Baseline Information of the Manobo Tribe's Amphibious Community Infrastructures Constructed Using the Indigenous Knowledge and Practices in Agusan Marsh, Philippines

Arc Siede Cabugsa[1, 4*], Joel Opon[2, 3] and Raquel O. Masalig[3]
[1]Graduate School of Engineering
[2]Center for Structural Engineering and Informatics
[3]Department of Civil Engineering and Technology
Mindanao State University – Iligan Institute of Technology
Iligan City, 9200 Philippines
[*]*arcsiede.cabugsa@g.msuiit.edu.ph*

[4]Civil Engineering Department
Xavier University – Ateneo de Cagayan
Cagayan de Oro City, 9000 Philippines

Date received: August 10, 2024
Revision accepted: November 27, 2024

Abstract

The Agusan Marsh in the Philippines has long been home to the indigenous Manobo people, who have developed unique amphibious houses designed to adapt to the region's fluctuating water levels. Despite their cultural importance, scientific studies on these structures still need to be expanded. This paper aims to provide baseline information on the construction of these amphibious houses, emphasizing the materials, structural components, and construction practices that enable them to thrive in the marsh's challenging environment. A rapid visual survey (RVS) and key informant interviews were conducted on 35 houses, most of which were built after 2012, with some dating back to the late 1990s. The RVS identified key materials such as bundled bamboo floaters, Mambog timber for framing, and nipa leaves or galvanized iron sheets for roofing. Essential structural components were also documented, including the Batangan (girders), Sakbat (floor beams), and Gal-gal (floor joists), which are critical for the stability of these houses. The study further highlighted the strategic placement of houses near trees to enhance stability and reduce environmental risks. The findings emphasize the value of indigenous knowledge in addressing environmental challenges, mainly through material selection and design flexibility, and offer insights into constructing resilient infrastructure.

Keywords: Agusan Marsh, amphibious houses, indigenous knowledge, Indigenous Manobo people, rapid visual survey

1. Introduction

Across the globe, an estimated 300 million indigenous people (IP) reside in over 90 countries, with approximately 70% located in Asia (Amnesty International, 2022). According to the Asian Century Institute (2014), Myanmar has the highest percentage of ethnic populations, with 68% of its population belonging to various ethnic groups. In China, minority groups comprise approximately 8.5% of the total population, while in India, they comprise about 8.2%. In Japan, the indigenous Ainu population ranges from 20,000 to 30,000, primarily residing on the northern island of Hokkaido, with around 5,000 in the greater Kanto region. In Mexico, the indigenous population is estimated to range between 20 and 70 million. In Vietnam, ethnic groups constitute 14% of the total population. In the Philippines, there are over 17 million indigenous people. Most of these communities reside on Mindanao Island, which accounts for 61% of the country's indigenous population (United Nations Development Programme, 2023). In northern Luzon, 33% of the indigenous population can be found, with smaller groups also present in the Visayas region.

The knowledge, innovation, and practices of indigenous peoples play a vital role in biodiversity conservation within a country (Global Environment Facility, 2019). For instance, the Indigenous Peoples of Myanmar have worked tirelessly to protect and sustain the largest areas of contiguous rainforest in mainland Southeast Asia (ICCA Consortium, 2021). In Indonesia, indigenous communities emphasize preserving cultural heritage and traditional wisdom as key to their conservation efforts (Fitrianggraeni *et al.*, 2023). Similarly, in the Philippines, the significance of indigenous knowledge is enshrined in Republic Act 8371, known as the "Indigenous Peoples Rights Act" (IPRA) of 1997. This legislation recognizes the capacity of indigenous peoples to manage their ancestral domains within the framework of national unity and development. Under IPRA, indigenous communities, such as the Manobo Tribe, are entrusted with safeguarding their ancestral domains, exemplified by their stewardship of the Agusan Marsh Wildlife Sanctuary (AMWS) in the Philippines.

The AMWS, commonly called Agusan Marsh, is a wetland and protected area in Agusan del Sur Province, Mindanao, Philippines. The marsh has approximately 14,835.989 hectares and is home to various biological and indigenous species. It plays a crucial role in providing natural flood control and water filtration for low-lying communities along the Agusan River, such as Butuan City. The indigenous Manobo people serve as guardians of the marsh, protecting the area from "unwelcome" visitors and pledging to safeguard both their community and the environment from trespassers (Gibbens, 2021; Tupas, 2010).

The Manobo tribe in the Agusan Marsh cultivates corn during the dry season. However, during the rainy season, typically between December and March, floods can reach as high as ten (10) meters, forcing them to shift from farming to fishing as their main livelihood (Lagsa, 2015). In response to the changing seasons and landscape, several Manobo families have adapted to the fluctuating waters of the marsh by building amphibious houses and using *bawto* (wooden canoes) for transportation. These amphibious houses, mainly constructed from bamboo and other locally available materials, demonstrate the Manobo Tribe's indigenous knowledge in adapting to the challenges of life in the marsh.

The structure of the amphibious houses is made up of bundled bamboo arranged in a raft-like system, allowing them to float up and down with the floodwaters during the rainy season. The number of bamboo poles in each bundle varies depending on the house size (Lagsa, 2015). In addition, *Mambog*, a type of wood sourced from the Agusan Marsh itself and other local materials, is used to construct these floating houses' floors, walls, columns, and roof frames. The houses are tethered to each other and nearby trees using ropes to provide extra stability and strength.

The Manobo community passes down indigenous knowledge through spoken communication, enabling the construction of their amphibious infrastructure in the marsh across generations. Indigenous knowledge is unwritten, developed through the life experiences of local people, their advanced understanding of, and deep connection to, their environment, and is transmitted orally through generations (Haque, 2018). However, there is a lack of documentation regarding the indigenous construction practices of the Manobo people, putting this knowledge at risk of being lost. Moreover, the absence of local standards for constructing these amphibious houses could introduce risks, leaving the Manobo people vulnerable to environmental hazards. For example, during Super Typhoon Rai (locally known as Odette), several floating houses were overwhelmed with debris, overstressing them and causing them to sink. Similarly, in Lake Tempe, Indonesia, floating homes collapse when struck by mounds of vegetation such as water hyacinths, lotus flowers, and water grass (Yusran *et al*., 2018). Despite these risks, anecdotal evidence suggests that most of the amphibious houses built by the Manobo Tribe in Agusan Marsh have withstood environmental hazards in the area for decades.

