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Food environments shaping small fish consumption among primary school-age children in Northern Uganda

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Abstract
Small fish are increasingly recognized as affordable, nutrient-rich animal-source foods, yet little is known about their consumption among primary school-age children, particularly within home and school food environments. This study applied Turner's food environment framework to examine factors influencing fish consumption among primary school-age children in three districts of Northern Uganda. Using a convergent parallel mixed-methods design, we combined quantitative data from a cross-sectional survey of 109 households involving 280 children with qualitative data from 16 focus group discussions with parents. Children consumed fish primarily at home, mainly as environmentally friendly processed small fish, while school meals largely comprised carbohydrate-rich, plant-based foods. Both external and personal food environment factors influenced fish consumption, but affordability emerged as the dominant driver, mediating the effects of availability, market access, convenience, and desirability. We demonstrate that applying the food environment framework provides a comprehensive understanding of how these interacting factors shape children's fish consumption. The limited inclusion of nutrient-dense small fish in school meals represents a missed opportunity to improve dietary quality and nutrition among school-age children, with implications for nutrition-sensitive and sustainable school feeding programs in Uganda and other low- and middle-income countries.

Keywords Fish in diets · Food environment · Nutrition-sensitive food systems · School-age children · School feeding · Uganda

1 Introduction

Small dried fish are affordable, nutrient-rich, and environmentally processed animal-source foods [32, 50, 62]. Small fish are increasingly recognized as an important component of sustainable food systems because they provide affordable animal-source protein, essential micronutrients, and livelihoods while requiring relatively low energy for processing and distribution compared with many other animal-source foods. Their contribution extends beyond nutrition to supporting progress towards Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), and SDG 12 (Responsible Consumption and

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Production). Defined by their size, typically under 25 cm, economic, and nutritional value rather than species (Bavinck et al., 2023); small fish are usually eaten whole, including head, viscera, eyes, and bones, providing more nutrients than larger filleted fish [37, 44, 62].

Fish consumption not only offers health benefits across all life stages (WHO and FAO, 2024) but directly contributes to achieving the UN Sustainable Development Goals (SDGs) by providing essential nutrients and supporting the livelihoods of millions. Despite these recognized benefits, comparatively little is known about how food environments influence fish consumption among school-age children, particularly within the home and school settings where dietary habits are formed.

Public health strategies largely focus on the first 1000 days and women of reproductive age [1]. However, important growth and development continue throughout childhood [11], prompting calls for a life-course approach that extends to the first 8,000 days, and includes previously neglected school-age children (6–14 years) [1, 11, 63]. This life-course perspective highlights school-age children as a critical yet frequently overlooked population for nutrition-sensitive interventions that can generate long-term health and educational benefits.

In our study context, Uganda, little is known about children's fish consumption. Information from existing studies on school feeding shows that school-age children largely consume plant-based and carbohydrate-rich foods [21]. Consequently, diets of many Ugandan primary school-age children remain limited in animal-source foods despite the country's abundant fisheries resources, creating an important nutrition paradox. Since this country's dominant model is parent-led, schools rely on cash and in-kind contributions from parents, mainly beans and maize (MoES, 2013). School feeding is also supported by parents, governments, religious organizations, NGOs, the private sector, and UN agencies (GCNF, 2024; BMAU, 2019). School-age children's diets are shaped by interactions between household food choices, school feeding arrangements, markets, and the wider food system. Schools therefore represent a strategic entry point for improving dietary quality through nutrition-sensitive food system interventions.

School-age is a critical period of rapid physical, cognitive, and emotional development, and nutrition plays a central role [52]. This stage features high brain energy demands and increased micronutrient needs, like vitamins B12 and D, iron, and calcium. Small fish have a high content of such micronutrients [50, 62]. Adolescents, especially, require more nutrients than adults due to rapid gains in weight and height [36, 52]. Middle childhood and adolescence represent a major final window to influence growth and development [52]. Improving dietary quality during this developmental stage has the potential to enhance learning capacity, cognitive development, physical growth, and future productivity.

As children grow up, they gain independence and develop habits that persist into adulthood, including food preferences that shape long-term nutrition and health [34]. As children increasingly eat outside the home [54, 57], the food environment becomes crucial in influencing dietary behaviors [49, 55]. Understanding these interacting environmental influences is therefore essential for designing effective food-based interventions capable of improving children's diets. The food environment encompasses the physical, economic, political, and socio-cultural context shaping food choices [26]. Although Uganda possesses abundant inland fisheries and small pelagic fish resources, geographical inequalities in access to fisheries, household purchasing power, market connectivity, and school feeding practices may substantially influence children's opportunities to consume fish. Understanding how these interacting food environment factors shape children's diets is therefore essential for designing context-specific interventions that improve nutrition while supporting sustainable food systems.

Existing research has examined the nutritional value of small fish, school feeding programs, and fish consumption separately. However, little is known about how household and school food environments interact to influence children's consumption of nutrient-dense small fish in low-income settings. To address this gap, we apply the food environment framework [60] to examine the drivers of nutrient-dense small fish consumption in three districts in Northern Uganda where differential distance to fisheries and markets influences fish access and intake [47, 53]. This represents an important knowledge gap because interventions that overlook food environment drivers are less likely to improve children's dietary quality in a sustainable manner. This study therefore applies

Turner's food environment framework (2018) to examine how external and personal food environment domains influence small fish consumption among primary school-age children in three districts of Northern Uganda, thereby generating evidence to inform future nutrition-sensitive school feeding interventions.

