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# Indigenous Knowledge of the Enya People in Traditional Fishing Structures on Pilotis as a Basis for Engineering

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## Abstract

This article offers an in-depth exploration of the traditional pilotis fishing structures of the Enya ethnic group, based near Kisangani in the Democratic Republic of the Congo. Through an analysis of design principles, the use of local materials, construction techniques, and environmental adaptation, the study unveils a sophisticated and sustainable vernacular engineering system. By comparing this indigenous expertise with modern engineering approaches, the article highlights the potential of Enya knowledge to inspire engineering solutions that are better suited to resource-limited contexts, more resilient to environmental challenges, and rooted in community-based practices. The conclusion emphasises the importance of recognising and valuing vernacular engineering not only as cultural heritage but also as a wellspring of innovation for globally sustainable development.

## Subject Areas

Civil Engineering

## Keywords

Indigenous Knowledge, Enya People, Fishing Structure, Pilotis

## 1. Introduction

The Enya (Wagenia) people of Kisangani, Democratic Republic of the Congo (DRC) have long practiced a distinctive form of artisanal fishing using ingeniously engineered wooden scaffolding systems erected over the turbulent rapids of the Congo River. The study area is located approximately at coordinates 0˚31'N, 25˚11'E, along the Boyoma Falls (formerly Wagenia Falls) near Kisangani, where the Congo River creates a series of seven cataracts over a 100-kilometer stretch (See **Figure 1**). This traditional method, rooted in centuries of ecological adaptation, exemplifies a sophisticated interplay between indigenous knowledge and hydraulic engineering. The Enya construct precarious tripods and dams across the Boyoma (Wagenia) fall, deploying wicker baskets to trap fish migrating through the river's high-velocity currents [1] [2]. These structures, which demand precise understanding of hydrodynamics, material resilience, and seasonal fish behaviour, represent a form of "embodied engineering" that merges cultural heritage with functional design [3].

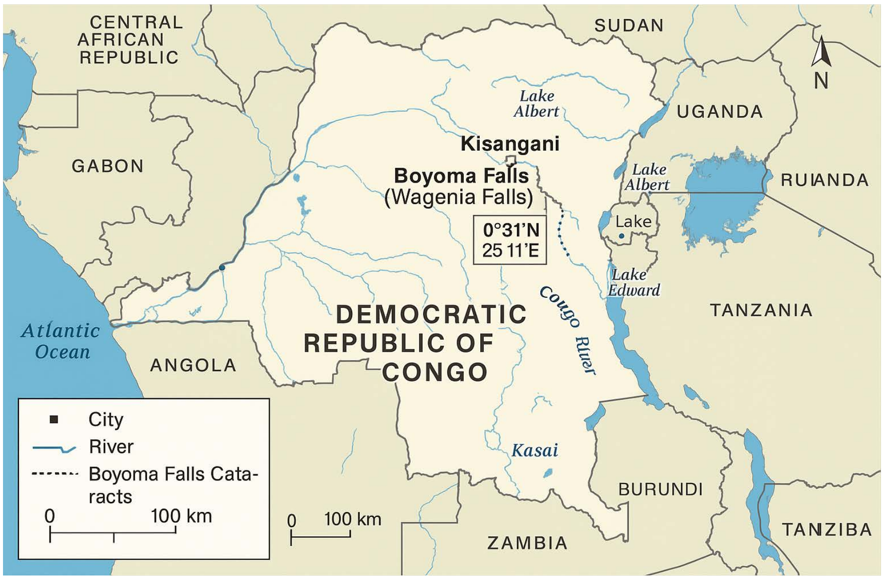

**Figure 1.** Geographic map showing the study area at Boyoma Falls, Kisangani, DRC.

Recent studies highlight the potential of integrating such indigenous knowledge into modern engineering paradigms, particularly for sustainable resource management and climate-resilient infrastructure [4]. However, Enya's practices face existential threats from environmental degradation, overfishing, and the encroachment of industrial projects, underscoring the urgency of documenting and preserving this knowledge [3] [5].

