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Beyond the Glass Walls: an Exploration of Sensory and Biomorphic Design of Aquarium in Jakarta

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Abstract

Humans and nature have always coexisted. However, humans have increasingly developed and distanced themselves from nature over time. Learning through physical experiences is also being forgotten due to the ease of obtaining information in the present era. Yet, physical experience is something crucial. This research examines how sensory architecture can be utilized in the design of public aquariums to create a more profound experience for visitors and enhance interactivity and relationships among visitors and aquatic life. The research methodology is a precedent, qualitative case study method involving literature reviews, case studies, and field studies. The design method employed in this research is the biomorphic method. The indicators for this study include circulation types, sensory design, and biomorphic architecture. Case studies discussed in this thesis include Nifrel Interactive Aquazoo, Osaka Aquarium Kaiyukan, and teamLab Planets Tokyo. The chosen site for this research is a coastal site on Ebony Island, Pantai Indah Kapuk. This research analysis proposes aquarium design strategies with sensory and biomorphic design aspects, also considering the surrounding environment of the site. The organism chosen for the biomorphic building form in this research is coral reefs. The result of this research is an aquarium building design that implements sensory design in animal exhibitions and features a biomorphic form of coral reefs visible from both the exterior and interior of the building.

KEYWORDS: aquarium; biomorphic design; exhibition circulation; Jakarta; sensory design.

Introduction

Humans and nature have always coexisted. This has been the case since the beginning of human existence. This, along with natural curiosity, drives humans to learn about and study their environment and the creatures that live within it. The human mind freely embraced meaningful experiences, fostering a genuine relationship with nature and appreciating its beauty (Venkatesh, 2018). However, as time passed, humanity evolved, developing technology and architecture to ensure survival and improve the quality of human life. While this has made life more comfortable and efficient, humans have also begun to lose touch with nature and their sense of curiosity and adventure. People became more concerned with worldly matters and started drifting away from nature (Venkatesh, 2018). With all the information available within the palms of my hands, people are no longer interested in learning things physically. However, even though the theoretical aspects of nature can be learned through technology, one aspect that technology cannot replace is the sensory experience, which can only be obtained through physical means. The senses are a fundamental part of being human; without them, we would not be able to comprehend fully what we are learning. This lack of physical experience not only deprives humans of sensory

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experiences and the true grandeur of nature but also alienates us. It makes people feel disconnected from reality and less empathetic, and as a result, many begin to neglect nature. This makes conservation efforts difficult to implement.

One of the natural environments that has been severely impacted due to this growing neglect is the aquatic environment. The aquatic environment has faced many threats both on a national and global scale. These threats include several problems, such as climate change, pollution, overfishing, and habitat destruction, which collectively contribute to the decline in biodiversity and the well-being of marine life. Marine debris, particularly plastic waste, is a significant issue affecting oceans worldwide. Indonesia is one of the countries most impacted by this issue due to its geographical location and oceanic currents (Purba, et al.). A review of numerous studies done between 1986-2021 found that nutrient concentrations within Indonesian coastal waters have exceeded the standard by 54% and 50% for heavy metals and organic pollutants respectively (Adyasari, et al., 2021). Regarding overfishing, it is reported that approximately 75% of Indonesia's fish resources are fully exploited or subject to overfishing, with nearly half of the wild fish stocks being put under the overfished classification as of 2022 (Napitupulu, et al., 2022) Coral reefs in Indonesia have also experienced a drastic decline in biodiversity, with reports indicating a 30% to 60% reduction in coral species diversity over the past 15 years due to land-derived pollutants (Nurdjaman, Nasution, Johan, Napitupulu, & Saleh, 2023). Because of this, addressing this neglect is now more important than ever.

One way to counter this apathy towards the aquatic environment is by rebuilding human connection with nature. The aquatic environment has always fascinated humans. This is natural because humans originate from the land. This is why aquariums have always been popular throughout time. Aquarium design has continuously evolved to adapt to the society of its time and always strives to amaze visitors. One way to capture visitors' attention is by making the base form of the aquarium building and interiors that mimic the natural aquatic habitats, as well as some interactive facilities and animal shows. Although these experiences can enhance the visitor experience, it is usually not enough to leave a lasting impression. The connection between humans and nature achieved by these experiences is still rather superficial and could be deepened further. This connection could be deepened by incorporating sensory-based designs into aquariums. Incorporating a sensory-based design offers an opportunity to create more immersive and meaningful experiences for visitors. Aquariums can stimulate visitors' senses by integrating sensory elements and fostering a stronger emotional connection to aquatic life. This research explores how sensory architecture can be utilized in the design of public aquariums to create a more immersive experience for visitors and enhance interactivity and the relationship between visitors and animals.

Based on the background described above, the research problem formulation is:

1. How can the design concept of an aquarium be developed using a sensory design approach?
2. How can an aquarium be designed with a biomorphic architectural form?

Theoretical framework

The research 'Beyond the Glass Walls: An Exploration of Sensory and Biomorphic Design in the Architectural Design of an Aquarium in Jakarta' aims to explore aquarium design that combines sensory experiences with natural inspiration. By integrating elements such as spatial stimulus coordination and building structures inspired by nature, this research seeks to go beyond the traditional 'glass wall' concept in aquarium design. 'Beyond the glass wall' does not mean that the aquarium design will not use glass, but rather that the design aims to merge sensory design concepts with the traditional 'glass wall' concept to create a new, more meaningful space and enrich the visitor experience at the aquarium.

As one of the foundations of this research, several theories will serve as the basis for the design process of the Sensory Aquarium. The theories discussed in this section include sensory design, biomorphic architecture, exhibition space circulation, and coral reefs.

Sensory Design

From a neurological standpoint, it has been proven that vision is the most dominant sense, as the human brain is programmed to process more information from what we see than any of the other senses (Spence, 2020). More than half of the human brain is used to process visual information, which contrasts with the percentage of processing from other senses: Touch (12%), Hearing (3%), Smell (less than 1%), and Taste (less than 1%) (Spence, 2020). There are several ways to implement aspects of multisensory design that can stimulate each of the senses into architecture (Table 1):

Table 1

Sensory Design Summary

Source: Senses of place: architectural design for the multisensory mind (Spence, 2020)

No	Senses	Stimulation	Application in Design
1.	Sight/Visual	– Shape – Light – Color – Material	– Creation of Visual Tricks – Interpretation of building forms and interiors (curvilinear/sharp) – Lighting systems in spaces – Use of contrasting colors – Use of symbolic materials
2.	Hearing/Auditory	– Echo – Music and Soundscape	– Defining identity, function, proportion, and scale of space using echo – Use of symbolic music – Use of soundscape to recreate natural sounds – Sound dampening
3.	Touch/ Somatosensory	– Form – Material – Temperature	– Form and material of objects that are touched by hands, such as door handles or buttons – Changes in height and texture of floors – Shape and material of furniture in buildings – Temperature regulation of spaces
4.	Smell/Olfactory	– Fragrance	– Fragrance from materials/objects – Representation of fragrance related to spatial experiences or specific memories – Use of aromatherapy – Arrangement of air circulation and ventilation systems
5.	Taste/Gustatory	– Color – Material – Architectural Details	– Use of specific colors or materials that have particular symbolic meanings or impacts