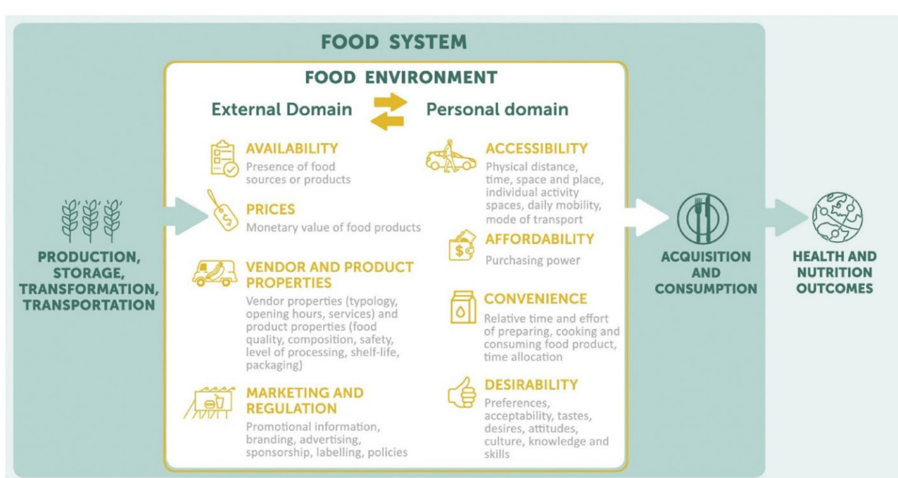
2 Theoretical framework

The food environment is situated in the broader food system, linking food production and diets [19]. It has emerged as a central concept in nutrition-sensitive food systems because it provides a practical framework for understanding how food availability, affordability, accessibility, and consumer preferences interact to influence dietary behavior. Glanz et al., [22] are credited with pioneering conceptual work on the food environment [12, 60]. They identified community nutrition environments (comprising number, type, location, and accessibility of food retail outlets) and consumer nutrition environments (aspects of the retail outlets that consumers engage with, where they buy food, including availability, cost, and quality of healthful food choices) [22]. Later, Swinburn et al., [55] introduced personal and external drivers, recognizing that these influence food choices and diets. Further developments were made to reflect convenience and desirability as important factors influencing consumption [25]. Together, these frameworks demonstrate the progressive evolution of food environment research from describing retail food settings to recognizing the multiple environmental, economic, and behavioral factors that jointly shape food acquisition and consumption.

The food environment concept has been used to study the availability of healthy food in homes, schools, and communities [14, 16, 17, 20, 24, 33, 49]. Considering the role of fish in food environments, scholars have investigated factors affecting fish acquisition and consumption [15], challenges of including fish in school meals [1, 3], and opportunities to promote consumption of healthy diets [29]. Despite these advances, relatively few studies have applied food environment frameworks to examine small fish consumption among school-age children in low-income countries, where informal markets, household food insecurity, and school feeding systems strongly influence dietary choices.

Turner et al., [60] situate the food environment within the broader food system, dividing it into two domains (Fig. 1). The external domain encompasses food-system factors operating outside the household but influencing household food choices, while the personal domain focuses on individual factors like accessibility, affordability, convenience, and desirability. The framework therefore allows simultaneous examination of structural determinants operating at the community level and behavioral determinants operating at household and individual levels. These domains interact to "shape people's food acquisition and consumption" [60]. This interaction recognizes that food choices are rarely determined by a single factor but emerge from the combined influence of market

Fig. 1 The food environment framework by Turner et al., [60]



conditions, household resources, physical access, cultural preferences, and individual decision-making. Unlike earlier frameworks, Turner et al., [60] explicitly incorporate both formal and informal food markets together with non-market food acquisition pathways such as household production, gifts, and subsistence harvesting. These features make the framework particularly suitable for analyzing food environments in low- and middle-income countries where informal food systems dominate household food access.

We used the food environment framework of Turner et al., [60] to investigate how external and personal domains influence fish consumption among school-age children in Northern Uganda, particularly in homes and schools where they spend most of their time. These two settings were selected because they constitute the primary food environments in which school-age children obtain and consume most of their daily meals.

The external domain was conceptualized as societal factors like fish supply from fisheries and markets and fish prices. The personal domain comprises individual- or household-level factors like income or fish preferences, influencing children's fish consumption at home and at school. Further details about the factors within these domains are provided in the methods section, where Turner's framework (Fig. 1) has been adapted to a fish-related food environment framework (see Fig. 3).

The food environment concept was used as an analytical lens to examine the drivers influencing children's consumption of nutrient-dense small fish across the three districts of Northern Uganda. In particular, it informed the design of the household survey and focus group discussions by focusing on the external and personal factors (see Fig. 3) influencing fish consumption. The concept also guided the interpretation of the findings by enabling us to examine how the drivers in the food environment influence fish consumption in households and schools of selected communities. Using the same framework throughout the study design, data collection, analysis, and interpretation ensured conceptual consistency and strengthened the validity of linking empirical findings to established food environment theory. This study extends Turner's framework by applying it to children's consumption of small fish across household, school, and market environments in a low-income African context, thereby broadening its application beyond previous studies focused primarily on general food access and consumer behavior. By integrating external and personal food environment domains, the framework enabled a comprehensive understanding of how environmental, economic, and behavioral factors collectively shape children's small fish consumption in Northern Uganda.

3 Materials and methods

3.1 Study area

This study focused on three districts in Northern Uganda: Gulu, Nwoya, and Pakwach (Fig. 2). The region's income poverty rate is 27%, while the food poverty rate is 13.5% (UBOS, 2025). In the Acholi sub-region, which includes Gulu and Nwoya, 16.7% of children under 5 years of age are stunted, and 24.6% in the West Nile sub-region, which encompasses Pakwach (UBOS, 2023). The main economic activities are farming (Amone, [4]) and fishing, primarily in Pakwach on the River Nile and Lake Albert. The northern region has two rainy seasons [6]. Rainfall raises water levels, releasing nutrients to water bodies that promote fish productivity [31]. Fishing, especially for pelagic small fish, is influenced by the moon cycle [32, 39].

In Gulu District, 90% of approximately 368 000 inhabitants (UBOS 2024) are farmers [45], growing grains (millet, maize, sesame), tubers (cassava, sweet potatoes), legumes (groundnuts, beans, soybeans), and vegetables (eggplants, okra). Nwoya District has about 220 000 inhabitants (UBOS, 2024), also primarily engaged in subsistence farming. Since both districts lack active fisheries, traders transport fish to regional markets for sale. The largest is the Gulu Main Market in the city of Gulu, whereas Nwoya hosts the more regional Anaka market (see Fig. 3), from which fish is further distributed to the rural communities.

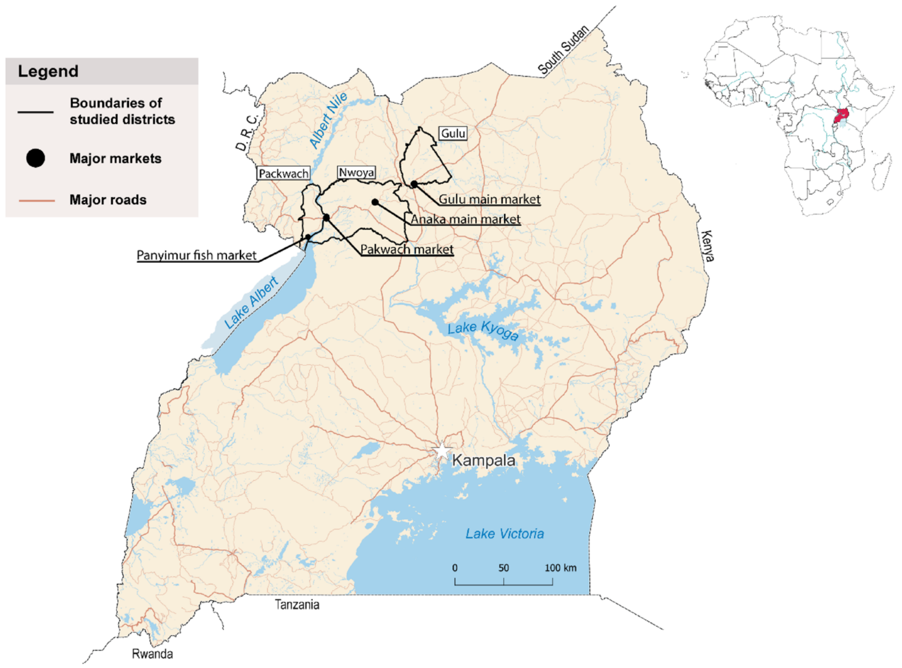


Fig. 2 Map of Uganda highlighting studied districts with major markets, transport routes, and water bodies. *Source*: OpenStreetMap contributors