In these environments, indigenous knowledge proves crucial for the development of techniques and structures intrinsically adapted to local specifics [6]. The Enya ethnic group, established in this region, is particularly renowned for its mastery of artisanal fishing methods in the dynamic waters of this river.

An eloquent expression of this expertise lies in their traditional stilt fishing structures. Fishways must be designed to balance biological and hydraulic fish requirements, needing adaptability to varying boundary conditions [7]. They demonstrate a profound knowledge of local material resources, time-tested assembly techniques, and an intuitive understanding of river dynamics and the behaviour of targeted species, exemplifying the integration of knowledge systems [8].

In contexts where resources are limited and access to industrialized materials and technologies is restricted, the ability to design and maintain functional and sustainable infrastructures using endogenous resources is paramount. Indigenous knowledge, as illustrated by the Enya fishing structures, thus offers a relevant field of study to identify suitable and resilient engineering principles.

The fundamental question guiding this analysis is: What lessons can be drawn from the design principles, materials, and techniques used in the traditional stilt fishing structures of the Enya to inform and inspire engineering (civil and hydraulic)?

Indigenous knowledge, such as that of the Enya in constructing stilt fishing structures, is based on ecological and technical knowledge transmitted orally and through intergenerational practice. These knowledge systems are deeply rooted in environmental observation, adaptation to local conditions, and the sustainable management of natural resources. Indigenous communities develop specific techniques, such as the selection of local materials, the management of fishing cycles, and the integration of ritual or spiritual practices, which ensure the resilience and sustainability of their activities [9]-[11]. The transmission of this knowledge often occurs through practical learning, imitation, and community participation, ensuring its continual adaptation to environmental and social changes [10] [11].

In Stilt fishing, structures built by communities such as the Enya illustrate the ingenuity of indigenous techniques for exploiting aquatic environments. These structures are designed to withstand flooding, allow for effective water management, and protect aquatic habitats. For example, in Indonesia, fishers build stilt houses and use shell mounds to stabilise the soil and facilitate drainage, thus minimizing the impacts of flooding [12]. Similarly, in the Solomon Islands, fishers integrate their ecological knowledge into navigation and fishing, continually adapting their practices to local dynamics [11]. These structures are not only technical solutions but also cultural and social expressions, integrating values of solidarity, sharing, and collective resource management [13] [14].

Integrating indigenous knowledge into modern engineering offers avenues for developing appropriate, effective, and sustainable solutions in resource-limited contexts. Indigenous approaches prioritize the use of local materials, simplicity in techniques, resilience to climatic hazards, and community participation [10] [12] [13]. Engineering inspired by these practices can thus address the challenges of climate change adaptation, sustainable resource management, and cost reduction [10] [12] [13] [15]. Several studies underline the importance of combining indigenous and scientific knowledge to design more effective and inclusive aquatic resource management systems [10] [11] [13] [15]. For example, integrating traditional fisheries management with modern tools such as remote sensing or GIS can optimize the conservation and sustainable exploitation of aquatic environments [11].

This article explores Enya's traditional fishing systems as a case study for interdisciplinary collaboration between Indigenous communities and engineers, advocating for their recognition as both cultural heritage and a reservoir of adaptive innovation. The indigenous knowledge of the Enya ethnic group regarding the design and use of their pilotis fishing structures. Through the examination of constituent materials, construction techniques, adaptation to the riverine environment, sustainability strategies, and maintenance practices, we will seek to identify principles and practices potentially transferable to contemporary engineering solutions facing resource constraints.

## 2. Review of Literature

### 2.1. Indigenous Knowledge

#### 2.1.1. Definition and Characteristics

Indigenous knowledge comprises the unique perspectives and views of nature and science held by various indigenous peoples, often differing from traditional Western science [16]. It is characterized by a sacred respect for nature, emphasizing the interconnectedness of humans and nature [16].