Biomorphic Architecture

Biomorphic architecture is a form of design where the form and pattern in buildings are inspired by nature (Agkathidis, 2017). The concept of biomorphic architecture emphasizes the process of forming the shapes of the building itself rather than its functionality. Biomorphic architecture

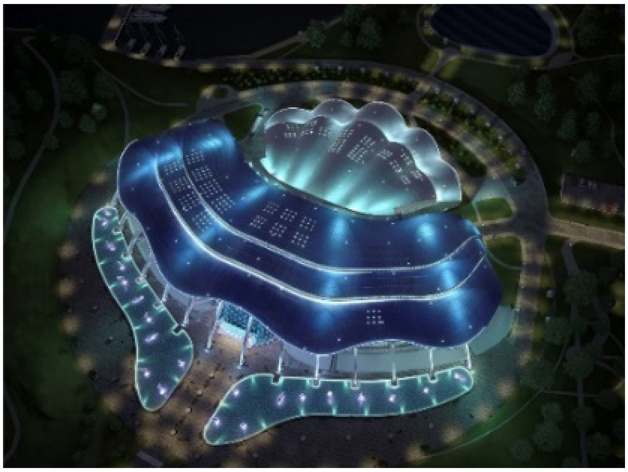


Fig. 1

Primorsky Oceanarium in Russia that has a Clam-like Structure

Source: In Progress: Primorsky Aquarium/OJSC Primorgrajdanproekt (Hitrov, 2012)

Fig. 2

Antalya Aquarium in Turkey is Shaped like Waves and depicts schools of fishes

Source: Antalya Aquarium/Bahadir Kul Architects (Kolektif, 2012)

aims to enhance awareness and strengthen the connection between humans and nature. There are three basic principles in biomorphic architecture (Fikriarini M. & Ishomuddin, 2016):

a Form
The biomorphic architecture features building shapes that resemble forms found in nature and often have abstract and organic shapes. The displayed forms can come from an analogy or metaphor of the original organism's shape, transformations, or natural movement systems.

b Material and Structure
The materials and structures of biomorphic buildings also refer to natural elements or follow patterns found in organisms. Most biomorphic architecture implements local, lightweight, and flexible materials that support organic shapes.

c Sustainability
Biomorphic architecture often incorporates eco-friendly factors. This is done to demonstrate an awareness towards nature.

Organisms that inspire a building's form analogy in biomorphic architecture can vary widely. Currently, most aquarium designs feature biomorphic shapes that are often symbolic of certain aquatic creatures, aquatic environments, or even natural phenomena (Figs 1 and 2).

In addition to aquatic animals, aquariums are now beginning to showcase some semi-aquatic and non-aquatic animals as part of their exhibitions. By incorporating animals that do not exclusively need to be inside an aquarium, visitors can interact directly with a cage-free habitat design.

Exhibition Space Circulation

Circulation is an important aspect to consider in the building design process. As a living gallery, several types of circulation must be addressed in the design of an aquarium, including visitor circulation, animal and keeper circulation, and supporting program circulation. The main circulation in the building and secondary circulation can be determined based on their scale; main circulation refers to the pathways leading to the main spaces, while secondary circulation refers to the pathways leading to smaller spaces (Ching, 2015). In this case, visitor circulation can be assumed to be the main circulation of the building, with animal circulation, keeper circulation, and other supporting program circulation as secondary circulation. Supporting program circulation, such as loading docks, medical areas, and management offices, can be separated from the main exhibition circulation but should still have some connected access to facilitate building management. The six circulation types are Linear, Radial, Spiral, Grid, Network, and Composite (Ching, 2015).

Coral Reefs

Coral reefs were chosen as the biomorphic inspiration for this research due to their essential role in marine ecosystems, making them an interesting subject for biomorphic design. This requires understanding coral reefs' morphology and basic shapes and the factors that influence their growth. There are five basic morphologies of coral reefs (Fig. 3) (Zawada, Dornelas, & Madin, 2019):

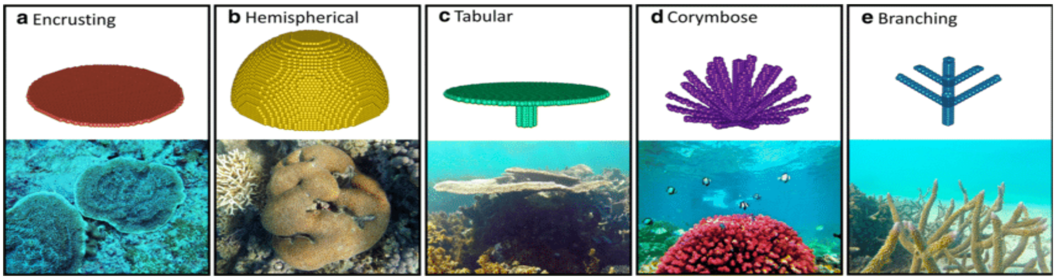


Fig. 3

Coral Reef Morphology Types

Source: Frequent Hydrodynamic Disturbances Decrease the Morphological Diversity and Structural Complexity of 3D Simulated Coral Communities (Cresswell, Thomson, Haywood, & Renton, 2020)

In addition to the morphology of coral shapes, another important aspect to consider in this research is coral growth. Coral growth is influenced by several geographical factors, namely (Vijaykumar, 2015; Dullo, 2005; Sheppard, Davy, Piling, & Graham, 2017; Heron, Morgan, Eakin, & Skirving, 2005):

1. Latitude
2. Temperature
3. Light
4. Salinity
5. Water turbidity
6. Wave movements
7. Exposure to air
8. Substrate

Methodologies

This research has two methodologies: 1) Research method and 2) Design method. The research methods used in this study are the precedent method and qualitative case studies (Creswell, 2007). These case studies are selected based on their relevance to sensory and biomorphic design principles and their ability to foster a connection with nature. Each case study will be analyzed using the research indicators derived from the literature, focusing on specific characteristics of forms and design elements to enhance sensory engagement and reflect biomorphic principles. For sensory design, design aspects that stimulate the human sensory systems found in the literature and case studies are evaluated for their role in creating immersive experiences.

Meanwhile, the design method used in this study is the biomorphic method (Agkathidis, 2017). Incorporating the findings from the theoretical frameworks on how biomorphic architecture could deepen the connections between humans and nature. The study examines architectural forms and patterns inspired by natural ecosystems, such as the influence of ocean waves or the structural intricacies of coral reefs, alongside material characteristics such as patterns and texture.

The indicators for this research are Sensory Design, Biomorphic Design, and Exhibition Circulation.

