadhyay, M., Biswas, S., Dasgupta, T., Krishnamurthy, R. (2023). Patterns of coexistence between two mesocarnivores in presence of anthropogenic disturbances in Western Himalaya. Environmental Monitoring and Assessment, 195(3): 397. https://doi.org/10.1007/s10661-023-11003-4

[16] Valladares, F., Bastías, C.C., Godoy, Ó., Granda, E., Escudero, A. (2015). Species coexistence in a changing world. Frontiers in Plant Science, 6: 866. https://doi.org/10.3389/fpls.2015.00866

[17] Gu, D.E., Yu, F., Hu, Y., Wang, J.W., Xu, M., Mu, X., Ye, Y., Luo, D., Wei, H., Shen, Z.X., Li, G.J., Tong, Y.N., Cao, W.X. (2020). The species composition and distribution patterns of non-native fishes in the main rivers of south China. Sustainability, 12(11): 4566. https://doi.org/10.3390/su12114566

[18] Levin, P.S., Achord, S., Feist, B.E., Zabel, R.W. (2002). Non–indigenous brook trout and the demise of Pacific salmon: A forgotten threat?. Proceedings of the Royal Society B Biological Sciences, 269(1501): 1663-1670. https://doi.org/10.1098/rspb.2002.2063

[19] Wainright, C.A., Muhlfeld, C.C., Elser, J.J., Bourret, S.L., Devlin, S.P. (2021). Species invasion progressively disrupts the trophic structure of native food webs. Proceedings of the National Academy of Sciences, 118(45): e2102179118. https://doi.org/10.1073/pnas.2102179118

[20] Danet, A., Giam, X., Olden, J.D., Comte, L. (2024). Past and recent anthropogenic pressures drive rapid changes in riverine fish communities. Nature Ecology & Evolution, 8(3): 442-453. https://doi.org/10.1038/s41559-023-02271-x

[21] Fudali, A., Pietrzak, B. (2024). Freshwater fish personalities in the Anthropocene. Ecohydrology & Hydrobiology, 24(2): 354-366. https://doi.org/10.1016/j.ecohyd.2024.01.002

[22] Su, G., Mertel, A., Brosse, S., Calabrese, J.M. (2023). Species invasiveness and community invasibility of North American freshwater fish fauna revealed via trait-based analysis. Nature Communications, 14(1): 2332. https://doi.org/10.1038/s41467-023-38107-2

[23] Mayfield, A.E., Seybold, S.J., Haag, W.R., Johnson, M.T., Kerns, B.K., Kilgo, J.C., Larkin, D.J., Lucardi, R.D., Moltzan, B., Pearson, D.E., Rothlisberger, J.D., Schardt, J.D., Schwartz, M.K., Young, M.K. (2021). Impacts of invasive species in terrestrial and aquatic systems in the United States. Springer eBooks, pp. 5-39. https://doi.org/10.1007/978-3-030-45367-1_2

[24] Osmundson, D.B. (2023). Body condition variation in a riverine piscivore: Have small non-native cyprinids benefited an endangered fish? Biological Invasions, 25(12): 3823. https://doi.org/10.1007/s10530-023-03138-9

[25] Saba, A.O., Ismail, A., Zulkifli, S.Z., Ghani, I.F.A., Halim, M.R.A., Ibrahim, M.A., Mukhtar, A., Aziz, A. A., Azrizal-Wahid, N., Amal, M.N.A. (2021). Invasion risk and potential impact of alien freshwater fishes on native counterparts in Klang Valley, Malaysia. Animals, 11(11): 3152. https://doi.org/10.3390/ani11113152

[26] Pennock, C.A., Ahrens, Z.T., McKinstry, M.C., Budy, P., Gido, K.B. (2021). Trophic niches of native and nonnative fishes along a river-reservoir continuum. Scientific Reports, 11(1): 12140. https://doi.org/10.1038/s41598-021-91730-1