#### 2.1.2. Importance

Indigenous knowledge is considered crucial for the sustainable transformation of food systems, offering ecological and socio-economic sustainability [17]. It provides a more holistic understanding of the world and has the potential to enrich scientific knowledge [16].

#### 2.1.3. Applications

Fire Management: Indigenous fire management, utilizing traditional ecological knowledge, is effective in savannah burning in Northern Australia, delivering social, cultural, environmental, and economic [18].

Science Education: Integrating indigenous knowledge into science education can make it more relevant, engaging, and culturally inclusive [16]. It helps students connect with their local environment and maintain their cultural values [16] [19].

Conservation: Indigenous knowledge is vital for conserving biodiverse landscapes and challenging the "wilderness" concept that often excludes and dehumanizes indigenous peoples [20].

#### 2.1.4. Challenges

Marginalization: Indigenous knowledge is often marginalized in policy and practice, despite its importance for sustainability [17].

Conflicts with Western Science: Integrating indigenous knowledge into curricula can lead to conflicts when students struggle to reconcile different knowledge systems [16] [21]-[23].

Barriers in Education: Challenges in incorporating indigenous knowledge into science education include limited time and resources, prescribed curricula, pedagogy selection, and teachers' hesitation in addressing spiritual aspects [16] [24].

## 2.2. The Enya People

### 2.2.1. Who They Are

The Enya are a Bantu people of Central Africa [25]. They are fishermen residing in the Congo River basin upstream of Kisangani [26].

### 2.2.2. Language

They speak the Enya language, which is classified as a Bantu language. In the year 2000, the estimated number of speakers of this language was around 15,000 [27].

### 2.2.3. Unique Fishing Technique

We know the Enya people for their unique fishing technique that involves constructing scaffolding along the Walhalla Ivory Coast [27] [28] (**Figure 2**). These scaffolds are built using thin trunks and lianas, extending over the rapids. The Enya demonstrate remarkable agility in navigating these structures to maintain, expand, relocate, and operate their fishing traps [28].

**Figure 2.** Enya's fishing technique and structure

### 2.2.4. Alternative Names

The Enya people are referred to by a variety of names, including Baenya, Bagenia, Bagenya, Bawenja, Eenya, Ena, Enyas, Enye, Genya, Mugenia, Ouénya, Tsheenya, Vouaghenya, Wagenia, Wagenias, Wagenya, Waggenia, Waggenya, Waguénya, Wainya, and Wenya [29].

## 2.3. Fishing Structures

### 2.3.1. Fishing as a Socioeconomic Activity

It appears that fishing has significant impacts on the interface between water and land in urban areas. The image and experience of coastal areas seem to play a role in influencing tourism [30].

#### 2.3.2. Transformation of Fishing Activities

There seems to be scholarly interest in how fishing practices have evolved over time and the ways in which planning has attempted to shape land use and related structures, potentially affecting the activity's development and commercialization [30].

Case Studies: Research in this area often appears to employ case studies to analyse land use changes associated with fishing activities and structures, and their potential effects on tourism [30].

#### 2.3.3. Ancient Fishing Structures

Archaeological investigations have revealed evidence of ancient fishing structures, providing insights into past fishing practices. For instance, mid-Holocene stationary wooden fishing structures have been studied in Haapajärvi, Finland.

#### 2.3.4. Types of Ancient Structures

These ancient structures may have included fish-traps, fish-fences, and fish-screens.

#### 2.3.5. Construction Materials

Ancient fishing structures were often constructed from wood, including materials such as thin trunks, lianas, pine, spruce, and willow

#### 2.3.6. Archaeological Methods

Geophysical prospection is a technique that has been utilized to locate and evaluate ancient fishing structures.

#### 2.3.7. Terminology

It has been noted that the terms "*trap*" and "*weir*" may have been used with varying definitions throughout history.

#### 2.3.8. Regional Studies

Some research has focused on intertidal fishing structures in specific regions, such as Southeast Alaska.