Case studies

The case studies in this research will be divided into the Aquarium Case Study and the Sensory Design Case Study. The aquarium buildings to be examined in this research are Nifrel Interactive Aquazo (Kaiyukan, 2023) and Osaka Aquarium Kaiyukan (Kaiyukan, 2023). Meanwhile, the sensory design case study to be discussed is teamLab Planets (Headout, 2023). Several design strategies from these case studies can be summarized as follows (Table 2):

Table 2
Case Study Summary
Source: Authors, 2023

No	Indicator		Nifrel Interactive Aquazoo, Osaka	Osaka Aquarium Kaiyukan, Osaka	Teamlab Planets, Tokyo
1.	Circulation Type		Linear (Multi-Story)	Linear – Spiral (Multi-Story)	Linear (Multi-Story)
2.	Sensory Design	Visual	– Exhibits/ aquarium – Color – Shadow projections – Light projections	– Exhibits/ aquarium – Light projections – Animal perspectives – Mirrors	– Light projections on the water surface – Video projections – Interactive objects (installations, water) – Color games – Mirrors/Visual tricks – Light echoes
		Auditory	– Music – Water sounds – Animal activities (wind chimes)	– Music – Water sounds – Heartbeat installation	– Soundscapes – Interactive objects (echoes, etc.)
		Somatosensory	-	– Heartbeat installation	– Water components – Flexible flooring – Interactive objects (balls, eggs, etc.)
		Olfactory	– Natural aromas from open habitats	– Natural aromas from open habitats	– Flower scents
		Gustatory	-	-	-
3.	Biomorphic Design		– Animal habitat decorations	– Animal habitat decorations	-

Site data

The site review for the design will be divided into macro and micro aspects. The macro review includes criteria such as being in a tourist destination area, sufficient surrounding infrastructure, and good site aesthetics. Meanwhile, the microsite review includes criteria such as being in a commercial zone, adequate accessibility, sufficient land and space, and the site's proximity to water. Therefore, the selected site is located on Laksamana Yos Sudarso St., Ebony Island, PIK, near a bike depot (Fig.4). The land designation for the site falls under the K-2 zone (Fig.5), with a total land area of 19,900 m^2.

The site boundaries are Mantra Building to the north, the beach and sea (mangrove view) to the south, a bike depot to the east, and the beach and sea (Penjaringan view) to the west. As a reclaimed island, the geographical area of the site is relatively flat, at an elevation of 2 meters above sea level. The site provisions stated in the DKI Jakarta regulations are Type K-2:

a Building Base Coefficient – maximum 55%

b Building Floor Coefficient – 4.5

c Basement Site Coefficient – 60%

d Green Base Coefficient – minimum 20%

Fig. 4

Chosen Site

Source: Google Earth, accessed on April 2024

Analysis

Based on the theoretical framework and the case studies discussed above, several approaches to designing an aquarium building with sensory and biomorphic design have been identified.

Fig. 5

Jakarta Satu Data Map of the Site

Source: *Jakarta Satu*, accessed on April 2024

Sensory design

Several potential applications of sensory design can be implemented within the aquarium design. Below are some diagrams of these ideas (**Figs. 6a-f**):

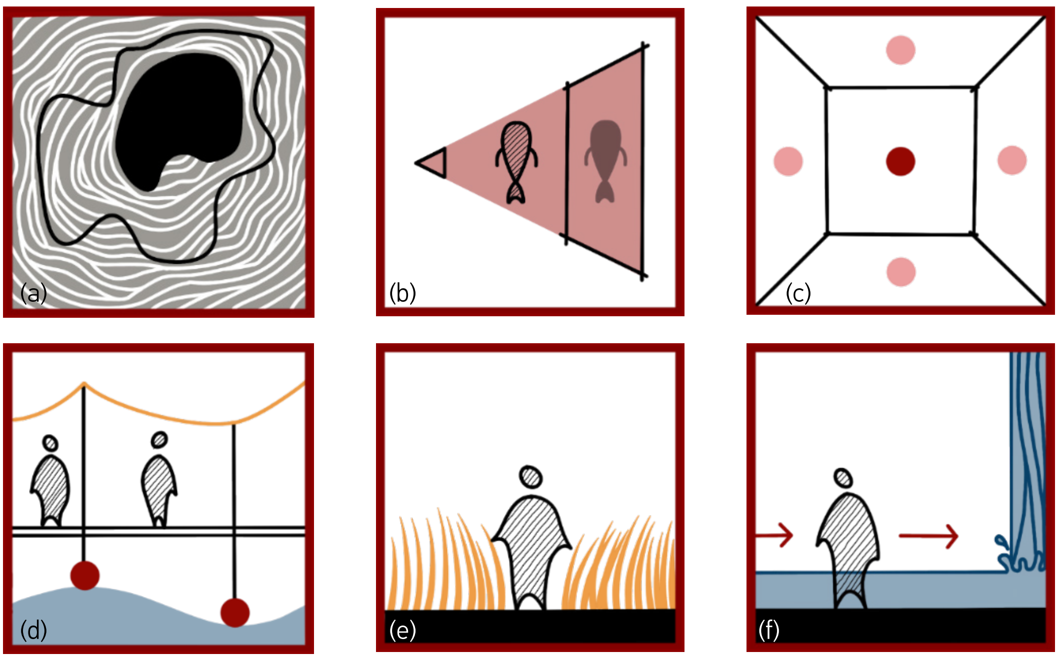


Fig. 6

a) Echolocation;
b) Shadow Projection;
c) Use of Mirrors;
d) Tensile Structures;
e) Movement through Grass;
f) Movement through Water

Source: Authors, 2024

Fig. 7

Table Coral
Source: https://oceanservice.noaa.gov/education/tutorial_corals/media/supp_coral03d.html, accessed on June 23, 2024

Fig. 8

Hemsphirical Coral, Favia Speciosa
Source: http://www.coralsoftheworld.org/species_ factsheets/species_factsheet_summary/favia-speciosa/, accessed on June 23, 2024

Biomorphic architecture

The coral reef is the organism highlighted as the inspiration for the biomorphic design in this research. Coral was chosen for its unique structure and shape, its functional role in marine ecosystems, and the site's location at the shoreline. Several keywords that describe coral include Colony, Adherence, Irregularity, Porous, and Complexity. There are various types of coral. However, two forms were selected for this design: table coral and hemispherical coral (Figs. 7 and 8). Hemispherical coral takes the shape of a dome. As for the table coral, it is shaped like a table. Here are some concept diagrams translating the shapes of these corals (Figs. 9a-e and 10).