The resilience of amphibious houses in Agusan Marsh offers valuable engineering insights for developing similar infrastructures (Dalisay, 2014; Jerez, 2021; Yahn, 2021). However, there needs to be more documented research on these structures. Previous studies have emphasized the importance of preserving indigenous knowledge to address global challenges. For example, indigenous housing practices like the Limas houses in Indonesia were designed to adapt to tidal floods using local materials and elevated structures (Hapsari and Hardayani, 2023). Similarly, in Africa, studies on indigenous climate-resilient housing have focused on using locally sourced materials and techniques for flood adaptation (Ajayi and Mafongoya, 2017). The 32nd Session of the Intergovernmental Panel on Climate Change (IPCC) recognizes that “indigenous and traditional knowledge may prove useful for understanding the potential for certain adaptation strategies that are cost-effective” ([IPCC], 2010). This highlights the importance of documenting indigenous construction techniques, such as those in Agusan Marsh, as they provide valuable insights for integrating traditional wisdom into modern frameworks. Such integration could greatly enhance infrastructure resilience and sustainability. Thus, this paper aims to establish baseline information on the amphibious houses in Agusan Marsh, Philippines, which are built using the indigenous knowledge of the Manobo people.

2. Methodology

2.1 Research Design

The first phase of the research (Figure 1) involved securing a permit from the Protected Area Management Board (PAMB) through Resolution No. 2023-030 to conduct research in the target study area. This phase also included obtaining consent from the Tribal Chieftain and the endorsement of the Local Government Unit (LGU) of the Municipality of Lapaz, Agusan del Sur where the study site is located.

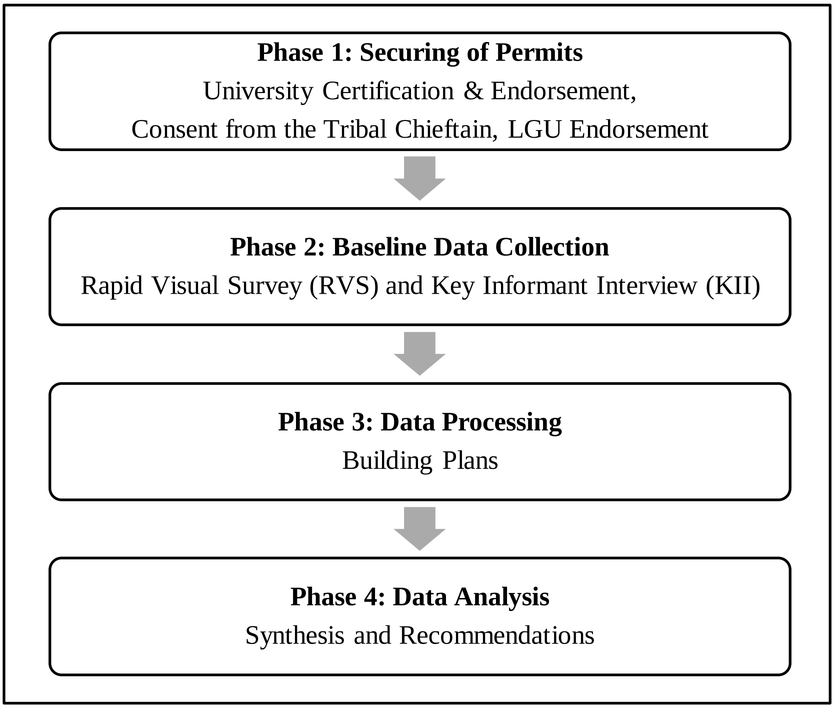

Figure 1. Research design

In Phase 2, data collection was conducted through rapid visual surveys (RVS), as detailed in Section 2.3. This data collection method aimed to gather general information on the geometry, structure, construction methodology, and hazards related to the amphibious houses in the marsh. Additionally, a key informant interview was conducted to obtain detailed insights into the construction process of these houses. In Phase 3, the baseline information was processed to catalog the building details of the amphibious infrastructure. Finally, in Phase 4, a comparative evaluation of the cataloged data was carried out to examine common practices and construction techniques used in building these houses.

2.2 Site Location and Survey Sample

The study focuses on the amphibious houses and community infrastructures of the indigenous Manobo people located in Lake Mambagongon within the Agusan Marsh (see Figure 2), with geographical coordinates of 8˚15'18.5"N and 125˚52'1.2"E. This study area was selected based on a recommendation from the Protected Area Management Board (PAMB) Office, the governing body responsible for managing the Agusan Marsh Wildlife Sanctuary under Republic Act No. 11038. The Manobo community residing in Lake Mambagongon is led by a Chieftain, locally referred to as *Datu*. The majority of families in this community are related to the *Datu* to some degree. According to the Barangay Health Unit, there are a total of 63 households in Lake Mambagongon. It is important to note that some households do not have their own homes but reside with their patriarch in the same amphibious house.

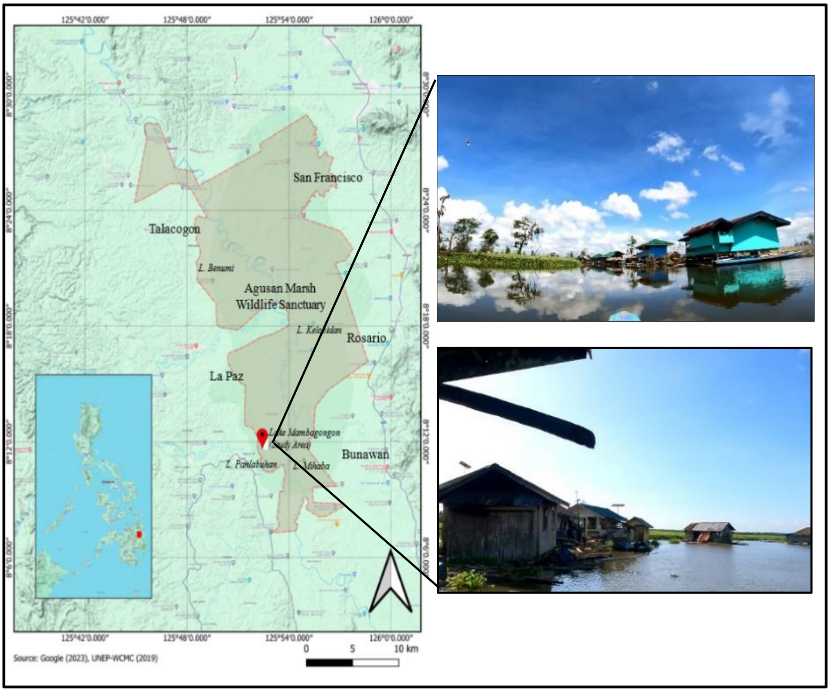

Figure 2. Location map of the Lake Mambagongon Manobo community

The study surveyed 70 percent of the amphibious infrastructures in the Lake Mambagongon community. This sample size was chosen due to the observed homogeneity in the community's construction and geometry of the houses. When selecting the amphibious houses or infrastructure for the survey, priority was given to buildings with special or mixed occupancy, the oldest and newest structures, and the largest buildings in terms of dimensions. Additional factors considered included the number of occupants, variations in the types of materials used, workmanship, structural systems, and the function or occupancy of the buildings.