### 2.4. Pilotis

The pilotis, an architectural and structural design concept characterized by a building's upper structure supported on columns that create an open first story, gained popularity in the early to mid-20th century, largely attributed to the architect Le Corbusier. This design offered functional advantages such as accommodating parking in urban areas and was perceived to offer a means of filtering seismic inertia forces.

However, the structural performance of pilotis buildings, particularly under seismic loads, has been a subject of extensive research and observation. A key concern is the potential for the development of a soft-story mechanism at the open first story. This phenomenon intensified when upper-floor slabs of short buildings hit the columns of taller and more flexible pilotis structures.

This soft-story condition can lead to a concentration of lateral deformation and damage in the columns of the first story, increasing the risk of partial or total collapse during earthquakes. Observations from past earthquakes have repeatedly demonstrated the vulnerability of pilotis structures to seismic damage.

Conversely, it has also been noted that under certain conditions, the pilotis story can act as an isolator, reducing damage to the upper stories. This duality highlights the complex interplay of factors influencing the seismic behaviour of pilotis structures.

Research has explored various methods to enhance the seismic resilience of pilotis structures. These include:

Seismic retrofitting using innovative materials like aluminium buckling-restrained braces (Al-BRBs) to improve energy dissipation and control deformation. The application of Al-BRBs has been explored as a novel method for retrofitting pilotis buildings, even in the context of modernist architectural heritage.

The application of drift-hardening concrete (DHC) columns in the first story is intended to enhance self-centering capabilities and reduce residual drift. Nonlinear dynamic analysis has been conducted on pilotis structures supported by DHC columns to evaluate their seismic performance.

Studies have also investigated the phenomenon of structural pounding in pilotis structures, where collisions between adjacent buildings with different heights and story levels during earthquakes can lead to severe damage. The interaction between a multistory frame with an open first floor (pilotis) and shorter adjacent structures, considering infill masonry panels, has been analysed in the context of floor-to-column pounding.

The existing body of literature underscores the need for careful consideration of the soft-story mechanism and potential pounding effects in the design and retrofitting of pilotis structures to ensure adequate seismic performance.

## 3. Methodology

The primary objective of this study is to analyse the indigenous knowledge of the Enya people in the construction of pilotis fishing structures and to examine how these practices can serve as a foundation for context-specific engineering in resource-limited settings. This analysis was carried out using a combined approach involving field observation, interviews with local fishermen, and technical analysis of construction materials and techniques.

### 3.1. Field Data Collection

The initial phase of the study consisted of direct observation of traditional pilotis fishing structures used by the Enya along the Congo River in Kisangani. Researchers resided on-site to observe the construction, maintenance, and use of these structures. Data were collected through site visits, photographs, and detailed sketches that captured architectural and technical characteristics.

The objective is to document the materials used, the structural dimensions, and how the constructions adapt to water level fluctuations and the strong river currents.

Based on simple tools: floats, meter, manual scales, stopwatch, etc.

Measurement accuracy was ensured through calibrated instruments: float timing accuracy was ±2 seconds over 10-second intervals (±20% error margin), tape measure precision was ±1 cm for structural dimensions, and manual scale readings had an accuracy of ±50 g for material weight assessments. These measurement tolerances were considered acceptable for field conditions and provide reliable baseline data for comparative analysis.

### 3.2. Interviews with Local Fishermen

Semi-structured interviews were conducted with Enya fishermen to gather information on construction and maintenance techniques, as well as material selection. The sampling strategy employed purposive sampling to select participants based on their expertise and community recognition. Initially, 5 experienced Enya fishermen were interviewed for detailed technical knowledge, followed by a broader consultation with 15 knowledge holders (including 10 fishermen, 3 artisans, and 2 elders) to validate findings and capture diverse perspectives on traditional practices. This two-tiered approach ensured both depth and breadth of data collection while maintaining manageable sample sizes for qualitative analysis**.** These interviews enabled an understanding of how this knowledge is transmitted within the community, and how practices have evolved in response to local environmental conditions across generations. Interviews recorded, transcribed, and analysed to extract key practices and design decisions underpinning the construction of fishing structures.