[27] Armstrong, R.A., McGehee, R. (1980). Competitive exclusion. The American Naturalist, 115(2): 151. https://doi.org/10.1086/283553

[28] Jaeger, R.G. (1974). Competitive exclusion: Comments on survival and extinction of species. BioSCIENCE, 24(1): 33. https://doi.org/10.2307/1296657

[29] DLHK. (2021). Daya Tampung Beban Pencemaran Air Danau Aneuk Laot Kota Sabang. Dokumen Kajian. Dinas Lingkungan Hidup dan Kebersihan, Kota Sabang.

[30] Prianto, E., Purwoko, R.M., Kasim, K. (2021). Stock status of Nile tilapia (Oreochromis niloticus) in Aneuk Laot Lake, Sabang District, Aceh Province, Indonesia. Biodiversitas Journal of Biological Diversity, 22(8): 3364-3370. https://doi.org/10.13057/biodiv/d220833

[31] Nurfadillah, N., Dewiyanti, I., Rahayu, S.R., Sari, S., Karina, I., Hasfiandi, H. (2022). Trophic status analysis and estimation of fish production in Aneuk Laot Lake aquatic resources management, Sabang City. Depik, 11(3): 469-475. https://doi.org/10.13170/depik.11.3.27499

[32] Nayek, S., Gupta, S., Pobi, K. (2018). Physicochemical characteristics and trophic state evaluation of post glacial mountain lake using multivariate analysis. Global Journal of Environmental Science and Management, 4(4):