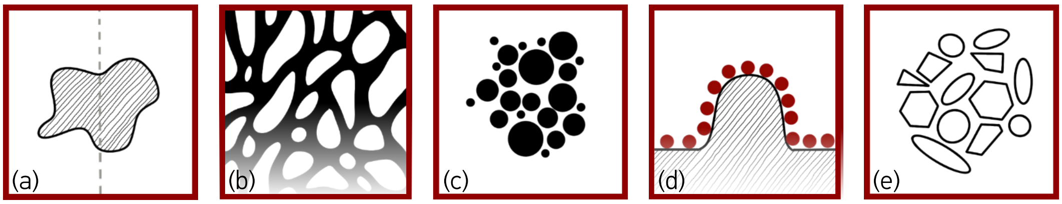


Fig. 9

a) Colony; b) Adherence; c) Irregularity; d) Porous; e) Complexity
Source: Authors, 2024

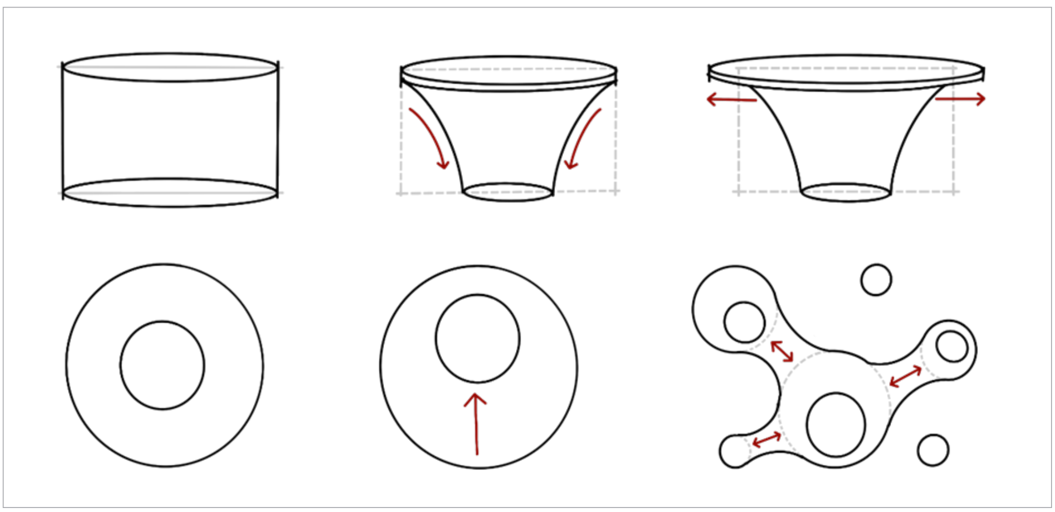


Fig. 10

Biomorphic Shapes Concept Diagram
Source: Authors, 2024

Figs. 9a-e and 10 show how coral development features relate to the design concept and are translated into simple spatial language diagrams. Geometric identities that shape the design's form are derived from diagrams with keywords such as colony, adherence, irregularity, porosity, and complexity. "Colony" refers to repetition and clustering, while "Adherence" illustrates how corals adhere and grow along a surface. "Irregularity" inspired organic, non-linear designs, while

"Porous" emphasizes apertures that resemble the coral's natural capacity to promote nutrient and water exchange. Lastly, "Complexity" depicts coral formations' complex spatial interconnection and layering. Fig. 10 depicts the thought process behind the shape formation for the design. The form shifts from simple geometric shapes to very organic, coralline or coral-like patterns with interlocked systems; this growth principle could be abstracted into biomorphic shapes that guide a spatial arrangement or structural evolution of the form.

Flow of activities

One of the main aspects to consider when designing a building is the activity flow of each user. The primary users of the aquarium building include visitors (Fig. 11), management (administrative) (Fig. 12), and animal care staff (keepers, researchers, and veterinary staff) (Fig. 13).

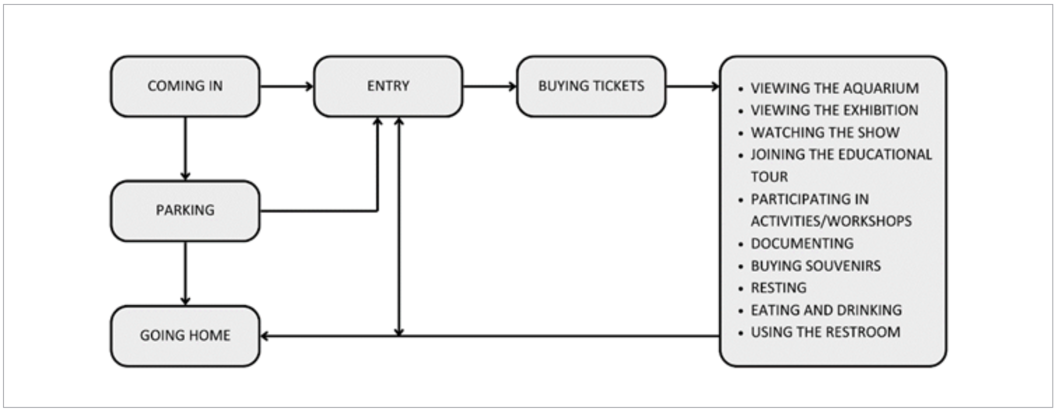


Fig. 11

Visitor's activity flow

Source: Authors, 2024

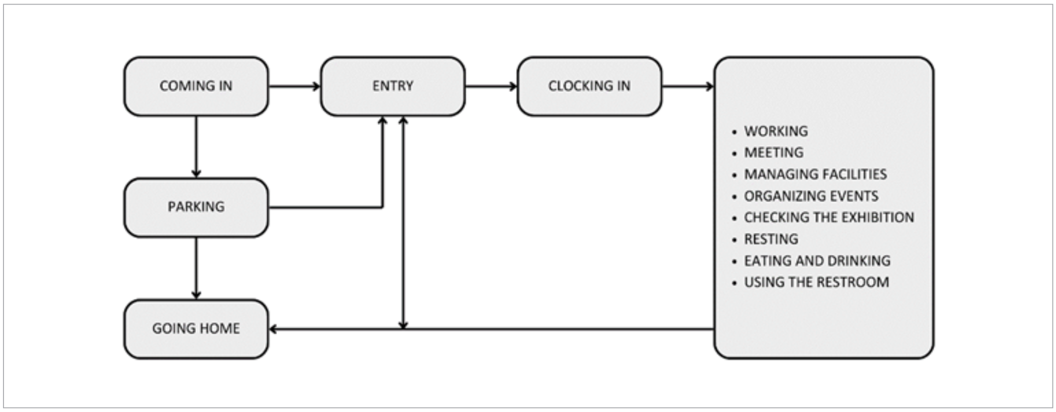


Fig. 12

Management's activity flow (Administrative)