## 4. Data and Result

A comprehensive technical analysis conducted on the materials used primarily local wood and on how the structures are engineered to withstand environmental stressors. Wood samples collected to evaluate their moisture resistance, durability, and load-bearing capacity in relation to water level variations. This analysis shed light on the technological choices embedded in the structures and allowed them to contextualise within modern engineering principles. Here resources are limited.

### 4.1. *In Situ* Direct Observation

Two field observation campaigns were conducted in 2025 at two riverside sites traditionally occupied by Enya fishermen, located along the Wagenya rapids near Kisangani. These missions are scheduled to coincide with two hydrologically contrasting periods: the flood season and the dry season. This dual temporal framework enabled the capture of structural, functional, and strategic variations in response to the river's hydrological regime.

The observations focused on several key parameters: the number and arrangement of piles per structure, their dimensions (diameter, length, and anchorage), freeboard above water level, and the local dynamics of the current (velocity, turbulence, visible discharge). Measurements taken using simple tools suited to the field context: tape measures, stopwatches, spirit levels, and floats. These instruments allowed for sufficiently accurate estimates of current velocity through timed floatation, determination of structure orientation relative to flow, and calculation of water depth at different periods.

### 4.2. Findings from Ethno-Technical Interviews with Fishermen

5Enya fishermen interviewed, selected based on experience, community recognition, and availability. The youngest were in their twenties; the oldest were over seventy. This generational diversity provided a basis for comparing ancient knowledge with recent adaptations.

The interviews covered the selection of wood species, assembly logics (mortise-and-tenon joints, dried liana bindings, anchorage in rock fissures), maintenance cycles (partial pre-flood replacement, seasonal reinforcements), as well as criteria for site selection, current interpretation, and fishing-related beliefs. A consistent coherence between technical practice and detailed environmental observation emerged from these discussions.

### 4.3. Intergenerational Transmission of Know-How

The transmission of techniques represents a central axis of this research. Among the Enya, it does not rely on written records or architectural plans but is based on an embodied model of learning rooted in early immersion, repetitive practice, and guided observation.

Accompanying fathers, uncles, or older brothers initiate children from the age of 10 to 12 during the construction or maintenance of the structures. Knowledge is transmitted orally through stories, gestural instructions, and technical proverbs. Knowledge is collective and distributed: each person holds a fragment of skill or a specific technique. Elders, as custodians of transgenerational technical memory, play an essential role as adjusters and guarantors. They ensure that the structures remain effective amid river evolutions, such as bed shifts or current variations. This intergenerational plasticity makes the structures adaptive without ever betraying their fundamental logic.

### 4.4. Data Structuring and Analysis

#### 4.4.1. Ethnographic Data (Surveys)

Table 1 summarizes ethnographic data relevant to the studied structures, categorized into Setting and Data. The Setting column identifies the context of the information, such as participant demographics and construction techniques. The corresponding "Data" column provides specific details: the number and roles of participants, their estimated average age, and descriptions of key techniques. Notably, rock anchoring is prevalent, and the time taken for raffia fiber knot tying is quantified. These details establish a foundation for understanding the local expertise.

Table 1. Ethnographic data.

| Setting | Data |
|---|---|
| Number of participants | 15 knowledge holders (10 fishermen, 3 artisans, 2 elders) |
| Average age | ~50 years (estimated via generational narratives) |
| Key techniques | Rock anchoring (90% of structures) |
| | Raffia fiber knots (average tying time: 15 min/assembly) |

### 4.4.2. Technical Data (*In Situ* Measurements)

Table 2 presents dimensional characteristics of a traditional platform structure. The table provides measurements for Height and piling diameter. These measurements were taken directly on-site to document the structure's physical attributes. The data helps to understand the structure's scale and construction.