2.3 Collection of Baseline Information by RVS

An RVS was employed to gather sufficient information on how a structure performs under the effects of hazards without the need for building plans or documentation on materials used in construction (Nassirpour, 2019). The RVS provides a simple, functional, and cost-effective vulnerability assessment of existing buildings (D'Ayala *et al*., 2016; Kumar *et al*., 2016). Additionally, it allows for the documentation of materials used in construction. In this research, the RVS was valuable in providing a foundation for infrastructure evaluation and enhancement while documenting the Manobo construction methods, as there are no written records of their construction practices. The RVS was divided into four sections: general information, building information, structural information, and structural condition. General information about the building includes its name, location, construction year, occupancy configuration, and any hazards present in the area. Building information helps visualize the surveyed structure by collecting geometric data. Structural information provides details on the materials used, while structural condition assesses the quality or status of the amphibious Manobo infrastructure. The baseline data collected through RVS were used to evaluate the structural capacity of the amphibious infrastructure and the forces acting upon it.

The RVS was conducted on April 18-19, 2024, during the summer, when most amphibious houses in Lake Mambagongon were afloat on shallow water, exposing significant land masses in the marsh due to low water levels. The survey was supported by the Protected Area Management Office – Agusan Marsh Wildlife Sanctuary (PAMO-AMWS) for entry permissions and coordinated with the *Datu*. The Municipal Tourism Office of LGU-La Paz facilitated access to the community. The target number of amphibious houses was divided across two days. The team measured various parts of the houses as part of the RVS entries and conducted key informant interviews.

2.4 Key Informant Interview

The study relied on key informant interviews (KII) to gather insights from individuals with firsthand experience in constructing amphibious infrastructure and managing interventions against natural hazards (Elmendorf and Luloff, 2006). Participants included a diverse range of stakeholders, such as community leaders (including the *Datu*) and indigenous (IP) builders, to provide a comprehensive understanding of the amphibious house construction process. A total of six KIIs were conducted, with participation being entirely voluntary. Informed consent was obtained through signed consent forms, and permission to record the interviews was requested and granted by all participants.

The KII was conducted in a structured yet flexible format to explore the Manobo community's construction techniques, hazard exposure, disaster history, and resilience strategies in response to threats like floods and strong winds. Each interview lasted approximately 30 minutes. The set of questions examined the Manobo's indigenous construction methods, covering material selection criteria, sourcing, assembly techniques, and potential improvements to amphibious structures. Collectively, these inquiries aimed to build a comprehensive understanding of local knowledge, practices, and strategies for resilient infrastructure in Lake Mambagongon, Agusan Marsh.

3. Results and Discussion

3.1 Results of Rapid Visual Survey

3.1.1 General and Building Information

A total of 35 amphibious infrastructures were surveyed using RVS over a period of two days within Lake Mambagongon. A typical structural plan of an amphibious house, based on the survey data, is illustrated in Figure 3. Among these structures, two served as community meeting areas and as a church gathering place, and one functioned as a variety store (locally known as sari-sari) – a small convenience store. Most buildings in Lake Mambagongon were constructed after 2012 (see Figure 4), with four built in the early 2000s. The oldest structure was the house of the local Datu, constructed in 1998. The local government unit of Lapaz and the PAMO-AMWS currently lack records, such as building permits, to verify the construction dates of the Manobo community's amphibious houses in Lake Mambagongon. Consequently, the construction dates were determined based on information gathered through key informant interviews, compensating for the absence of government data. Eight amphibious structures had indeterminate build years and were marked as unknown in Figure 4.

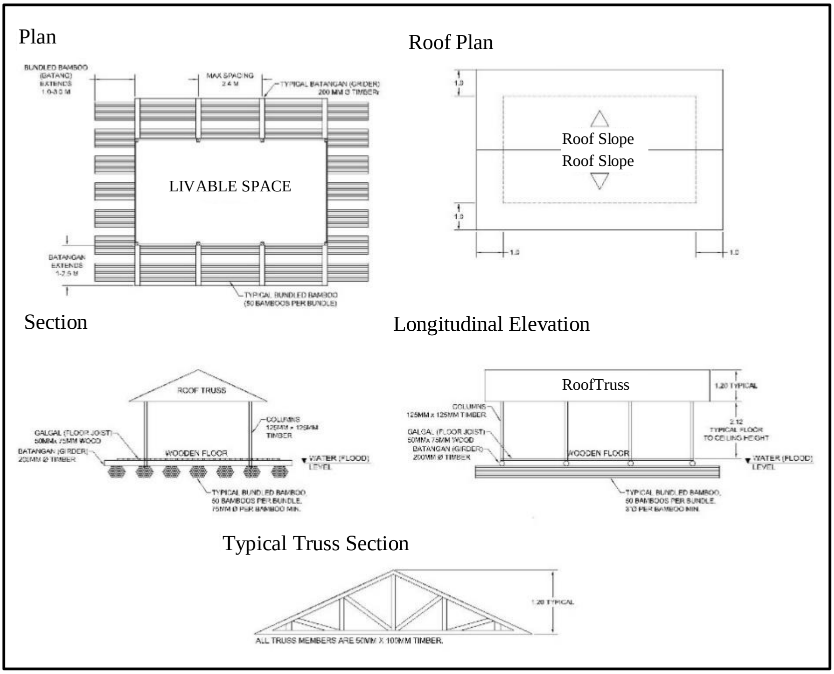

Figure 3. Typical structural plan of an amphibious house

Despite the variation in construction years among the surveyed amphibious structures, there was a notable similarity in materials, structural systems, functions, workmanship, and technology. This indicates the shared indigenous knowledge within the community regarding material selection and construction methods. All surveyed amphibious structures utilize bundled bamboo floaters and timber for floor beams, girders, joists, columns, and roof framing. Most amphibious houses have a single floor level, although five structures (about 14%) are elevated by at least 3 feet from the girder level. According to the KII, some owners chose to elevate their amphibious houses primarily for ventilation and cooling. Elevated houses allow air to circulate freely beneath the structure, providing natural cooling, which is crucial in the hot and humid climate of the Marsh. This design helps lower indoor temperatures and improves overall comfort.