Source: Authors, 2024

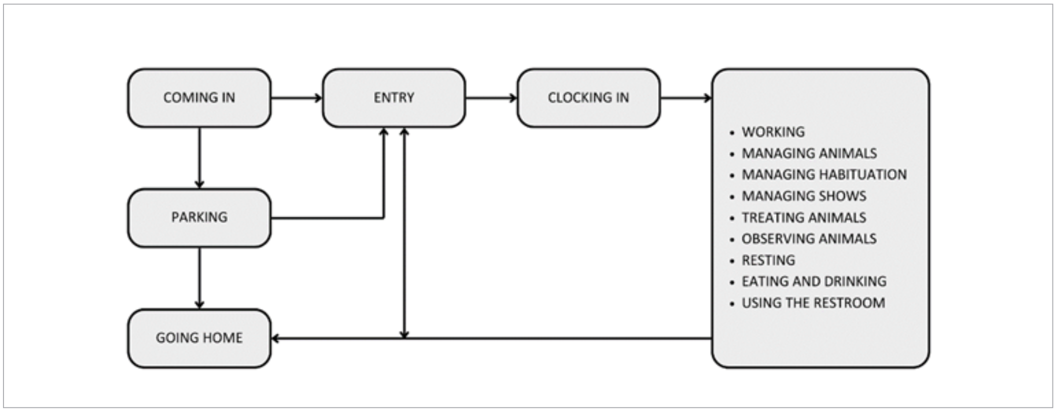


Fig. 13

Animal care staff's activity flow

Source: Authors, 2024

Facilities and space requirements

An aquarium building must have several facilities and space requirements to operate effectively. The space areas are divided into a Reception Area, Exhibition Area, Touch Pool, Amphitheater, Mini Theater, Recreation Area, Souvenir Shop, Café, Management, Quarantine, Zoological Laboratory, Botanical Laboratory, Utility Area, and Parking Area. To facilitate understanding of the table above, a diagram illustrating the percentage of space is provided below (**Fig. 14**):

Fig. 14

Space divisions
Source: Authors, 2024

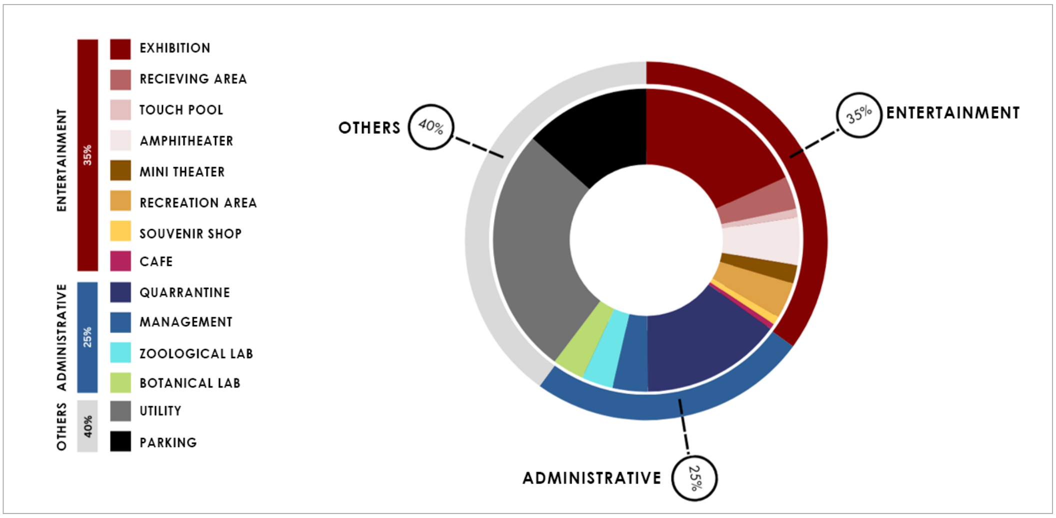


Fig. 15

Seating Area Placement
Source: Authors, 2024

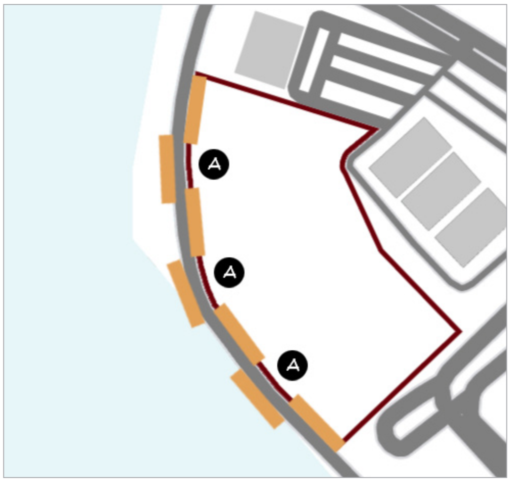
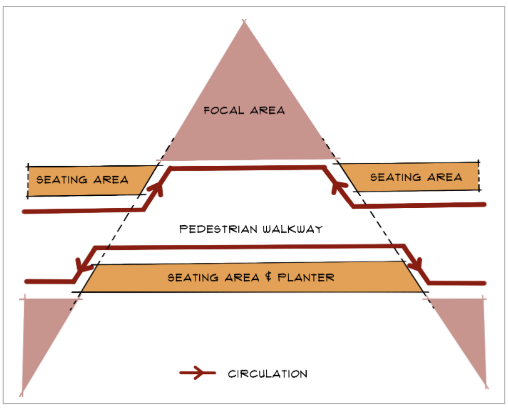


Fig. 16

Pedestrian Movement
Source: Authors, 2024



Site analysis

There is a pedestrian walkway located between the site and the beach. Due to its rocky beach type, this area has the potential to be developed into a street food area similar to The Cove at Batavia PIK. There are several seating areas along this path, indicated by the yellow positions in **Fig. 15**. The angled seating areas will indirectly influence the path's direction and also create a focal area between them (marked in pink in **Fig. 16**). This focal area can be utilized as an access point, observation area, and other areas that require more attention. These areas are marked with the letter A in **Fig. 15**

Several viewpoints need to be considered around the site (**Fig. 17**). Number 1 shows the observation deck and restaurant area. Number 2 shows the back of the bike depot. Number 3 shows the view of the sea and mangrove forest. Number 4 shows the view along the pedestrian walkway. Number 5 shows the view of the sea and the Penjaringan area. Number 6 shows the building adjacent to Mantra. Number 7 shows the pedestrian bridge to the PIK 2 area. Number 8 shows the view from the bike depot into the site.

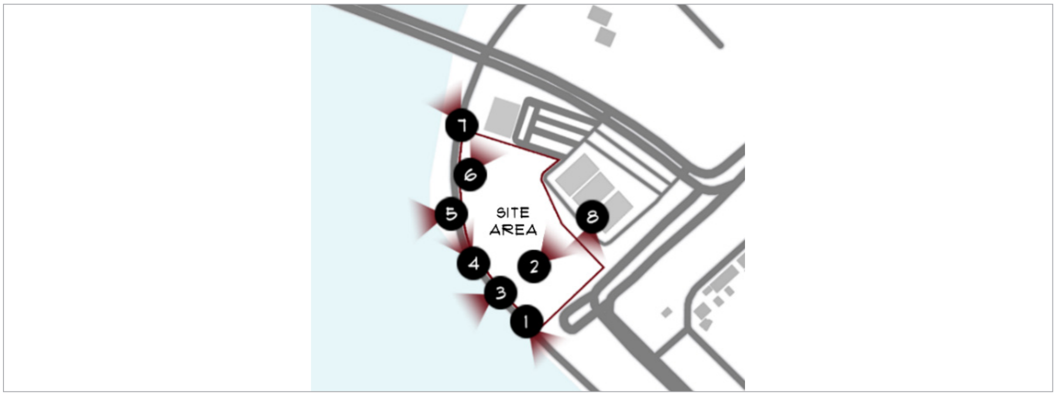


Fig. 17
View around the site
Source: Authors, 2024

Results and discussion

Design scheme

There are several stages in the design (Fig. 18):

a The first stage involves the extrusion of the site to make the building more prominent and attract more attention from the surrounding environment.

b The second stage includes creating access areas on the site and several focal areas using the results of the circulation analysis around the site.

c The third stage involves the addition of a pond as one of the main focal points on the site.

d The fourth stage is the creation of the building mass around the circulation paths on the site and the central area of the pond.