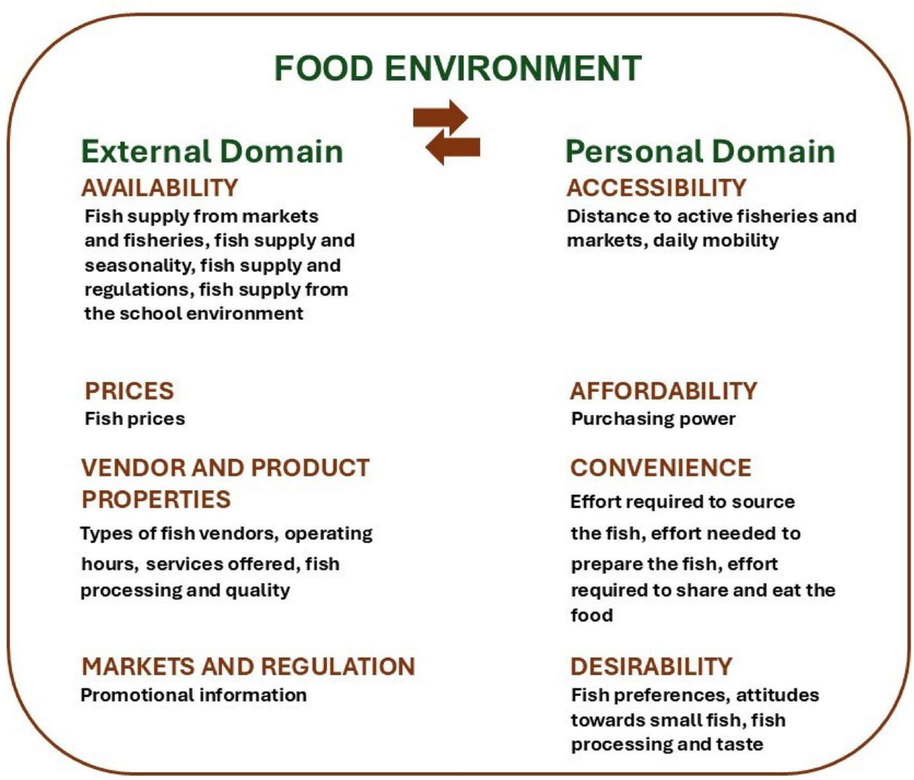


Fig. 3 Fish-related food environment framework adapted from Turner et al., [60] to operationalize the external and personal food environment domains investigated in this study

Also in Pakwach District on the western bank of the Albert Nile in the West Nile sub-region [40], a large share of the approximately 200 000 inhabitants (UBOS, 2024) are subsistence farmers, but in lakeshore and riparian communities, many are engaged in fishing. Fish are distributed through the market in Pakwach town and the Panyimur fish market (see Fig. 3), a regional lakeshore wholesale market that supplies Northern Uganda and distant markets in the Democratic Republic of the Congo and South Sudan (Saevarsson, 2017).

Lake Albert and the Nile River are the main water resources supporting multispecies fisheries. Over 70% of Lake Albert's catches are pelagic small fish like *Brycinus nurse* (local names: ragooge/ragoogi) and *Engraulicypris bredoi* (local name: muziri) [32, 41]. Muziri in Lake Albert resembles *Rastrineobola argentea* (common name: Silver cyprinid, local name: mukene), endemic to Lakes Victoria, Nabugabo, and Kyoga [32, 41].

The study areas, briefly described above, were selected to represent districts located at varying distances from active fisheries and major markets where fish is sold. This enables us to analyze how factors in geographically varying food environments influence children's fish consumption and the potential to increase it through school meals. The three districts were purposively selected to represent contrasting food environments with differing proximity to fisheries, fish markets, and school feeding contexts, thereby allowing comparison of how these environmental differences influence children's fish consumption.

Among the three study districts, only Gulu has a School Feeding Ordinance (2018) that requires parents to provide lunch (BMAU, 2019). Parents contribute grains, tubers, and legumes or cash for the cook's wages, grain processing, and seasoning (BMAU, 2019). Although most primary schools offer lunch, only 35–70% of children receive it, depending on parental cash or in-kind contributions (BMAU, 2019). In Nwoya, half of the government-funded schools tried a school feeding model like Gulu's, but included home-packed meals [58]. Like Nwoya, Pakwach faces challenges in implementing school feeding. Sustaining school feeding is difficult due to high poverty levels and variable agricultural output, limiting parents' capacity to contribute effectively (BMAU, 2019). Consequently, many households cannot provide school meals.

3.2 Data collection

Fieldwork was conducted from November to December 2023. We employed a convergent parallel mixed-methods design that combined quantitative and qualitative approaches. Quantitative and qualitative data were collected concurrently, analyzed separately, and integrated during interpretation to provide complementary evidence on the determinants of children's fish consumption. Adults aged $\geq$18 years participated in a household survey ($n=109$) and 16 focus group discussions (FGDs) to examine factors influencing school-age children's consumption of small fish at home and school in 30 selected communities in the three study districts.

3.2.1 Household survey

Due to resource constraints, 109 eligible households (HH) were identified using convenience sampling. Although the sample was not intended to provide statistically representative estimates for Northern Uganda, it was considered sufficient to describe household fish consumption patterns and explore relationships between food environment factors and children's fish consumption within the selected communities. A household was eligible if it had a primary school-age child (6–14 years). Although Uganda's official primary school-age is 6 to 12 years (UBOS, 2021), it was extended to 13–14 years due to COVID-19-related school closures, which delayed grade progression [23]. A HH was defined as a group of related or unrelated individuals, living together and recognizing one adult as the HH head. Members absent over three months were excluded. Community leaders facilitated participant recruitment by identifying and selecting eligible HH. Research assistants independently verified household eligibility before enrolment using the predefined inclusion criteria to minimize selection errors. Selection bias was minimized by sampling households from different areas in the study districts. To verify adherence to the criteria, local leaders provided sketch maps of their villages, showing the selected HH's location.