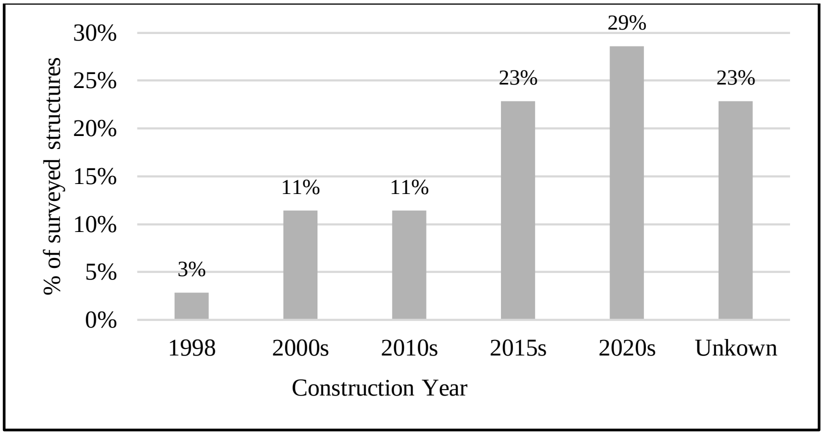

Figure 4. Construction year of surveyed structures

From the RVS, most amphibious structures feature an open-plan layout, typically square or rectangular, with minimal internal partitions made of plywood or curtains for dividers. Floor areas range from 22 to 35 square meters, with roof heights ranging from 2.1 to 3.0 meters. Common features include a balcony, common area, bedrooms, and kitchen, with occupancy varying from 3 to 7 people, depending on family size. There is also an amphibious classroom in the lake, which can accommodate up to 48 students and 4 teachers. The RVS also revealed signs of decay common to the amphibious houses. For instance, bamboos were observed to manifest cracks or splits, especially at the nodes, with roughening and dulling as oils were lost, and rotting, making them soft in areas where water accumulated. Timber also showed signs of deterioration, including cracks parallel to the grain, discoloration, and rotting due to prolonged exposure to moisture, turning the wood soft or crumbly.

The RVS also revealed that the Manobo people strategically position their floating houses in shallow lake areas near trees for stability and protection from environmental forces. Furthermore, the KII clarified that trees serve as natural anchors, preventing drift caused by currents or strong winds, while shallow waters reduce wave impact. When floating, the amphibious house is able to rotate around anchor points, orienting itself to minimize wind resistance. This dynamic positioning not only leverages tree cover for disaster protection but also creates a temperate microenvironment with shade that helps regulate indoor temperatures. Additionally, it ensures easy access to land, while the view from the house is periodically altered, offering varied visual experiences over time (Naing *et al*., 2029). However, water hyacinths, abundant in the area, pose a significant hazard as they can entangle the houses, impede water flow, and increase the risk of debris buildup and rot. The additional weight from these invasive plants may lead to instability or damage, making vigilant management of water hyacinth proliferation essential for maintaining stability and preserving traditional living practices.

3.1.2 Basic Structural Components of the Amphibious Structures

Three primary components of amphibious houses relevant to stability are the floaters (Figure 5), foundation framing (Figure 6), and house structure. In the Agusan Marsh, local communities use *Bambusa blumeana* (locally known as *kauayan-tinik*) bamboo to create floating platforms called "*batang*" (see Figure 5). Each *batang* is made by bundling untreated bamboo culms with a minimum diameter of 75 mm and lengths ranging from 9 to 12 meters, as revealed by the RVS. The bamboos are sourced from nearby areas and tied together with nylon rope. Bamboo's natural buoyancy and strength make it ideal for supporting structures in the marsh's challenging environment (Espiloy, 1992; FPRDI, 2022; Salzer *et al*., 2017).

The foundation framing (Figure 6) in amphibious houses typically consists of girders, floor framing, and beams. The girders, locally known as *Batangan*, play a crucial role in stabilizing and connecting the livable space to the bundled bamboo floaters. These *Batangan* are usually made from Mambog (*Annona muricata*), a soft to medium wood abundant in Lake Mambagongon, and are sawn into lumber with a cross-sectional area of 200 mm by 200 mm, with varying lengths depending on the house's dimensions. The *Batangan* extends 1-2.5 meters on both sides of the house to serve as outriggers for stability. The oldest structure in the community, however, uses washed-up hard timber, a rare and durable hardwood found in the more remote areas of the marsh. The use of this type of wood, which enhances the structure's longevity, reflects the community's rich indigenous knowledge of the marsh's resources. The number of *Batangan* used in a structure varies depending on the size of the house, with typical spacing set at 2.40 meters. Centrally located within this framing system is the *Sakbat* (floor beam), which supports the entire floor system by transferring loads to the *Batangan*. The floor beams generally have a cross-sectional area of 50 mm by 150 mm and are spaced between 900 mm and 1800 mm on center.

Figure 5. Floater using bundled bamboo (*Batang*)

Figure 6. Structural components of the foundation framing and the house section

In addition to the *Batangan* and *Sakbat*, the *Gal-gal* (floor joist) directly supports the floor decking, helping prevent deflection. These joists are usually made from the same timber as the *Batangan* and *Sakbat*, with cross-sectional dimensions of 50 mm by 75 mm and spaced 300 mm to 400 mm apart. The structure of a floating house in the Manobo community also includes columns, roof framing, and various coverings that protect occupants from environmental elements. The timber used for these structural components is generally consistent across all surveyed amphibious structures, ensuring uniformity and ease of construction. This consistency also reflects the shared indigenous knowledge within the community regarding the construction of amphibious infrastructure. A typical floating Manobo house features 6 to 10 timber columns, each with a cross-sectional area of 100 mm by 100 mm, spaced no more than 2.40 meters apart. These columns support the roof framing, which is usually made from locally sourced timber. The roof is commonly covered with thatch or corrugated iron sheets, depending on availability and preference, to protect the occupants from rain and sun. The overall structural system demonstrates a deep understanding of local materials, environmental challenges, and efficient construction techniques passed down through generations.