451-464. https://doi.org/10.22034/gjesm.2018.04.006
[33] Jia, P., Hu, M., Hu, Z., Liu, Q., Wu, Z. (2012). Modeling trophic structure and energy flows in a typical macrophyte dominated shallow lake using the mass balanced model. Ecological Modelling, 233: 26-30. https://doi.org/10.1016/j.ecolmodel.2012.02.026
[34] Pratiwi, M.A., Wardiatno, Y., Adrianto, L. (2014). Analisis ecological footprint sistem perikanan di kawasan taman wisata perairan Gili Matra, Lombok Utara. Jurnal Ilmu Pertanian Indonesia, 19(2): 111-117.
[35] Muchlisin, Z., Musman, M., Siti Azizah, M. (2010). Length-weight relationships and condition factors of two threatened fishes, *Rasbora tawarensis* and *Poropuntius tawarensis,* endemic to Lake Laut Tawar, Aceh Province, Indonesia. Journal of applied ichthyology, 26(6): 949-953. https://doi.org/10.1111/j.1439-0426.2010.01524.x
[36] Bai, J., Zhang, H., Zhou, H., Li, S., Gao, B., Chen, P., Ma, L., Xu, Z.-F., Zhang, Z., Xu, C., Ruan, L., Ge, G. (2021). Winter coexistence in herbivorous waterbirds: Niche differentiation in a floodplain, Poyang Lake, China. Ecology and Evolution, 11(23): 16835 https://doi.org/10.1002/ece3.8314
[37] Choden, Y., Sharma, M.P., Pandey, G., Gupta, S.K., Dema, K.D. (2022). Ecological health assessment of Renuka Lake, Himachal Pradesh, India. Nature Environment and Pollution Technology, 21(1): 167. https://doi.org/10.46488/nept.2022.v21i01.018
[38] Guo, C., Li, S., Li, W., Liao, C., Zhang, T., Liu, J., Li, L., Sun, J., Cai, X., Hansen, A.G. (2022). Spatial variation in the composition and diversity of fishes inhabiting an artificial water supply lake, Eastern China. Frontiers in Ecology and Evolution, 10: 1-14. https://doi.org/10.3389/fevo.2022.921082
[39] Gu, X., Mao, Z., Ding, H., Wang, Y., Zeng, Q., Wang, L. (2018). Progress and prospect of lake fishery. Journal of Lake Science, 30(1): 1-14. https://doi.org/10.18307/2018.0101
[40] Mehner, T., Attermeyer, K., Brauns, M., Brothers, S., Hilt, S., Scharnweber, K., Van Dorst, R.M., Vanni, M.J., Gaedke, U. (2022). Trophic transfer efficiency in lakes. Ecosystems, 25(8): 1628-1652. https://doi.org/10.1007/s10021-022-00776-3
[41] Levine, J.M., HilleRisLambers, J. (2009). The importance of niches for the maintenance of species diversity. Nature, 461(7261): 254. https://doi.org/10.1038/nature08251
[42] Dimopoulos, P., Kokkoris, I. (2021). Protection and management of species, habitats, ecosystems and landscapes. MDPI eBooks. https://doi.org/10.3390/books978-3-0365-0177-2
[43] Weiskopf, S.R., Rubenstein, M.A., Crozier, L.G., Gaichas, S., Griffis, R.B., Halofsky, J.E., Hyde, K.J. W., Morelli, T.L., Morisette, J.T., Muñoz, R.C., Pershing, A.J., Peterson, D.L., Poudel, R., Staudinger, M.D., Sutton-Grier, A.E., Thompson, L.M., Vose, J.M., Weltzin, J.F., Whyte, K.P. (2020). Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. The Science of The Total Environment, 733: 137782. https://doi.org/10.1016/j.scitotenv.2020.137782
[44] Marchetti, M., Light, T., Moyle, P.B., Viers, J.H. (2004). Fish invasions in California watersheds: Testing hypotheses using landscape patterns. Ecological Applications, 14(5): 1507. https://doi.org/10.1890/03-5173
[45] Alam, S., Begum, A. (2004). Conserving fish stocks in an inland aquatic ecosystem: The effect of community based fisheries management in Bangladesh. Biodiversity, 5(4): 22. https://doi.org/10.1080/14888386.2004.9712745
[46] Davis, M.T., McCarthy, C., Beazley, K. (2016). A risk assessment for the introduction of invasive fish for Kejimkujik National Park and National Historic Site, Canada. Marine and Freshwater Research, 68(7): 1292. https://doi.org/10.1071/mf16069
[47] Koel, T.M., Arnold, J.L., Bigelow, P.E., Brenden, T.O., Davis, J.D., Detjens, C.R., Doepke, P.D., Ertel, B.D., Glassic, H.C., Gresswell, R.E., Guy, C.S., MacDonald, D.J., Ruhl, M.E., Stuth, T.J., Sweet, D.P., Syslo, J.M., Thomas, N.A., Tronstad, L.M., White, P.J., Zale, A.V. (2020). Yellowstone lake ecosystem restoration: A case study for invasive fish management. Fishes, 5(2): 18. https://doi.org/10.3390/fishes5020018
[48] Edyanto, C.H. (2008). Penurunan permukaan air Danau Aneuk Laot di Pulau Weh Propinsi Nangroe Aceh Darussalam. Jurnal Hidrosfir Indonesia, 3(1).
[49] Zuliani, Z., Muchlisin, Z.A., Nurfadillah, N. (2016). Kebiasaan makanan dan hubungan panjang berat ikan julung-julung (*Dermogenys* sp.) di Sungai Alur Hitam Kecamatan Bendahara Kabupaten. Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah, 1(1): 12-24.
[50] Effendie, M. (2002). Biologi Perikanan [Fisheries Biology]. Yayasan Pustaka Nusantara. Yogyakarta.
[51] Hurlbert, S.H. (1978). The measurement of niche overlap and some relatives. Ecology, 59(1): 67-77. https://doi.org/10.2307/1936632
[52] Pianka, E.R. (1974). Niche overlap and diffuse competition. Proceedings of the National Academy of Sciences, 71(5): 2141. https://doi.org/10.1073/pnas.71.5.2141
[53] Setyohadi, D., Pamungkas, R.S., Purwanto, H., Sunardi, Sulkhany, E., Syawli, A., Rahman, M.A., Kadhafi, M. (2024). Enhancing fisheries management and sustainability: A stowage factor analysis of fish species at Mayangan Port, Indonesia. International Journal of Design & Nature and Ecodynamics, 19(6): 1939-1949. https://doi.org/10.18280/ijdne.190610
[54] Tetelepta, J.M.S., Natan, Y., Ajub, P.J., Bernardus, A.S. (2022). Population parameters and sustainable status of lompa fish *Thryssa baelama* (Forsskal, 1775) manage through sasi approach at Haruku Village. Fisheries and Aquatic Sciences, 25(2): 101-116. https://doi.org/10.47853/fas.2022.e10
[55] Gayford, J.H., Sternes, P.C., Seamone, S.G., Godfrey, H., Whitehead, D.A. (2024). Insights into ontogenetic scaling and morphological variation in sharks from near-term brown smooth-hound (*Mustelus henlei*) embryos. bioRxiv (Cold Spring Harbor Laboratory). Cold Spring Harbor Laboratory. https://doi.org/10.1101/2024.02.05.578906
[56] Gupta, N., Everard, M., Nautiyal, P., Kochhar, I., Sivakumar, K., Johnson, J.A., Borgohain, A. (2020). Potential impacts of non-native fish on the threatened mahseer (*Tor*) species of the Indian Himalayan biodiversity hot spot. Aquatic Conservation: Marine and Freshwater Ecosystems, 30(2): 394-401. https://doi.org/10.1002/aqc.3275
[57] Nurfadillah, N., Hasri, I., Fahmi, R., Misran, M. (2021).