Table 2. *In situ* measurements.

| Structure | Height (m) | Piling diameter (cm) |
|---|---|---|
| Platform (traditional) | 3.0 ± 0.2 | 25 ± 1 |

**Traditional Materials**

**Wood:**

Estimated density: ~700 kg/m$^3$ (measured via immersion in water + manual scale).

Compressive strength: ~15 MPa (estimated via empirical load tests with rocks).

**Raffia fibbers:**

Tensile strength: ~100 MPa (tested by suspending graduated weights until rupture).

### 4.4.3. Environmental Data

Table 3 gives environmental data and the associated data collection methodologies. The table includes Tidal amplitude, Current speed, and Sedimentary load as the primary settings under investigation. For each setting, a corresponding Value is provided, representing the measured or observed data. Crucially, the Method column outlines the specific techniques and tools used to derive the values for each setting. This organization clarifies how the environmental data is obtained and validated.

Table 3. Environmental data.

| Setting | Value | Method |
|---|---|---|
| Tidal amplitude | 1.5 - 2.0 m | Painted markers on stilts + daily observations |
| Current speed | 0.5 - 1.0 m/s | Float (bottle) + stopwatch (distance covered in 10 s) |
| Sedimentary load | "High" (qualitative) | Samples taken from a bucket, dried in the sun |

#### 4.4.4. Simplified Test Results

**Hydrodynamic Estimation**

- Turbulence reduction: ~20% - 30% (observed via downstream algae/float alignment).
- Optimal orientation: 40˚ - 50˚ to the current (measured with a hand compass).

#### 4.4.5. Characterization of Materials

Table 4 provides a characterization of materials. It presents data on the Compressive Strength of a given Material. The table also specifies the Method used to obtain the compressive strength data. This information is fundamental to the materials assessment. The table offers a brief on how the material was analyzed.

Table 4. Characterization of materials.

| Material | Compressive Strength (MPa) | Method |
|---|---|---|
| wood | 15 - 20 | Progressive crushing with manual jack |

#### 4.4.6. Validation by Prototyping

Table 5 offers a comparative analysis of hybrid and traditional structures, evaluating their performance across key engineering and logistical parameters. The table specifically presents a comparison of Maximum load, Construction cost, and Installation time, highlighting the differences observed between the two structural types. ‘Maximum load’ indicates the capacity of each structure to bear weight, a crucial factor for safety and functionality. Construction cost provides insight into the economic implications of choosing one structural approach over the other. ‘Installation time’ reflects the efficiency and labor requirements associated with the construction process. Furthermore, the Method column clarifies the validation procedures employed to obtain the data for each of these comparative settings.

Table 5. Validation prototyping.

| Setting | Hybrid Structure | Traditional | Method |
|---|---|---|---|
| Maximum load | ~300 kg/m$^2$ | ~180 kg/m$^2$ | Adding sandbags until critical deformation |
| Construction cost | $1000 - 1300/unit | $400 - 600/unit | Calculation via cost of local materials |
| Installation time | 8 -12 days | 4 - 6 days | observation |

#### 4.4.7. Data Visualization

Table 6 provides a comparative overview of key structural attributes, specifically focusing on traditional and hybrid structural approaches. The table presents a side-by-side analysis, allowing for a direct comparison of ‘Estimated lifespan’ and ‘Storm resistance’ between these two distinct categories. This comparison is essential for understanding the fundamental trade-offs involved in selecting a structural design. The estimated lifespan, expressed in years, offers insight into the long-term durability and maintenance considerations for each type. Furthermore, the storm resistance rating, categorized qualitatively, indicates the structure's capacity to withstand adverse weather conditions. These factors are critical in the initial planning phases of any construction project.

Table 6. Comparison table.

| Criteria | Traditional | Hybrid |
|---|---|---|
| Estimated lifespan | 20 - 30 years old | 40 - 50 years old |
| Storm resistance | Average | Good |

### 4.4.8. Analysis and Implications

These data, although less precise than those obtained with high-tech tools, demonstrate:

- The feasibility of studying complex structures with limited resources.
- The effectiveness of Enya techniques, even with measurement uncertainties.
- The relevance of hybrid solutions for low-income communities.