The roof framing consists of timbers with a cross-sectional area of 50 mm by 100 mm that connect to the columns. The roof design typically features a box gable configuration, which is effective in shedding rainwater and providing an additional roof cavity that helps regulate indoor temperatures. The roof coverings are commonly made from nipa leaves or galvanized iron sheets, depending on the household's financial capacity. Nipa leaves are traditional, sustainable, and provide good insulation, while galvanized iron sheets offer enhanced durability and protection against severe weather conditions. The wall coverings of the amphibious houses are primarily made of plywood. In some cases, traditional materials such as woven bamboo (*amakan*) (Figure 7) or newer materials like fiber cement boards are used. These materials offer varying degrees of insulation, durability, and aesthetic appeal, reflecting the adaptability of the Manobo people to available resources and environmental conditions.

Figure 7. Woven bamboo (*Amakan*) wall covering

Regular visual inspections, combined with the traditional expertise of the Manobo people, are essential for preserving the structural integrity of the amphibious structures in the Agusan Marsh. The bundled bamboo and girders are especially vulnerable to deterioration due to continuous submersion or exposure to water. As revealed in the KIIs, when approximately 30% of the cross-sectional area of the bundled bamboo shows signs of decay, all deteriorated bamboo pieces should be replaced. Similarly, the girder or Batangan requires replacement when significant rotting or splitting is detected, as assessed by the Manobo people. In contrast, other structural elements, such as columns, beams, floor joists, and roof frames, are less prone to deterioration and often remain in good condition for years without needing replacement. Table 1 summarizes the structural components of the amphibious structures.

Table 1. Summary of materials for the structural members from RVS

Members	Material name	Size	Approximate maintenance period
Bundled Bamboo (Batang)	*Bambusa blumeana* (Kauayan-tinik)	75-mm diameter minimum	Replace when deteriorated bamboos when 30% has deteriorated.
Girder (Batangan)	Mambog (*Annona muricata*) Bangkal (*Nauclea orientalis*)	200 mm diameter or 200 x 200 mm (if sawn timber)	
Beams (Sakbat)	Mambog (*A. muricata*)	50 x 150mm	Replace when rotting or splitting occurs.
Floor Joist (Galgal)	Mambog (*A. muricata*))	50 x 75mm	
Columns	Mambog (*A. muricata*))	100 x 100mm	
Roof frame	Mambog (*A. muricata*))	50 x 100mm	

3.2 Construction Process of the Amphibious House based on Key Informant Interview

KII revealed that the construction of amphibious infrastructure by the Manobo community is a flexible process that adapts to seasonal variations, whether built on land or in water. The construction process can be outlined in general terms, as shown in Figure 8. The process begins with the collection and bundling of bamboo to form the *Batang* (floater). Each bundle of bamboo consists of up to 50 pieces. The number of bundles used in the *batang* varies depending on the size of the house. Small houses require 150 to 250 pieces (3-5 bundles), medium-sized houses need 250 to 400 pieces (5-8 bundles), and large houses use more than 400 pieces (more than 8 bundles). These bamboo poles are manually arranged by the builder to form a bundled cross-section, with uniformity depending on the builder's skill and experience. The bundles are then secured with nylon rope, ranging from 10 to 30 mm in diameter, to ensure structural integrity. The *Batang* extends beyond the livable space, with the extent varying based on the length of the bamboo. It protrudes 1.4 to 2.5 meters on the sides and has variable lengths at the front and rear, providing stability and buoyancy to the entire structure.

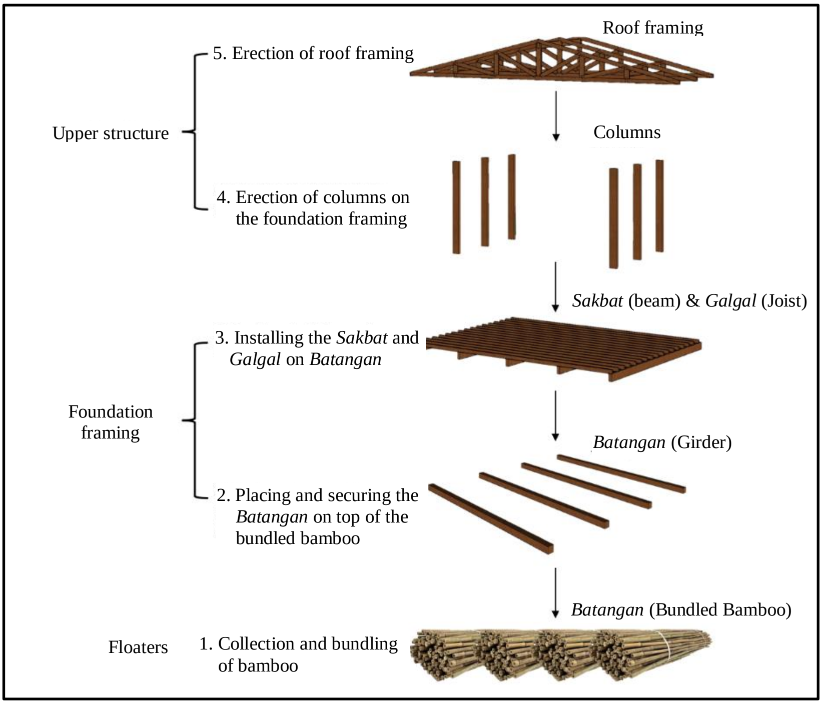

Figure 8. Construction METHOD DIAGRAM

During the flood season, the house is constructed directly at its intended final location, starting with the arrangement of bundled bamboo. These bundled bamboos provide buoyancy, allowing construction of the structure on top to proceed effectively. However, if construction begins during the dry season, when parts of the Mambagongon community are on dry land, the house is initially built on land, though strategically close to its intended location. When the water level rises, the completed amphibious house is then towed to its final position using ropes and motorboats.