The competition index and growth performance between tilapia (*Oreochromis niloticus*) and native fish spesies Laut Tawar Lake in polyculture system. IOP Conference Series Earth and Environmental Science, 674(1): 12080. https://doi.org/10.1088/1755-1315/674/1/012080

[58] Adamek-Urbańska, D., Kamaszewski, M., Wiechetek, W., Wild, R., Boczek, J., Szczepański, A., Śliwiński, J. (2023). Comparative morphology of the digestive tract of african bush fish (*Ctenopoma acutirostre*) and Paradise Fish (*Macropodus opercularis*) inhabiting Asian and African freshwaters. Animals, 13(16): 2613. https://doi.org/10.3390/ani13162613

[59] Takahashi, T. (2008). Description of a new cichlid fish species of the genus *Benthochromis* (Perciformes: Cichlidae) from Lake Tanganyika. Journal of Fish Biology, 72(3): 603. https://doi.org/10.1111/j.1095-8649.2007.01727.x

[60] Mutengu, C., Mhlanga, W. (2018). Occurrence of clinostomum metacercariae in *Oreochromis mossambicus* from Mashoko Dam, Masvingo Province, Zimbabwe. Scientifica, 2018(1): 6565049. https://doi.org/10.1155/2018/9565049

[61] Wang, Y., Ren, L., Xu, D., Fang, D. (2022). Exploring the trophic niche characteristics of four carnivorous Cultrinae fish species in Lihu Lake, Taihu Basin, China. Frontiers in Ecology and Evolution, 10. https://doi.org/10.3389/fevo.2022.954231

[62] Milardi, M., Gavioli, A., Soininen, J., Castaldelli, G. (2019). Exotic species invasions undermine regional functional diversity of freshwater fish. Scientific Reports, 9(1): 17921. https://doi.org/10.1038/s41598-019-54210-1

[63] Preston, D.L., Hedman, H.D., Esfahani, E.R., Pena, E.M., Boland, C.E., Lunde, K.B., Johnson, P.T.J. (2017). Responses of a wetland ecosystem to the controlled introduction of invasive fish. Freshwater Biology, 62(4): 767. https://doi.org/10.1111/fwb.12900