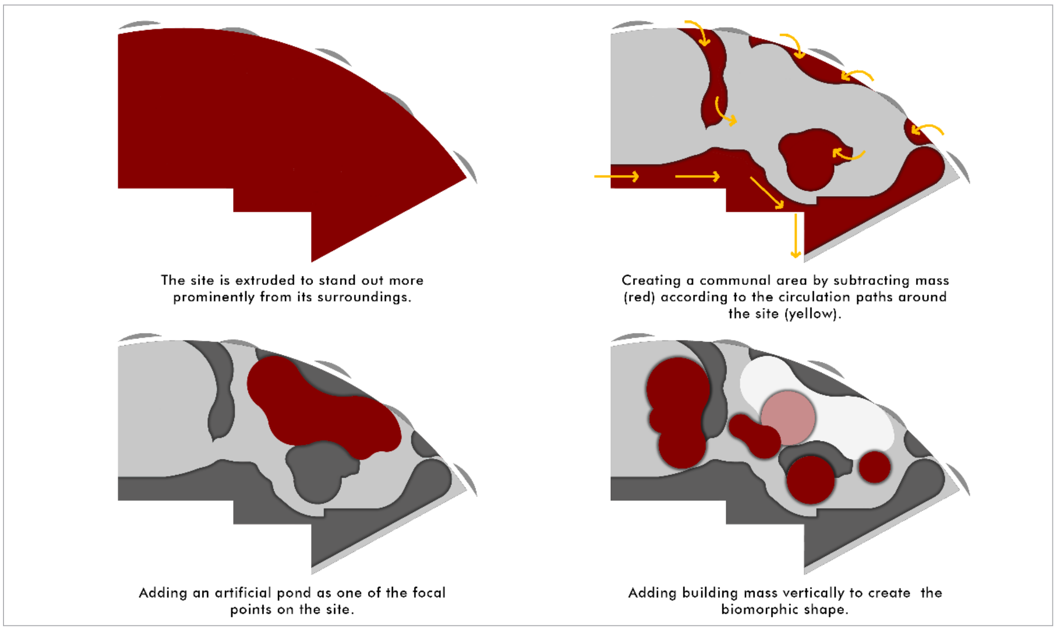


Fig. 18
Design Scheme Diagram
Source: Authors, 2024

Massing and zoning

The shape and form of the building are arranged to resemble the structure of coral reefs. This is accomplished not only through the design of each building but also through the placement and layering of each floor (Fig. 19). There are two types of building lattices used: one for tabular coral structures and one for hemispherical coral. The lattice for tabular coral is designed to resemble tree structures similar to table coral. A double lattice structure is arranged with a porous pattern for the dome section. The zoning of the building is illustrated in Fig. 20.

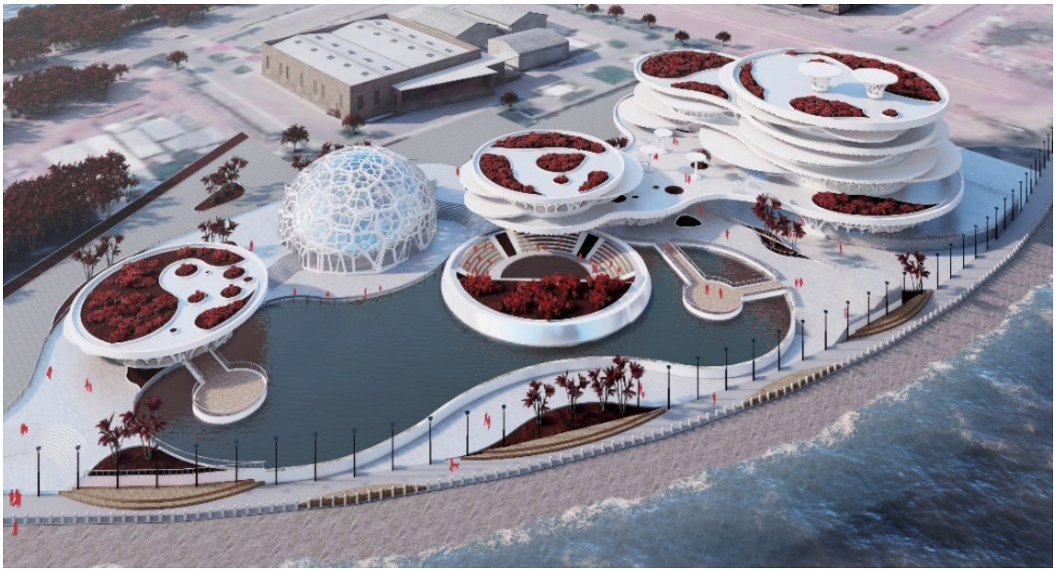


Fig. 19
Exterior Visualization of the building
Source: Authors, 2024

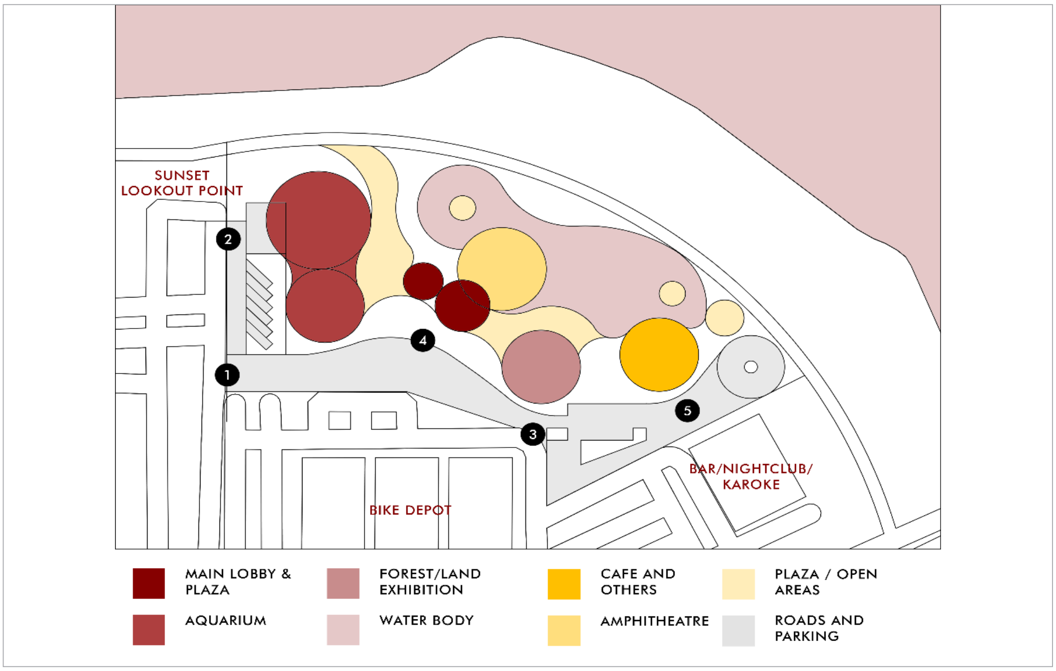


Fig. 20
Site Zoning and areas
Source: Authors, 2024

Regulation calculation

Below is a comparison of the design results with the existing regulations (**Table 3**):