The HH survey was administered in local languages (Alur in Pakwach and Acholi in Nwoya and Gulu) by trained research assistants from the region, including the study districts. Data were collected using a tablet-based questionnaire assessing household characteristics and children's fish consumption using a non-validated 7-day food frequency questionnaire (FFQ). Household characteristics included child-level variables (age, sex, education, whether they carried home-packed meals), adult-level variables (age, gender, marital status, education, employment status), and household participation in school feeding programs (SFPs). The interviewer administered FFQ recorded each child's fish consumption, species, and frequency within the 7 days preceding the survey. Interviewer administration reduced potential literacy barriers and improved consistency in recording responses across participants. Our FFQ was not validated, and we did not use food models, because the purpose of this tool was to identify general dietary patterns rather than measure portion sizes or absolute nutrient values.

3.2.2 Focus group discussions (FGDs)

Trained research assistants facilitated 16 FGDs, each with up to eight participants, held in public areas and homes of community leaders. Each discussion lasted approximately 90–165 min. The FGDs were conducted in the local languages, Alur (Pakwach) and Acholi (Nwoya and Gulu), audio-recorded, and transcribed into English. Of these, 11 were gender-mixed (four in Gulu and Pakwach, three in Nwoya), recruiting adults knowledgeable about fish availability and access, childcare and feeding practices, meal preparation, school feeding, and household decisions. In addition, five women-only FGDs – two in Gulu and Pakwach, one in Nwoya – explored fish consumption among school-age children in households and home-packed meals. Women knowledgeable about household and child food preparation and consumption were selected through community leaders, using the same criteria as the household survey, to capture diverse perspectives and minimize bias. As part of a larger project on school feeding, each primary community was required to have a school. One gender-mixed focus group was selected per community. Women-only groups, selected based on differences in proximity to the main market (Gulu) and active fisheries (Pakwach), included a group in Nwoya for logistical reasons.

3.3 Data analysis

Descriptive analyses of survey data were performed using R for Windows version 4.3.2. For categorical variables, frequencies and percentages were summarized and presented in tables and figures. Statistical analyses were descriptive because the study aimed to characterize fish consumption patterns and identify food environment drivers rather than test causal relationships.

The fish consumption question had seven response options, including one for specifying frequency, which was re-coded into 11 reported frequencies. Weekly intake was calculated following Markhus et al. (2013) by converting reported frequencies from the 7-day FFQ to numerical values, e.g., twice a day corresponded to 14, 10 times a week to 10, and so on. After converting categorical FFQ responses into estimated weekly consumption frequencies, the resulting continuous variable was summarized using means, standard deviations, and percentiles.

FGDs were analyzed thematically using inductive and deductive approaches to identify patterns across the data. This approach was used because it is flexible and provides a rich and detailed account of our data [10]. Guided by the food environment concept [60], we alternated between data and concepts to determine whether aspects like availability, price, and convenience (see Fig. 2), as overall themes, were present. We operationalized the variables across the eight dimensions of this food environment framework into distinct fish-related features relevant in our study context (see Fig. 3). The data were manually coded, and various codes or variables were clustered into the identified themes.

Integration of quantitative and qualitative findings occurred during interpretation by comparing household survey results with themes emerging from the focus group discussions. Areas of convergence and divergence were identified to provide a comprehensive understanding of how food environment factors influenced children's fish consumption.

In the next section, we present results on how the fish-related food environment's external domain (fish availability, prices, vendor and product properties, and markets and regulations) and personal domain (fish accessibility, affordability, convenience, and desirability) shape children's fish consumption at home and in school.

Table 1 Households with children that consumed fish ($n = 104$) by district and fish species during the last 7 days

Districts (number of households)	Fish Species				
	Mukene	Nangnang/ Ragoogi	Nile perch	Nile Tilapia	Other species[a]
Greater Gulu ($n = 40$)[b]	35 (88%)	1 (3%)	1 (3%)	10 (25%)	1 (3%)
Nwoya ($n = 31$)	30 (98%)	0	0	7 (23%)	0
Pakwach ($n = 38$)	23 (61%)	12 (32%)	6 (16%)	17 (45%)	19 (50%)
Total	88	13	7	34	20

[a] The other fish species are mainly large fish species such as angara (Alestes baremoze), tiger fish (Hydrocynus forskahlii), Elephant snout fish (Mormyrus) and Omel (African catfish)

[b]Greater Gulu refers to the administrative areas of Gulu city and rural Gulu district

Table 2 Children's weekly fish consumption (times/week) by district

Location	N	Percentile							Mean	SD
		5th	10th	25th	50th	75th	90th	95th		
Overall	263	1	1	2	3	3	5.5	7	3.2	2.2
Greater Gulu	92	1	1	2	3	5.5	7	7	3.8	2.9
Nwoya	87	1	1	2	3	3	3.3	5.5	2.6	1.2
Pakwach	84	1	1	2	3	5.5	5.5	5.5	3.2	2.0

4 Results

4.1 Children's fish consumption patterns

Children from 104 (95%) of the surveyed households consumed fish during the seven-day recall period. Across the three districts, fish consumption averaged three meals per week, although the species consumed differed markedly by district (Tables 1 and 2).

The analyzed household sample ($n = 109$) included 742 individuals: 303 adults (≥ 18 years), 60% of whom were married, and 439 children (< 18 years). The mean household size was 6.8 members. Among the children, 280 (130 males, 150 females) were aged 6–14 years, a typical age for primary school. Nearly all children in this age group (91%) attended school. Of these, 124 (95%) were male, and 130 (87%) were female.

Mukene[1] dominated fish consumption in Greater Gulu (88%) and Nwoya (98%), whereas children in Pakwach consumed a more diverse range of species, including Nile tilapia (45%), Nile perch (16%), and several other species (50%), reflecting greater proximity to active fisheries.

Children in Greater Gulu recorded the highest mean weekly fish consumption despite living farther from fisheries, suggesting that market access and availability of processed small fish may compensate for geographic distance from production areas.

Household survey data indicate that 99 (39%) primary school-age children ate at school (either home-packed meals or school meals). Of these, 42 (42.4%) brought home-packed meals. Across the three study districts, not all schools provided meals, and those that did served a varying proportion of children.

The following section examines how factors in the external and personal domains of the fish-related food environment (see Fig. 3) explain the above-described patterns in children's fish consumption.

[1] In markets across Gulu, Nwoya, and Pakwach, small fish, about the size of muziri, are normally called "mukene". Traders and buyers often do not distinguish between muziri and mukene, referring to both simply as "mukene". While mukene, harvested from Lakes Kyoga and Victoria, is sold in these markets, muziri – endemic to Lake Albert – is also traded there as "mukene".

4.2 External domain factors and children's fish consumption

4.2.1 Availability

Fish availability varied according to proximity to fisheries, market infrastructure, and seasonality. In this study, 'availability' includes fish supply from fishers, markets, mobile vendors (including those around campus), roadside traders, and from the school environment (SFPs, home-packed meals, school tuck shops). It also considers how seasonality and regulations impact fish supply.