Once the bamboo bundles are prepared, the *batangan*, which serve as the anchorage points for the floor beams and building columns, are placed on top, forming the structure's skeleton. The weight of the structure above the bundled bamboos generally holds them in place, eliminating the need for ropes or other anchoring mechanisms, and preventing the bamboo bundles from detaching from the structure (Figure 9a). This method relies on the density and arrangement of the bamboo, which, when compressed under the structure's weight, forms a stable base. However, families with additional resources often enhance this arrangement by securing the *Batangan* and the *Batang* with extra ropes (Figure 9b). These ropes, typically made of nylon and ranging from 10 to 30 mm in diameter, provide added security by tightly binding the components together. This practice reduces the risk of the *Batang* shifting or separating under dynamic conditions, such as strong winds, currents, or the movement of occupants within the structure.

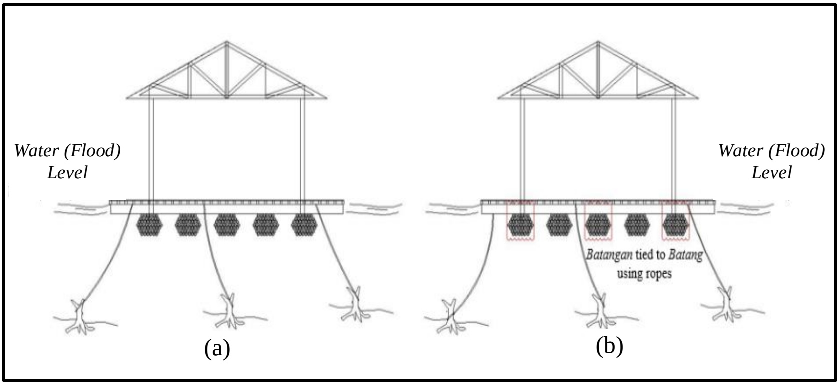

Figure 9. Typical Batangan-batang connection (a); Batangan-batang connection with ropes (b)

The *Sakbat* and *Galgal* are then nailed to the *Batangan*, further restraining the movement of the *Batangan*. Timber risers or shimming blocks may be added to ensure the floor beams are level and properly supported, an important step for the stability and usability of the livable space above. After securely placing the *Batangan* and *Sakbat*, additional ropes are used to tie these components to the bundled bamboo, further strengthening the connection between the floating base and the main structure. This step is crucial for ensuring that the infrastructure remains stable and cohesive, even as it floats on water.

The next phase in the construction process involves the erection of timber columns and roof trusses. The recent preference for sawn timber among the Manobo community reflects a shift toward materials that are more accessible and easier to level and maintain plumbness, thereby improving the overall quality and longevity of the construction. Sawn timber also facilitates a more precise and streamlined building process, which is especially beneficial given the challenging conditions of constructing in a flood-prone environment. As illustrated in Figure 10, the connection between the floater and the foundation frame of the amphibious house begins with securing the Batangan on top of the bundled bamboo. The *Sakbat*, extending in two directions, is then nailed to the *Batangan*, and once the foundation system is properly joined and leveled, the columns are erected and nailed to both the *Batangan* and *Sakbat* to ensure their plumbness. Additionally, the *Galgal* is nailed to the *Sakbat* to provide a stable floor covering.

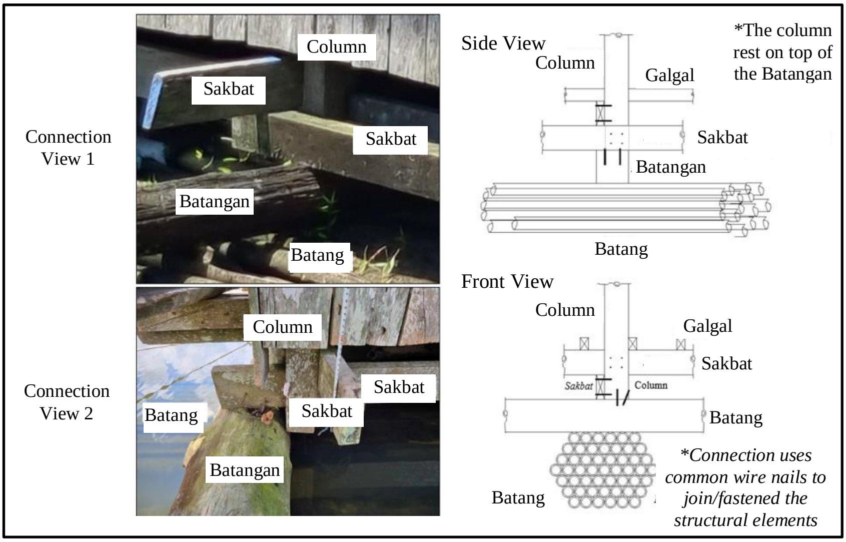

Figure 10. Connection diagram

The abundance of *Mambog* trees, used in the construction of amphibious structures in the Agusan Marsh, makes it a sustainable resource for local construction. This accessibility reduces reliance on external resources and supports the community's self-sufficiency, also reflecting the indigenous construction knowledge shared within the community. Additionally, *Mambog* timber is highly valued for its durability, which is essential for structures that are constantly in contact with water and exposed to the harsh environmental conditions of the marshlands. However, *Mambog* timber has several disadvantages that need consideration. Over time, it can discolor, crack, and weaken under UV exposure. Prolonged exposure to water or damp conditions can lead to wood rot, weakening the material and reducing its lifespan (Lee *et al.*, 2023; Reinprecht, 2016; Singh, 1999). As a result, *Mambog* timber requires regular replacement every 2 to 3 years to maintain its structural integrity. Occasionally, washed-up hardwood is used in some amphibious houses in Lake Mambagongon, which has high resistance to decay and weathering. This property is crucial for structures in the marshlands, where constant exposure to moisture and varying environmental conditions can quickly degrade less robust materials. However, hardwood timber also presents challenges, as it is found in remote areas of the marsh and is protected by laws, limiting its widespread use in the communities.

Once the *Batang*, *Batangan*, *Sakbat*, *Gal-gal* columns, and roof truss are in place, the roof covering, such as nipa leaves or galvanized iron sheets, is installed. In the Manobo community, roof coverings typically consist of galvanized iron sheets or nipa leaves. Metal roofs provide notable advantages, including durability and resistance to extreme weather conditions, which are crucial due to the frequent heavy rains and strong winds in the region. However, the high initial cost of metal roofs presents a significant challenge, especially for families with limited financial resources. Nipa roofs, a traditional choice in the Manobo community, offer several benefits that suit their lifestyle. They are affordable and sustainable, as nipa is locally sourced and renewable, making it an accessible option for the community while preserving cultural heritage and traditional building practices. Nipa roofs also provide excellent natural insulation, helping to keep homes cooler in the tropical climate and reducing the need for artificial cooling, in line with the community's commitment to sustainable living. However, nipa roofs have a shorter lifespan than metal roofs, requiring regular maintenance and frequent replacement, which can be both labor-intensive and costly over time. Additionally, they are more susceptible to damage from pests and severe weather, leading to leaks and structural instability. These factors necessitate ongoing upkeep.