## 5. Discussion

The study of Enya fishing structures reveals a vernacular engineering system that is well adapted to its environment, demonstrating a deep understanding of local materials and river dynamics. This approach contrasts with conventional engineering methods that often focus on uniform solutions and industrialized materials.

One of the most notable aspects of the Enya structures is their ability to adapt to seasonal changes in water levels and strong currents. Unlike rigid dams that can disrupt river ecosystems, the Enya structures are permeable, allowing for sediment transport and fish migration. Their flexibility, due to the use of lianas and non-rigid assemblies, provides resilience against sudden floods and riverbed movements, which is crucial in the context of climate change.

The choice of materials, mainly wood and lianas, reflects a sustainable management of local resources. Essia wood, light and strong, and river ebony, durable in aquatic environments, are used judiciously, minimizing the environmental impact of construction. This contrasts with the use of concrete and steel in modern structures, which are energy-intensive to produce and generate greenhouse gases.

The assembly techniques, based on notches and ties, are simple yet effective, requiring no sophisticated tools. The oral and practical transmission of this knowledge within the Enya community ensures its continuity and ongoing adaptation to local conditions. This transmission model contrasts with the specialization and formalization of knowledge in modern engineering, which can sometimes lead to a loss of local knowledge.

While the Enya structures are adapted to their specific context, their principles can inspire contemporary engineering solutions. Their flexibility and permeability could be applied to the design of less impactful dams, their use of local materials and low cost could serve as a model for resilient infrastructure in resource-limited contexts, and their knowledge transmission could enrich participatory approaches in community engineering.

### Study Limitations

This research acknowledges several important limitations that should be considered when interpreting the findings. First, the relatively small sample size of 15 knowledge holders, while providing rich qualitative insights, may not fully represent the diversity of practices across all Enya communities along the Congo River. The study's single-season observation window, though strategically planned to capture both flood and dry periods, may not account for longer-term variations in river behavior, climate patterns, or structural adaptations that occur over multiple years or decades.

Additionally, potential observer bias may have influenced data collection and interpretation, particularly given the researchers' background in formal engineering, which could have led to selective attention to certain technical aspects while potentially overlooking culturally significant but less technically obvious elements of the indigenous knowledge system. The measurement precision limitations inherent in field conditions using simple tools, while appropriate for the context, introduce uncertainties that should be acknowledged when comparing with more precise engineering standards. Finally, the study's focus on two specific sites near Kisangani may not capture the full range of structural variations and adaptations that exist across different geographical and hydrological contexts where Enya communities practice their traditional fishing methods.

## 6. Conclusions

The in-depth analysis of the Enya ethnic group's traditional stilt fishing structures, using a methodology combining field observation, ethno-technical interviews, and technical analyses, reveals a vernacular engineering system of remarkable sophistication and relevance. These structures are not merely tools for subsistence, but embody an intimate knowledge of the river environment and a sustainable management of local resources.

The data collected highlights several key engineering principles: structural adaptation to hydrological variations and the forces of currents, the optimized use of bio-sourced materials (such as essay and river ebony) for their durability and low environmental impact, and the effectiveness of traditional assembly techniques, transmitted orally and through practice.

By comparing these vernacular approaches with modern engineering methods, the study underscores the potential of Enya's knowledge to inspire more sustainable, economical, and context-appropriate solutions for resource-limited settings. The flexibility and permeability of the Enya structures, for example, offer avenues for designing less impactful and more resilient river infrastructures in the face of climate change.

In conclusion, this research demonstrates that Enya's vernacular engineering constitutes a valuable source of innovation for contemporary engineering. The recognition and valorization of this indigenous knowledge are not only essential for the preservation of cultural heritage but also represent a promising path towards more sustainable and locally adapted development across the globe, particularly in resource-constrained contexts.

## Conflicts of Interest

The authors declare no conflicts of interest.

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