While children in Pakwach ate fish sourced from both fishers and markets, those in the more remote Nwoya and Gulu districts relied solely on market sources (see Table 3). In rural communities far from district markets, households often bought fish from door-to-door traders and home- or roadside-sellers.

Fish were usually available year-round, though seasonal variations occurred. Participants from nine out of eleven gender-mixed FGDs linked high rainfall to increased catches, while a few (participants in 4 out of 11) noted that certain species were more abundant in the dry season. Some participants linked the availability of mukene to the moon cycle.

Fish availability increased consumption, as a man from urban Gulu explained, "… when water levels are high during the rainy season, there is much fish in supply, so most households consume fish, even those we would say are poor." Although increased fish availability was perceived to lead to reduced fish prices (in the food environment's external domain, see Fig. 3), income (in the personal domain) remained crucial in determining fish consumption, as we shall elaborate later.

Fish availability was also linked to fishing regulations. Participants from all gender-mixed FGDs thought that enforcing regulations reduced fish availability because military officials seized and destroyed undersized fish, along with illegal gear like nets and boats (see also [59]). As juvenile fish are affordable, they are frequently consumed in the same way as other small fish. Therefore, the strict enforcement of regulations resulted in reduced fish supply, as an FDG participant explained, "… if you are living close to the lakes, you can see that they burn confiscated fish. That means the quantity reaching consumers also goes down." A government official added that some confiscated fish are distributed to public schools and hospitals.

Schools had a limited supply of fish, and SFPs mainly provided carbohydrate-rich, plant-based foods such as thin maize porridge for mid-morning meals or a typical lunch of posho (stiff maize porridge) with beans (see Fig. 4). In other cases, cassava bread, a stiff porridge from cassava flour, was served instead of posho. Access depended on parental contributions, as one FGD participant said, "Because your parent has not paid, you do not get food."

Fish such as Nile perch, considered affordable and meaty, were served. Children who could afford deep-fried ragoogi (*Brycinus nurse*, a small pelagic fish) from local retailers added it to their school lunches.

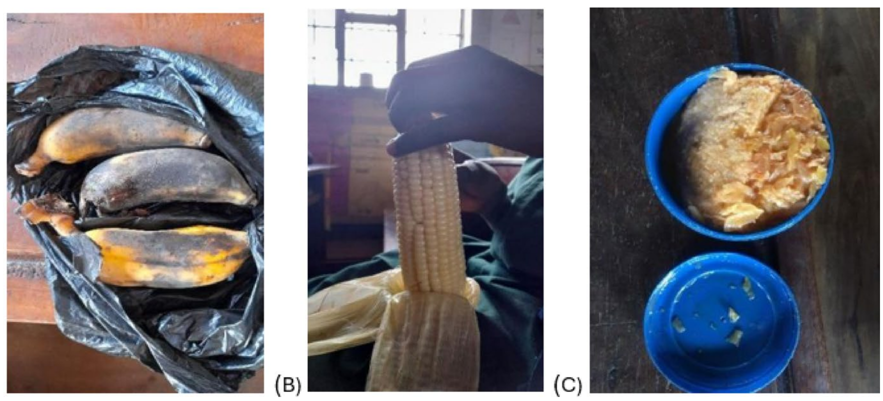
As mentioned earlier (see page 13), our survey indicates that 42.4% of children who ate at school brought packed meals. FGD participants noted that nursery school children were more likely to carry packed meals than primary school children. Additionally, children with packed meals often came from families with surplus food or lived far from school. Packed items included cooked dishes (e.g., posho with cabbage, beans, and small fish), uncooked foods (e.g., bananas; Fig. 5), and ready-to-eat snacks purchased from the community.

Table 3 Sources of fish consumed at home by children in the sampled households ($n=104$)

Fish sources	District		
	Greater Gulu (%)	Nwoya (%)	Pakwach (%)
Market in the community	81	85	71.2
Market in the district	20	17	0
River Nile	0	0	15
Lake Albert	0	0	14
Gift	0	0	0.6

The numbers are percentages

Fig. 4 Children being served school lunches of posho with beans. Photo: First author



(A) (B) (C)

Fig. 5 Examples of home-packed meals. **A** Bananas, **B** boiled maize, **C** posho with cabbage. Photo: First author

Besides packed meals and SFPs, children relied on vendors in and around schools who sold doughnuts, "chapattis" (unleavened whole-wheat flatbread), fried cassava, "anyoya" (boiled beans and maize), or similar plant-based foods.

Children who lacked meals (from SFP, packed meals, money for snacks) went home to eat, shared meals with friends, picked fruit from homes near the schools, or went hungry. Children in grades 3–7, who often spent 8–10 h at school, were among those who went hungry and likely only had meals at home.

Together, these findings indicate that geographical proximity to fisheries influenced fish availability, but market networks and mobile vendors played a critical role in maintaining fish access for communities located farther from production areas.

4.2.2 Prices

Fish prices varied, with larger species costing more than smaller ones. Small fish were sold by volume in various units (e.g., about 300-400 ml containers), such as by piece, in plastic basins, in cups of various non-standardized sizes (see Fig. 6), or small plastic sachets weighing a few grams.

Deep-fried ragoogi, eaten as a snack, was sold by the piece. An official in Pakwach estimated that 10 pieces cost 1,000 shillings ($0.30), comparable to a big cup of dried ragoogi. According to our November 2024 field observations in markets, mukene of about 100 g (Fig. 6B and C) cost 1,000 shillings ($0.30) across districts. In Pakwach, a cup of mukene cost about $0.30 during high catch periods, but in lean seasons prices rose to 2,000 shillings ($0.60), or 500 shillings ($0.15) for smaller quantities. Mukene was considered affordable because a