No.	Regulation	Amount	Site Area (M^2)	Calculation of Regulation (M^2)	Calculation of Design (M^2)
1	Building Base Coefficient	Max. 55%	19.900	10,945	10,256
2	Building Floor Coefficient	4.5		89,550	24,288
3	Basement Site Coefficient	60%		-	-
4	Green Base Coefficient	Min. 20%		3,980	7,227

As can be seen from the result above, the design is according to site regulations.

Space explanations

The circulation in the exhibition area is linear, but within each zone, visitors are free to explore at their leisure (Figs. 21 and 22). After visiting the exhibitions on the first and second floors, visitors will return down via the escalator (Fig. 22).

The discussion will be divided based on each area and zone, along with some key terms from those zones and their visualizations. The explanation is as follows:

a Aquarium – Entrance and Orientation Zone

This area serves as an orientation area that explains the concept of sensory design in the aquarium to visitors.

b Aquarium – Darkness zone (Fig. 23a)

This zone simulates the perspective of nocturnal animals and cave habitats. This space has very low lighting, with light sources coming only from cove lighting, light projections, and the animals' habitat. The light projections reflect the echolocation system found in certain nocturnal animals, such as bats. In this zone, audio of the echolocation echo soundscape will also be played to enhance the auditory experience of the space. The key terms for this space are Cave, Darkness, Echo, and Echolocation.

c Aquarium – Colors Zone (Fig. 23b)

This zone focuses on the colors of the displayed animals. The room is divided into several small areas, each with a different color. These colors will be used to classify the animals based on their color. This is done so visitors can more easily match the spatial system with the animals' colors. The room color outside the colored areas is white, creating a sharper contrast. Color in this room is also intended to stimulate the sense of taste. The key terms for this space are Color, Contrast, and Grouping.

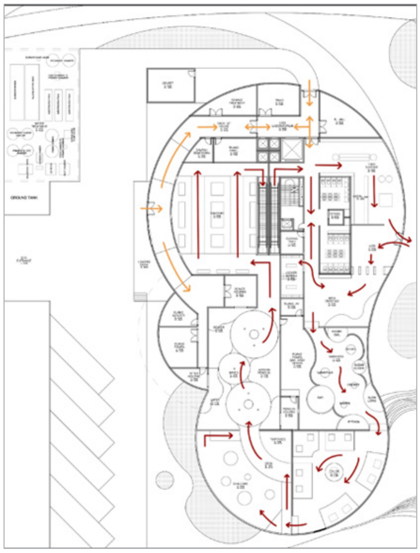


Fig. 21

1st Floor Aquarium Circulation

Source: Authors, 2024

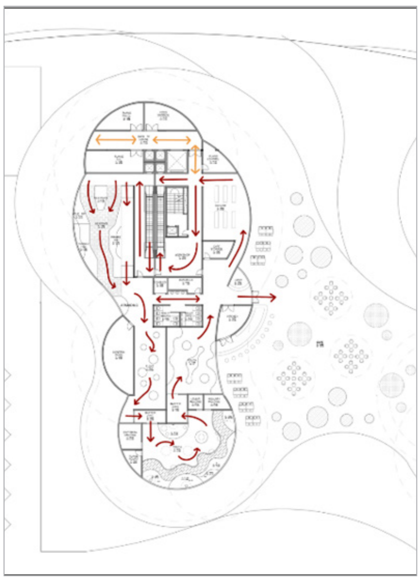


Fig. 21

2nd Floor Aquarium Circulation

Source: Authors, 2024

d Aquarium – Shallows Zone (Fig. 23c)

This zone reflects the tidal area for shallow water creatures. Visitors will walk through the water and experience its movement, with the water level changing based on the ocean's tides. Visitors can take two different paths: the main route is the water and the dry secondary path through a deck. The secondary path is implemented mainly for visitors with difficulties wading through the waters, such as the elderly or people with disabilities. The key terms for this space are Tides, Movement in water, Time-based change, Natural light, and Water sounds.

e Aquarium – Waves Zone (Figs. 23d and 23e)

This zone represents life within currents and waves. It features tensile structures connected to buoys floating on the water surface beneath the floor deck, which causes the tensile structure to reflect the water movement. This creates the sensation of walking underwater. Additionally, visitors can hear the sound of waves moving beneath the deck. The key terms for this space are Waves, Floating, Under the waves, and Water sounds.

f Aquarium – Shadows Zone (Fig. 23f)

In this zone, visitors are encouraged to observe the shapes of animals through shadows projected on the walls and ceiling rather than by directly viewing the animals. The light source is beneath the habitat podium and will be directed at the wall and ceiling areas. This design features two layers of pools: an inner aquarium where the animals will be exhibited and an outer pool. Water droplets will fall from above into the outer pool, creating ripples that will reflect on the projection area and serve as an auditory stimulant in the space. Visitors can also touch the outer pool and observe the movement of the water ripples in the projection. This creates an immersive experience where the spatial experience changes based on the visitors' movements. The key terms for this space are Shadows, Dynamic, Dripping water sounds, and Water ripples.

g Aquarium – Meadows Zone (Fig. 23g)

This zone reflects a grassland habitat, showcasing animals with burrows. The burrows will be displayed with visual layering, and visitors will walk through the grass. Visitors' movement through the grass will produce sounds based on their movements. The second circulation path is a bridge on the side of the room, designated for disabled access. Habitat is located next to the bridge, allowing visitors to observe the animals up close even if they do not take the main circulation path. The key terms for this space are Grass rustling, Moving through grass, Layered views, Open habitat, and Plant aromas.

h Aquarium – Float Zone (Fig. 23h)

This zone features jellyfish and aims to make visitors feel as if they are "floating." This effect is achieved through mirrors on the room's surfaces. The use of glass creates a visual effect that makes the room appear to have no definite boundaries, giving the impression that objects in the space are floating in the air. These objects include both the visitors and the animals on display. The animals exhibited in this zone are jellyfish due to their ability to absorb light well and their movement, which appears to float in the water. The key terms for this space are Floating, Mirrors, and Visual effects.

i Aquarium –Touch Zona (Fig. 23i and j)

This is a zone for free interaction between visitors and animals, with a cage-free environment. The zone is divided into two areas: the cage-free area and the touch pool zone. Animals will be released freely in the cage-free zone and can interact directly with visitors. Visitors can see, touch, hear, and smell the animals up close without barriers. There is an area for animals that visitors cannot access, as this area is separated by water. The key terms for this space are Open habitat, Touch, and Natural lighting.

j Forest Dome – Canopy & Forest Floor (Figs. 23k and l)

This area is a glass dome featuring an open and free habitat. It is divided into two levels: the Canopy and the Forest floor. An artificial waterfall is also in the center, acting as a sensory stimulant. The entire habitat is open, allowing visitors to smell the scents from within the habitat and the fragrances of the plants growing inside the Forest Dome directly. The key terms for this space are Natural lighting, Open habitat, Waterfall sounds, and Layering.