[64] Johnson, N.S., Miehls, S., O'Connor, L., Bravener, G., Barber, J., Thompson, H.T., Tix, J.A., Bruning, T. (2016). A portable trap with electric lead catches up to 75% of an invasive fish species. Scientific Reports, 6(1): 28430. https://doi.org/10.1038/srep28430

[65] Declerck, S., Louette, G., Bie, T.D., Meester, L.D. (2002). Patterns of diet overlap between populations of non-indigenous and native fishes in shallow ponds. Journal of Fish Biology, 61(5): 1182-1197. https://doi.org/10.1111/j.1095-8649.2002.tb02464.x

[66] Jackson, M.C., Grey, J., Miller, K.A., Britton, J.R., Donohue, I. (2016). Dietary niche constriction when invaders meet natives: Evidence from freshwater decapods. Journal of Animal Ecology, 85(4): 1098-1107. https://doi.org/10.1111/1365-2656.12533

[67] Hayden, B., Palomares, M.L.D., Smith, B.E., Poelen, J.H. (2019). Biological and environmental drivers of trophic ecology in marine fishes - A global perspective. Scientific Reports, 9: 11415. https://doi.org/10.1038/s41598-019-47618-2

[68] Feiner, Z.S., Brey, M.K., Burgett, C. (2019). Consistently high trophic overlap between invasive white perch and native black crappies in southeastern reservoirs. North American Journal of Fisheries Management, 39(1): 135-149. https://doi.org/10.1002/nafm.10256

[69] Isroliyah, A., Solichin, A., Rudiyanti, S. (2021). Kebiasaan makanan dan luas relung ikan red devil (*Amphilophus Labiatus*) di Perairan Waduk Jatibarang, Semarang. Jurnal Pasir Laut, 5(2): 96-102. https://doi.org/10.14710/jpl.2021.35190

[70] Situmorang, T.S., Barus, T.A., Wahyuningsih, H. (2013). Studi komparasi jenis makanan ikan keperas (*Puntius binotatus*) di Sungai Aek Pahu Tombak, Aek Pahu Hutamosu dan Sungai Parbotikan Kecamatan Batang Toru Tapanuli Selatan. Jurnal Perikanan dan Kelautan, 18(2): 48-58.

[71] Cerveira, I., Dias, E., Baptista, V., Teodósio, M.A., Morais, P. (2021). Invasive fish keeps native feeding strategy despite high niche overlap with a congener species. Regional Studies in Marine Science, 47: 101969. https://doi.org/10.1016/j.rsma.2021.101969

[72] Khayra, A., Muchlisin, Z.A., Sarong, M.A. (2016). Morfometrik lima species ikan yang dominan tertangkap di Danau Aneuk Laot, Kota Sabang. Depik, 5(2): 57-66. http://dx.doi.org/10.13170/depik.5.2.4907

[73] Pastore, A.I., Barabás, G., Bimler, M.D., Mayfield, M.M., Miller, T.E. (2021). The evolution of niche overlap and competitive differences. Nature Ecology & Evolution, 5(3): 330. https://doi.org/10.1038/s41559-020-01383-y

[74] Sun, J., Li, Y., Deng, D., Yang, S., Wu, Y., Shi, H. (2021). Niche analysis of dominant species in alpine desert grassland communities in Qaidam Basin. E3S Web of Conferences, 257: 3021. https://doi.org/10.1051/e3sconf/202125703021

[75] Hedianto, D.A., Sentosa, A.A. (2019). Interaksi trofik komunitas ikan di Danau Matano, Sulawesi Selatan pasca berkembangnya ikan asing. Jurnal Penelitian Perikanan Indonesia, 25(2): 117-133. https://doi.org/10.15578/jppi.25.2.2019.117-133

[76] David, P., Thébault, E, Anneville, O., Duyck, P.F., Chapuis, E., Loeuille, N. (2017). Impacts of invasive species on food webs: A review of empirical data. Advances Ecological Research, 56: 1-60. https://doi.org/10.1016/bs.aecr.2016.10.001