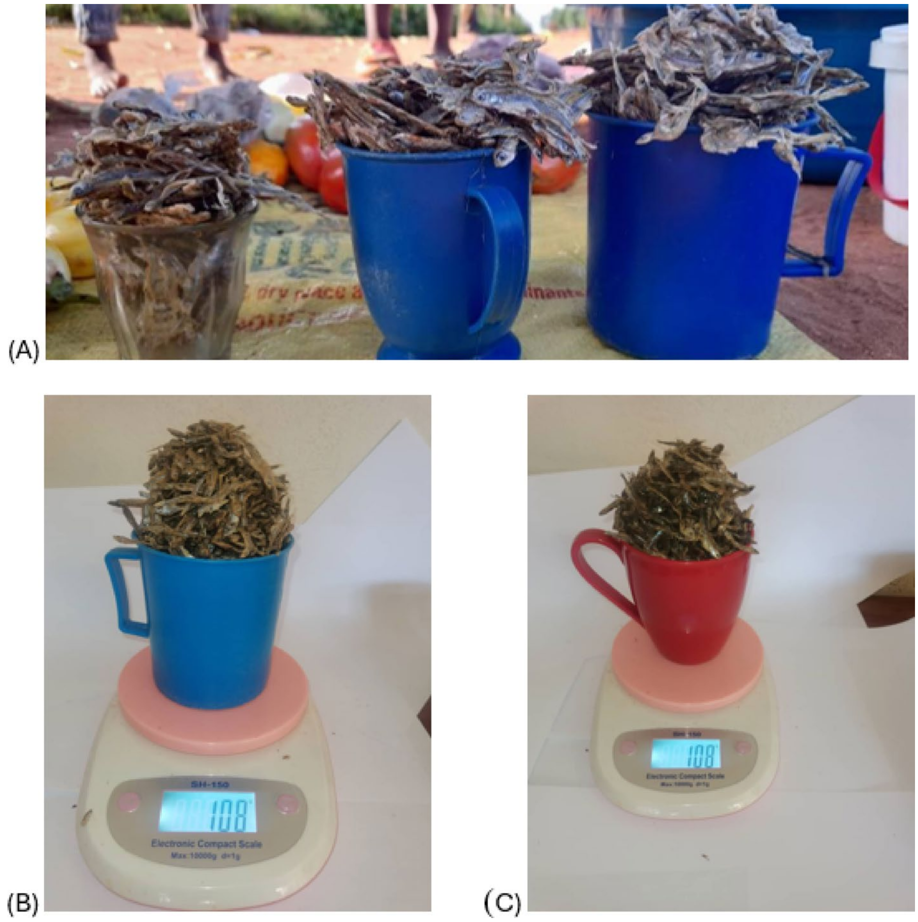


Fig. 6 Different-sized non-standardized measuring cups used as units for selling mukene. **A** Measuring cups at a roadside market in Pakwach with the glass cup (far left) used when the supply of mukene is low, **B** and **C** Weight of mukene in some non-standardized cups Photo: First author, Ampa Eve Akongo & Mary Namwanje

small quantity of 1–3 cups (Fig. 6A (blue cups), B & C), or 100–300 g, could feed a family on a low budget. These small fish were sold in small, low-priced quantities, making them accessible for children's diets.

4.2.3 Vendor and product properties

Vendor and product properties include types of food vendors, operating hours, services (e.g., measuring, bulk-breaking, and packaging), and product attributes (e.g., quality, processing, and shelf life) (see Fig. 3).

Markets differed in size, operating hours, and services. Major district markets, such as Gulu Main Market and Panyimur fish market (see Fig. 2), served as both wholesale and retail outlets. These markets offered more fish species than the community markets. Children, particularly from remote farming communities in Nwoya and Gulu, consumed fish purchased from these local markets and door-to-door traders. In some communities, residents preferred retailers who sold small fish from home during the farming season, while others relied on these retailers and roadside traders, especially on non-market days. These retailers, sourcing fish from major markets, also sold cooking ingredients such as tomatoes for small-fish dishes, making them a convenient one-stop shop. However, markets remained a preferred source because fish was cheaper and available in larger quantities.

Children from fishing households were likely to eat fish from the daily catch, and non-fishing households near fisheries bought whole, fresh fish directly from fishers rather than at higher prices from middlemen and retailers. Traders sourcing from fishers sold either whole or processed fish by the piece. Some communities along the River Nile faced competition for fish supply from traders with direct links to fishers. Door-to-door retailers who sourced from fishers supplied households that could not or preferred not to buy directly from fishers. These mobile retailers, along with the local community markets, were important for supplying mukene in some communities distant from fisheries.

Traders in markets distant from fisheries (e.g., in Anaka and Gulu, see Fig. 2) mainly sold processed fish (smoked, salted, and sun-dried). Fresh Nile tilapia was sold in Gulu, but its freshness varied. Children near Lake Albert and the River Nile ate fish from markets and landing sites, accessing large, fresh species processed at home or bought preprocessed (see Table 3). A fisher noted, “We mainly eat fresh fish. Smoking or sun-drying fish is like wasting time for people living along the lake.” Mukene was sold dried across districts, while ragoogi, mostly in Pakwach, was typically retailed fried or sun-dried.

Fish quality was assessed using indicators like appearance, color, rottenness, and the presence of maggots and impurities, including sand and snail shells. FGD participants living near Lake Albert viewed fresh fish as good quality (fresh), though a few noted that freshness deteriorated immediately after capture, likely due to the lack of cold storage in Pakwach. Mukene quality varied, with poor quality fish appearing discolored and often containing debris such as sand and snail shells. However, quality issues did not seem to affect consumption, and those distant from fisheries sometimes considered mukene better than large species. A man from Gulu city stated,

“You might find omel (African catfish) looking nice at the market, but they are spoiled and have maggots in them. So, such things make me decide to buy [dried] mukene because it is easier to get good quality mukene”.

Bigger fish were more likely to spoil than smaller ones of the same species because big and fleshy fish are harder to preserve; they take longer to dry and require more fuel to smoke.

4.2.4 Marketing and regulations

Marketing and regulations encompass promotional information, advertising, sponsorship, and policy regulations related to food sales; here, it refers to promoting the nutritional benefits of fish [60].

While mukene consumption was associated with poverty, its nutritional value was recognized and likely influenced children’s consumption. Health centers and non-profit organizations such as the Agency for Accelerated Regional Development (AFARD)[2] were among those that informed women, mothers of young children, and communities about mukene’s health benefits. These promotions motivated some people near fisheries to incorporate them into their diets. As a fisher in Pakwach illustrates, “Generally, people do not like small fish! … We eat [them] because of what we heard about what they do to the body. …I started eating mukene because we were told it builds the body.”

However, rather than preference, the availability and price of fish were the most decisive factors influencing children’s fish consumption in the external domain. Below, we examine the personal domain of children’s fish-related food environment.

4.3 Personal domain factors and children’s fish consumption

4.3.1 Accessibility

Accessibility, in this context, refers to distance to fisheries and markets, and daily mobility (see Fig. 3).

Sun-dried mukene, the most ubiquitous fish, was often sold within walking distance of residents at homes, roadsides, and community markets. In Pakwach, especially along the River Nile (fisheries), residents either walked to nearby landing sites or traveled farther to buy fresh fish directly from fishers. In addition, traders sold fresh fish door-to-door to households along roads and near fisheries, as well as at markets. Generally, fish, especially small, dried fish, were made accessible through community markets and door-to-door sellers, while living near active fisheries facilitated children’s access to large fresh species.

[2] https://afard.net/.