Meanwhile, plywood, woven bamboo (*amakan*), or fiber cement boards are used for wall coverings. The Manobo community's preference for *amakan* or fiber cement boards as wall coverings in the Agusan Marsh is influenced by a combination of cultural, environmental, and financial factors. *Amakan*, made from locally abundant bamboo, is not only a material deeply rooted in indigenous craftsmanship but also a cost-effective choice, which is particularly important in a community with limited financial resources. Its breathable and lightweight properties are well-suited to the humid, marshy environment, offering practical benefits in terms of comfort and structural integrity. While fiber cement boards are more expensive, they offer greater durability and moisture resistance, potentially reducing long-term maintenance costs.

As the floodwaters rise, the floating home is carefully guided using motorboats to its designated location on the lake. The final positioning of the amphibious house involves securing it to pre-determined anchors, typically tree stumps submerged in the lake. Ropes are used to tether the structure (Figure 11), with knots that provide both stability and flexibility. This anchoring method ensures that the homes stay securely in place while allowing slight movement with the water's ebb and flow, preventing damage from rigid resistance to natural forces.

The use of nylon ropes and nails is essential in ensuring the structural integrity and longevity of amphibious communities. Nylon ropes are selected for their exceptional strength and resistance to moisture—key qualities in an environment where the houses are constantly exposed to water. These ropes effectively secure various components of the house, such as *batang* and *batangan*, providing stability and durability against the elements. Their flexibility and ease of use during construction aid in tying materials together, supporting the overall building process efficiently. Similarly, nails are crucial for securely attaching the main structural elements and house coverings, such as floors, walls, and roofing. They play a significant role in maintaining the stability of the floating houses, ensuring they can withstand environmental stresses like wind and water currents.

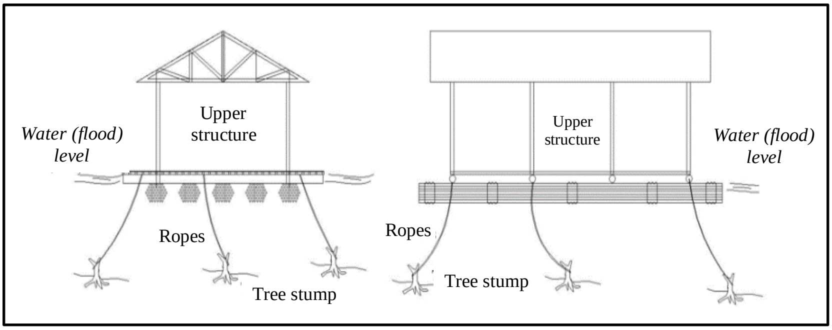

Figure 11. Anchorage of floating house

4. Conclusion and Recommendation

This paper provides critical baseline information on the construction of amphibious houses in Agusan Marsh, Philippines, focusing on materials, structural components, and construction techniques. An RVS was conducted on 35 amphibious structures, revealing that most were built after 2012, with a few older structures dating back to the late 1990s. Based on key informant interviews, the construction primarily utilizes bundled bamboo floaters, *Mambog* timber for framing, and traditional nipa leaves or galvanized iron sheets for roofing. The houses are mostly one-story, with floor areas ranging from 22 to 35 square meters, and many structures are elevated by at least 3 feet to improve ventilation and cooling. The baseline data also detailed structural components critical for stability, such as *Batangan* (girders), *Sakbat* (floor beams), and *Gal-gal* (floor joists), which are integral to the construction process. Additionally, RVS documented the strategic positioning of houses near trees and in shallow waters to minimize environmental impact and increase stability. Equally significant is the indigenous knowledge embedded in these practices. The Manobo people's use of local materials like *B. blumeana* bamboo and Mambog timber demonstrates their deep understanding of the environment. Their adaptive techniques, such as positioning homes near trees for stability and maintaining structures through regular inspections, highlight the shared indigenous knowledge within the community. These findings provide valuable insights into the construction practices and materials employed by the Manobo people to adapt to the region's environmental conditions.

5. Acknowledgment

The authors express their gratitude to the Manobo community in Lake Mambagongon for welcoming the researchers into their floating houses. Special thanks are extended to PAMO-AMWS for their supportive role in this research.

6. References

Ajayi, O., & Mafongoya, P. (2017). Indigenous knowledge systems and climate change management in Africa. Wageningen, The Netherlands: CTA.

Amnesty International. (2022). Indigenous peoples' rights. Retrieved from https://www.amnesty.org/en/what-we-do/indigenous-peoples/

Asian Century Institute. (2014). Asia's indigenous peoples. Retrieved from https://asiancenturyinstitute.com/society/804-asia-s-indigenous-peoples

D'Ayala, D., Galasso, C., Putrino, V., Fanciullacci, D., Barucco, P., Fanciullacci, V., & Yu, K. (2016). Assessment of the multi-hazard vulnerability of priority cultural heritage structures in the Philippines ingredients of a multi risk framework for heritage structures. Proceedings of the 1st International Conference on Natural Hazards & Infrastructure, Chania, Greece.

Dalisay, S. (2014). Engaging Local Knowledge for Disaster Risk Reduction. Kasarinlan: Philippine Journal of Third World Studies, 29(2), 75-102.

Elmendorf, W., & Luloff, A. (2006). Using key informant interviews to better understand open space conservation in a developing watershed. Arboriculture & Urban Forestry, 32(2), 54.

Espiloy, J. (1992). Properties of six erect bamboo species grown in the Philippines. Forest Products Research and Development Institute (FPRDI) Journal, 21(3-4), 79-88.