[77] Juanes, F. (2016). A length-based approach to predator–prey relationships in marine predators. Canadian Journal of Fisheries and Aquatic Sciences, 73(4): 677. https://doi.org/10.1139/cjfas-2015-0159

[78] Win, N.N. (2020). The Length-weight relationship and condition factor of *Barbonymus gonionotus* from Nyaung Kaing In, Sagaing Division, Myanmar. IOP Conference Series: Earth and Environmental Science, 416: 012016. https://doi.org/10.1088/1755-1315/416/1/012016

[79] Fuadi, Z., Dewiyanti, I., Purnawan, S. (2016). Hubungan panjang berat ikan yang tertangkap di Krueng Simpoe, Kabupaten Bireun, Aceh. Universitas Syiah Kuala, Banda Aceh.

[80] Simorangkir, R.B., Padmarsari, W., Kurniadi, B. (2024). Pola pertumbuhan dan faktor kondisi ikan Dokun (*Barbodes lateristriga*) di Sungai Tebudak Desa Pisak Kabupaten Bengkayang. Akuatik Tropis: Journal of Tropical Aquatic Resource Management, 2(1): 45-55. https://doi.org/10.26418/akuatik%20tropis.v2i1.80674

[81] Nguyen, H.Q., Dang, H.T.T., Ta, T.T., Do, C.L., Tran, H.D. (2024). Length–weight relationships for 11 freshwater fish species (Actinopterygii) from four protected areas, northern Vietnam. Acta Ichthyologica et

Piscatoria, 54: 269-273. https://doi.org/10.3897/aiep.54.135133
[82] Morey, G., Moranta, J., Massuti, E., Grau, A., Linde, M., Riera, F., Morales-Nin, B. (2003). Weight–length relationships of littoral to lower slope fishes from the Western Mediterranean. Fisheries Research, 62(1): 89-96. https://doi.org/10.1016/S0165-7836(02)00250-3
[83] Perdana, A.W., Batubara, A.S., Aprilla, R.M., Nurfadillah, N., Nur, F.M., Iqbal, T.H. (2018). Length-weight relationships of three popular fishes from Banda Aceh, Indonesia. IOP Conference Series Earth and Environmental Science, 216: 12053. https://doi.org/10.1088/1755-1315/216/1/012053
[84] Nurfadillah, N., Maulidawati, S., Anggraini, R., Defira, C.N., Perdana, A.W. (2024). Pollution status of Aneuk Laot lake Sabang based on pollution index and saprobic index. BIO Web of Conferences, 87: 02012. https://doi.org/10.1051/bioconf/20248702012
[85] Hedianto, D.A., Satria, H. (2017). Pendekatan pola peremajaan dan laju eksploitasi ikan louhan untuk pengendalian ikan asing invasif di Danau Matano, Sulawesi Selatan. Jurnal Penelitian Perikanan Indonesia, 23(4): 227-239. https://doi.org/10.15578/jppi.23.4.2017.227-239
[86] Humanica, A.P., Putri, A.K., Sari, L.K., Junaidi, T., Sanjayasari, D., Samudra, S.R., Fikriyya, N., Mahdiana, A., Baedowi, M., Meinita, M.D.N. (2024). Beberapa aspek biologis ikan hibrida invasif, ikan louhan dari Waduk Pb Sudirman, Kabupaten Banjarnegara, Jawa Tengah. Prosiding Seminar Nasional LPPM UNSOED, 13(1): 50-58.
[87] Mohamed, A.R.M., Abood, A.N. (2021). Trophic relationships among fourteen native and non-native fish species in the Shatt Al-Arab River, Iraq. World Journal of Advanced Research and Reviews, 11(1): 190. https://doi.org/10.30574/wjarr.2021.11.1.0345