Table 4 Illustration based on FGD discussions of how seasonal agricultural income and children's peak fish consumption coincide

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural income												
Peak fish consumption												

White months indicate lean seasons, while colored months indicate agricultural income and peak fish consumption

4.3.2 Affordability

Affordability – defined as purchasing power, the ability to buy fish for household consumption and to support SFPs (see Fig. 3) – was the key driver of children's fish consumption.

Affordability significantly influenced the type and size of fish children ate across districts, with small pelagic fish, notably mukene, considered the most affordable due to their low prices. Residents near landing sites, where large fish were more available but inaccessible to the poor, were similarly impacted: "…we are eating mukene here because of poverty; otherwise, those who have money do not buy mukene for their households, because we are near the water body."

Although some FGD participants linked the frequency and type of fish consumption to its availability, affordability was decisive. A male participant from Pakwach noted, "… sometimes people lack money, implying that they cannot buy [fish] even when fish is available." Peak fish consumption varied, but generally coincided with seasonal agricultural incomes, as most FGD participants were farmers (Table 4). During this period, they were able to buy and eat more of the larger species. However, in lean agricultural seasons (depicted as 'white months' in Table 4), a few FGD participants reported eating beans, vegetables, and mukene.

Since mukene is versatile and used in many local dishes, mixing small amounts with vegetables can nourish a family on a limited budget.

Parents' financial or resource constraints limited children's participation in SFPs. Meals were primarily offered to children whose parents contributed money or in-kind. A man from rural Gulu noted, "… the [school feeding] program is good, but not everyone can afford it." Parents had to choose between funding SFPs and feeding their families, given seasonal fluctuations in agricultural income and the financial burden of dependency. Households near schools, therefore, often preferred that children go home for meals rather than contribute to SFPs. Overall, affordability emerged as the dominant personal food environment factor determining both the frequency and species of fish consumed by children.

4.3.3 Convenience

Convenience includes the time and effort required to prepare, cook, and eat food, as well as the time allocated for accomplishing various activities. In this study, convenience encompassed the effort required to source, prepare, share, and eat the fish (see Fig. 3).

Home-based fish vendors, mostly in rural communities, were located within walking distance; thus, less effort was required to source small fish. Like the roadside fish traders, home-based fish vendors remained open when markets were closed, becoming key sources of fish.

Furthermore, small, dried fish like mukene require less effort to prepare than other small fish, such as sun-dried ragoogi, which is slightly larger and bonier.

Participants in all five women-only FGDs stated that all parts of sun-dried mukene are edible; therefore, it is mainly cooked whole (i.e., with head, bones, and viscera). However, four of the five FGDs reported that they remove the bony parts of ragoogi, including heads, bones, viscera, and tails, before cooking it.

Consequently, mukene are easier to eat because of their soft bones and can easily be shared among family members. Unlike larger species, they require only small amounts mixed with local ingredients for a meal.

4.3.4 Desirability

Desirability factors, such as attitude, preferences, tastes, and culture, shaped children's fish consumption across all districts. This study examined fish preferences, attitudes toward small fish, and fish processing forms and taste (see Fig. 3).

Participants in nine of the 11 gender-mixed FGDs primarily referred to 'big' fish species when discussing fish, indicating their preferences for these fish. In their view, fish meant species other than mukene. A male participant from rural Gulu describes, "Since fish is a little scarce here and fish traders are also few, fish is expensive. So, someone who does not have the ability in terms of money cannot eat fish but eats mukene." Similarly, a female participant from urban Nwoya illustrates, "When there is no fish in the market, I personally opt for mukene when I feel I want to eat fish." These perceptions shaped children's fish consumption. Moreover, people preferred larger fleshy species like Nile perch and those with fewer bones.

Fish species such as tilapia (large species) and nangnang (small species) were preferred over others, partly because of their taste and aroma. Mukene was tasty and used to flavor local vegetable dishes. Although residents near landing sites preferred fresh fish, they also used processing methods to enhance their taste. A fisher near Lake Albert mentioned, "…because of [the] desire to change the taste, or when somebody is tired of eating fresh [fish], he or she can smoke or sun-dry the fish, then eat [it]."

Attitudes also influenced small-fish consumption. Children near Lake Albert and the Nile fisheries had access to and ate a wider variety of fish. Consequently, their parents preferred not to eat small fish. One participant noted, "…we who live near the water body, we don't like small fish." Those living near fisheries regarded small fish as food for the poor. This attitude, combined with the availability of big fish, could explain why children in Pakwach ate the least mukene (see Table 1). The ease of sourcing, preparing, and sharing small dried fish increased their suitability for routine household meals.

5 Discussion

Our findings demonstrate how the external and personal domains of the food environment jointly shape children's fish consumption in Northern Uganda, with most children consuming fish at home approximately three (3) times per week.

Affordability (parents' income) was the key decisive factor influencing children's fish consumption, often limiting them to the nutrient-dense small fish. This finding supports our conceptual framework by demonstrating that although fish may be physically available in markets, household purchasing power ultimately determines whether children consume fish and which species they eat. These fish are often more affordable, and when eaten whole, provide more nutrients than larger species [2, 37, 62].

Markets are crucial for children's fish consumption across all districts, supporting existing research on the importance of markets for fish availability (Hapke et al., 2023; FAO et al., 2023). Our findings further demonstrate that market networks compensate for geographical distance from fisheries by maintaining access to processed small fish in inland communities. On the other hand, proximity to fisheries enhances the consumption of diverse species through direct purchases from fishers and various marketing channels, including retailers who bring fish to the consumer's doorstep. Their role in linking consumers with markets and fisheries is vital. Thus, proximity to fisheries and markets increases access to a variety of fish species [47], although 'big' fish remain inaccessible to low-income individuals, even when they reside close to fisheries.

In Uganda, the high cost of large fish contributes to low fish consumption [18]. Fish prices vary, with larger species costing more [61]. Small, dried fish like mukene are affordable, versatile, and easy to incorporate into children's diets. Long-distance traders help ensure overall access to fish in markets, whereas door-to-door retailers play a key distributional role in providing low-income groups and households in communities located remotely from fisheries and markets with access to small, sun-dried fish. Furthermore, availability makes small fish the preferred choice for individuals with limited incomes, offering a cheaper alternative to fish and meat. Together, these findings indicate that affordability mediates the relationship between availability and consumption, making it the dominant personal food environment factor influencing children's fish intake. Our findings support research indicating that people with low incomes tend to buy inexpensive fish [8, 28, 56].

Seasonal variation affects fish catches [46] and market availability, while rain hampers drying, especially for mukene, resulting in postharvest losses [28]. Consistent with our findings, seasonal fluctuations influenced market availability rather than completely restricting fish access because traders redistributed fish across districts. Additionally, fishing regulations aimed at conserving large species limit the capture and utilization of abundant and productive small pelagic fish [30, 32]. This can affect food and nutrition security, given Uganda's low per capita fish consumption [18].