Fitrianggraeni, S., Avianti, F.N., & Purnama, S. (2023). The Indonesia indigenous peoples bill: The case to streamline cultural heritage protection. Retrieved from https://www.lexology.com/library/detail.aspx?g=a3190a3b-d6d9-4335-aaf8-42a8fb758c3e

Forest Products Research and Development Institute (FPRDI). (2022). Bamboo processing and industry development. Retrieved from https://fprdi.dost.gov.ph/program-projects/forest-products-research-and-development/bamboo-processing-and-industry-development

Gibbens, S. (2021). The world's wetlands are slipping away. This vibrant sanctuary underscores the stakes. Retrieved from https://www.nationalgeographic.com/environment/article/world-wetlands-are-slipping-away-agusan-marsh-underscores-stakes

Global Environment Facility. (2019). Indigenous peoples in the Philippines leading conservation efforts. Retrieved from https://www.thegef.org/newsroom/feature-stories/indigenous-peoples-philippines-leading-conservation-efforts

Hapsari, H., & Hardayani, H. (2023). The role of indigenous knowledge in achieving a flood-resilient society in flood risk areas of the Musi River: A case study of 3-4 Ulu Palembang, Indonesia. Proceedings of the 3rd Sriwijaya International Conference on Environmental Issues (SRICOENV 2022), South Sumatera, Indonesia.

Haque, M. (2019). Indigenous knowledge and practices in disaster management: Experiences of the coastal people of Bangladesh. In B. Zutshi, A. Ahmad, & A.B. Srungarapati (Eds.), Disaster risk reduction (pp. 59-72). Singapore: Palgrave Macmillan.

ICCA Consortium. (2021). The fight for the forest: Indigenous peoples in Burma speak out on threats following the February military coup. Retrieved from https://www.iccaconsortium.org/2021/11/12/the-fight-for-the-forest-indigenous-peoples-in-burma-speak-out-on-threats-following-the-february-military-coup/

Intergovernmental Panel on Climate Change (IPCC). (2010). Climate change assessments: Review of the processes and procedures of the IPCC. Retrieved from https://archive.ipcc.ch/pdf/IAC_report/IAC%20Report.pdf

Jerez, M. (2021). Challenges and opportunities for indigenous peoples' sustainability. united nations department of economic and social affairs. Retrieved from https://www.un.org/development/desa/dspd/2021/04/indigenous-peoples-sustainability/?fbclid=IwAR39czK4dUdB0X7dzay3tJFOhSbr3mjjATU0zdQL3hGCi4aAlThCF7lo2zo

Kumar, S., Rajaram, C., Mishra, S., Kumar, R.P., & Karnath, A. (2016). Rapid visual screening of different housing typologies in Himachal Pradesh, India. Natural Hazards, 85(3), 1851-1875. https://doi.org/10.1007/s11069-016-2668-3

Lagsa, B. (2015, July 28). How Agusan Marsh residents adapt to a 4-month flood. Rappler. Retrieved from https://www.rappler.com/moveph/97747-agusan-marsh-4-month-flood/

Lee, H., Lee, E., Shin, Y., Jo, H., & Song, D. (2023). Surface discoloration of ultraviolet (UV)-irradiated *Phyllostachys bambusoides* bamboo. Journal of the Korean Wood Science and Technology, 51(3), 173-182. https://doi.org/10.5658/wood.2023.51.3.173

Naing, N., Happy, R., & Ispurwono, S. (2009). Sustainability of the floating house at Tempe Lake, Sulawesi Island. Proceedings of the 43rd Annual Conference of the Architectural Science Association, Tasmania, Australia.

Nassirpour, A. (2019). Multi-hazard rapid visual survey (RVS) & physical vulnerability prioritization. Manila Philippines: PRISMH workshop on structural mitigation & increasing resilience of schools to multi-hazards. Xavier University, Cagayan de Oro City, Mindanao, Philippines.

Reinprecht, L. (2016). Wood deterioration, protection and maintenance. United Kingdom: John Wiley & Sons, Ltd.

Republic Act No. 11038. (2018). An act declaring protected areas and providing for their management, amending for this purpose Republic Act No. 7586, otherwise known as the "National Integrated Protected Areas System (NIPAS) Act of 1992," and for other purposes. Official Gazette of the Republic of the Philippines.

Republic of the Philippines Congress of the Philippines Metro Manila. (1997, October 29). Republic Act No. 8371. An act to recognize, protect and promote the rights of indigenous cultural communities/indigenous peoples, creating a national commission on indigenous peoples, establishing implementing mechanisms, appropriating funds therefor, and for other purposes. Retrieved from https://www.officialgazette.gov.ph/1997/10/29/republic-act-no-8371/

Salzer, C., Wallbaum, H., Alipon, M., & Lopez, L.F. (2017). Determining material suitability for low-rise housing in the Philippines: Physical and mechanical properties of the bamboo species *Bambusa blumeana*. BioResources, 13(1). https://doi.org/10.15376/biores.13.1.346-369

Singh, J. (1999). Dry rot and other wood-destroying fungi: Their occurrence, biology, pathology and control. Indoor and Built Environment, 8(1), 3-20. https://doi.org/10.1159/000024606

The President of the Philippines. (1996). Declaring certain parcels of land of the public domain situated in the municipalities of San Francisco, Bunawan, Veruela, Loreto and La Paz, all in the province of Agusan del Sur as protected area under the category of wildlife sanctuary and its peripheral areas as buffer zone. Retrieved from https://www.officialgazette.gov.ph/1996/10/31/proclamation-no-913-s-1996/

Tupas, J. (2010). Enchanting adventure in Agusan Marsh. Retrieved from https://palompontravelandtours.blogspot.com/2010/08/enchanting-adventure-in-agusan-marsh.html

United Nations Development Programme. (2023). Fast facts: Indigenous peoples in the Philippines. UNDP Philippines. Retrieved from https://www.undp.org/philippines/publications/fast-facts-indigenous-peoples-philippines#:~:text=The%20Philippines%20is%20a%20culturally,groups%%2020in%20the%20Visayas%20area.

Yahn, D. (2021). Embracing indigenous cultures to address infrastructure needs. Retrieved from https://www.wsp.com/en-hk/insights/embracing-indigenous-cultures-to-address-infrastructure-needs?fbclid=IwAR3-F6CmGEuqa_SHI6qi9fKO_uQUCtxjVuzIDH2qfwLV-c6huvq6-2G9JsQ

Yusran, N., Ali, M., Dahliana, B., Salman, D., Rahmadanih, N., Dirpan, A., & Viantika, I. (2019). Community resilience in dealing with temple lake disaster. IOP Conference Series Earth and Environmental Science, 235, 012108. https://doi.org/10.1088/1755-1315/235/1/012108