While seasonal variations are mitigated for those farther from fisheries, issues like poor processing (e.g., incomplete drying) and storage lead to post-harvest losses, compromising the quality and safety of fish in the market [9, 42]. Our findings on vendor properties indicate that processed fish is crucial for children living far from fisheries, and that market linkages like community markets, roadside traders, and door-to-door sellers are vital for delivering fish. This illustrates the importance of informal market actors in sustaining access to nutritious foods within local food systems. Fish quality, particularly, largely affects fish consumption among children who mainly rely on processed fish. These findings highlight that product quality is an important component of the external food environment because it influences both consumer confidence and children's willingness to consume fish [38].

Our results on marketing, regulations, and desirability align with research showing that sharing promotional information and taste preferences influences fish consumption [7, 35, 61]. A recent study in Uganda found that increased small fish consumption was partly due to an awareness campaign on their nutritional benefits developed by NutriFish [18]. This is particularly crucial for those living near active fisheries, with negative attitudes towards small fish, and in areas where larger fish species are common. These communities process fish to alter its taste, resulting in distinct, desirable flavors. Sundried mukene is used as an ingredient to enhance the taste of local dishes. Beyond physical availability, these findings demonstrate that knowledge, preferences, and cultural perceptions shape children's fish consumption, highlighting the interaction between external and personal food environment domains. Though seen as fish for the poor (Bavinck et al., 2023), small nutrient-dense fish are vital for children in northern Uganda. Typically sun-dried, small fish are an energy-efficient food source [32] supplying the children with essential nutrients, supporting their food security, and helping to achieve SDG 2 (Zero Hunger). These findings reinforce the potential contribution of affordable small fish to nutrition-sensitive food systems that support Sustainable Development Goal 2 (Zero Hunger), particularly among school-age children in low-income settings. Since low household incomes restrict children's participation in school meal programs [51], our findings indicate that there is potential to strengthen school-feeding regulations and to enrich school meals with small fish products.

School meals primarily consist of carbohydrate- and plant-based food, often lacking essential micronutrients crucial for children's growth [43, 52]. Our findings therefore identify school feeding as a critical intervention point within the food environment where the nutritional quality of meals could be improved using locally available small fish products. Most children spend long hours at school, often without food, hampering learning. Given its unique nutritional qualities and relative affordability compared to other animal-source proteins, small fish – whether fried or powdered and mixed into stews [5, 48] – can serve as a food-based strategy to improve diets and increase dietary diversity through school meals. Fish are believed to contain the meat factor, a substance that enhances the absorption of micronutrients from plant-based foods [13]. School feeding regulations and national school meal guidelines could shape the food environment to improve children's nutritional outcomes [27]. Overall, the study demonstrates that children's fish consumption is determined by interactions between external food environment factors (availability, market access, prices, vendors, and regulations) and personal factors (affordability, accessibility, convenience, and desirability). Applying Turner's food environment framework provided a comprehensive explanation of why nutritionally valuable small fish remain central to children's diets despite economic and geographical constraints.

This study had some limitations. First, using convenience sampling may have favored accessible participants with similar characteristics, potentially biasing the findings. Secondly, it used a cross-sectional design and a non-representative sample, so the findings are not generalizable. These constraints also limit the ability to infer causality or assess long-term eating patterns. In addition, the FFQ was administered only once, which may not capture seasonal shifts in children's intake. Finally, the study relied on parent-reported fish intake, which is susceptible to recall bias. Further research should focus on establishing children's habitual fish consumption across seasons. Despite these limitations, the study contributes to food environment research and provides insight into the factors influencing children's consumption of the environmentally friendly processed small fish.

6 Conclusion

This study demonstrates how interactions between the external and personal domains of the food environment shape children's consumption of small fish in Northern Uganda, with affordability emerging as the dominant factor influencing fish intake.

Our analysis of the factors shaping children's food environment revealed that schools are the arena where fish are missing. We conclude that the absence of accessible, nutrient-dense small fish in school meals is a missed opportunity for reducing malnutrition, especially among children farther from active fisheries.

The school food environment can impact children's diets and increase the availability and accessibility of nutrient-dense small fish in school meals and home-packed meals by strengthening national school feeding guidelines and district-level school feeding regulations to support the inclusion of affordable, nutrient-dense small fish in school meals where locally available. Additionally, this can also be achieved by collaborating with partners, such as scientists specializing in small fish, to design cost-effective interventions targeting low-income households.

Since children develop eating habits that may persist in adulthood, creating food environments that promote healthy choices is important. These choices can impact health outcomes for future generations. Furthermore, children need nutrients to support their growth and development at different stages. Therefore, school-age children – often overlooked in nutrition interventions – should be considered key targets for improving health and nutrition outcomes through improved food environments.

Our study not only addresses gaps in understanding factors affecting school-age children's fish consumption but also extends discussions on the influence of proximity to fisheries on fish consumption [47, 53] by providing granular information on how and where communities access fish and species consumed.

Although our research focuses on a particular demographic in Uganda, its findings serve as a baseline for informing hypotheses for future studies on factors influencing children's fish consumption. These findings extend the application of Turner's food environment framework by demonstrating its usefulness for understanding children's diets in fisheries-dependent, resource-constrained settings where school feeding programs are expanding. Applying Turner's food environment framework revealed that improving children's diets requires interventions addressing both external factors (availability, markets, regulations) and personal factors (affordability, convenience, and desirability), rather than focusing solely on food supply. These findings have broader relevance for low- and middle-income countries seeking to strengthen nutrition-sensitive and sustainable school feeding programs through the inclusion of locally available, nutrient-dense small fish. More broadly, the findings provide evidence for designing nutrition-sensitive and sustainable school food systems in low- and middle-income countries by leveraging locally available small fish to improve dietary quality among school-age children.

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Data availability Data availability statementThe household survey and FGD data that support this study's findings are part of an ongoing project and are not yet publicly available. However, anonymized data are available on reasonable request from the authors.

Declarations

Ethics approval and consent to participate In Uganda, the protocol was approved by Makerere University's Social Sciences Research and Ethics Committee (MAKSS REC) (MAKSSREC 07.2023.694) in accordance with the guidelines and regulations set by the Uganda National Council for Science and Technology (UNCST), which also provided additional approval (SS2301ES). In Norway, we complied with the legal requirements under Article 30 of the Personal Data Act, protocols for processing activities, and the University of Bergen guidelines for processing personal data. Accordingly, the project is registered with the University of Bergen System for Risk and Compliance (RETTE). Before data collection, written informed consent was obtained from all household survey participants and from two members of each focus group. Participants were informed of the study's purpose and could withdraw at any time without providing a reason. Participants' identities have been anonymized.

Competing interests The authors declare no competing interests.

Consent for publication Not applicable.

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