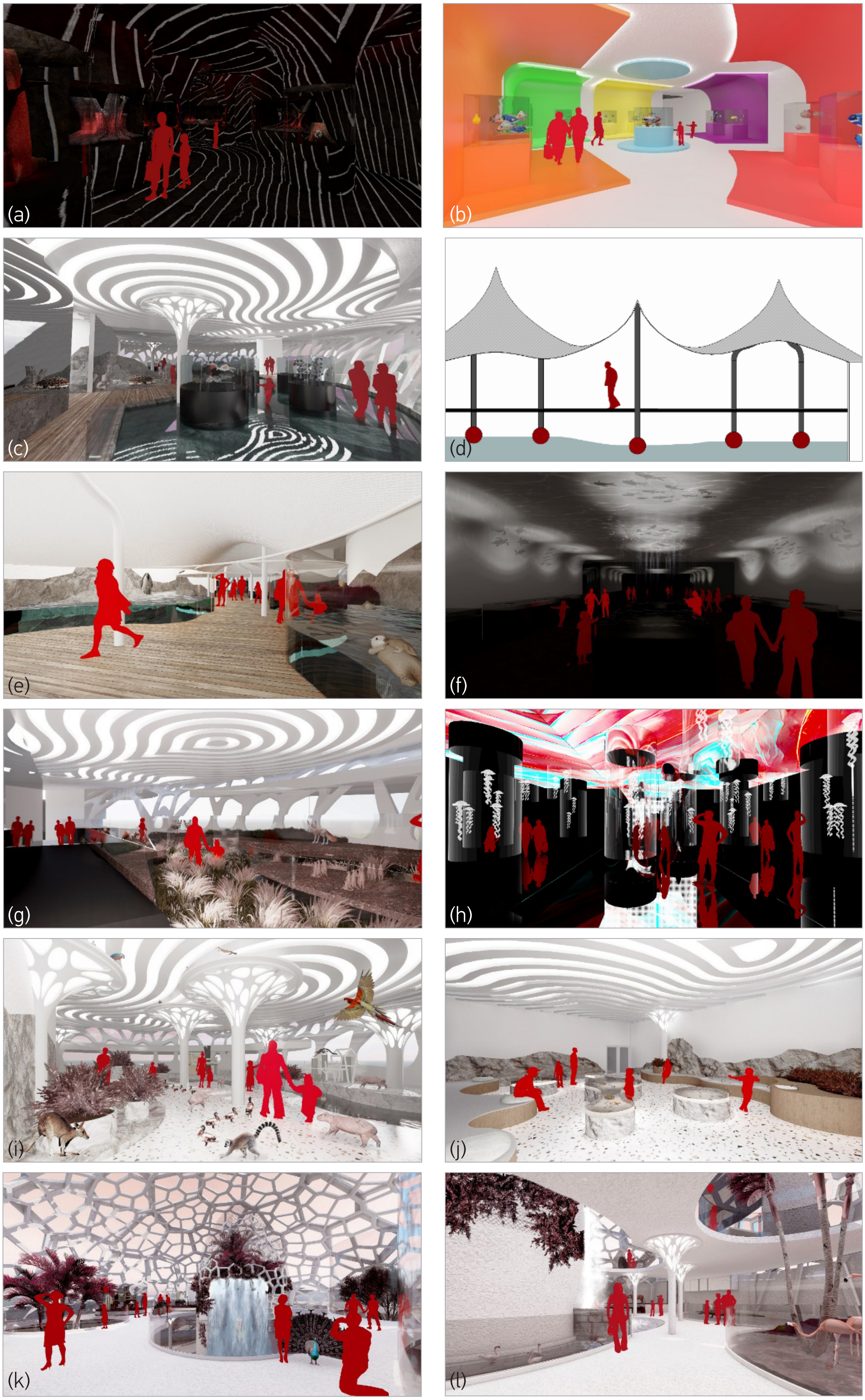


Fig. 23

a) Darkness Zone;
b) Colors Zone;
c) Shallows Zone;
d) Waves Zone Diagram;
e) Waves Zone;
f) Shadows Zone;
g) Meadows Zone;
h) Float Zone;
i) Touch Zone 1;
j) Touch Zone 2;
k) Canopy Zone;
l) Forest Floor Zone
Source: Authors, 2024

Conclusions

This research aimed to explore how sensory architecture can be hosted in the public aquarium design to develop a more exciting and immersive experience for visitors and to establish interactivity and relationships between the visitor and the animals. The study explored how approaches integrating sensory and biomorphic design can identify gaps in strengthening the human relationship with nature, especially aquatic life. It has been found that through theoretical analysis, case studies, and design development how through these strategies aquarium design can be transformed, taking the design "Beyond the Glass Walls" to create meaningful, immersive spaces. Although glass walls are still used, this design allows visitors to experience the space from the animals' perspective, providing a unique experience as if there are no boundaries between visitors and the animals.

It is found that sensory design can be used to encourage visitors' engagement with the animals in different and new ways which could deepen their connection. Firstly, it could be done by taking the visitors to experience the spaces from the animals' perspective, which would create an interesting and immersive connection between visitors and animals. This would allow visitors to better understand their behaviour, movement, and ecosystems. By taking on this perspective the visitors would become more engaged in their interpretations and interactions. Thus, gaining a deeper sense of empathy with nature. Moreover, the division of spaces could be done by classifying animals based on their characteristics rather than their environment. Doing so would help the visitors to better realize the identity features and behaviours associated with individual species rather than what was normally embraced by humans while placing them into a category - their habitat.

Regarding visual stimulation, this could be done by projecting light, using color, spatial layering, shadow projection, mirror reflection effects, and observing animals up close. These design approaches create an immersive experience for the visitors, which imitates natural habitats even better, taking the visitors to observe animals through a new lens, which would, in turn, spark their curiosity, and fascination, and deepen the connection between them. Meanwhile, the auditory aspect could be designed with sounds of natural elements and artificial audio. These would further enhance the experience of immersion into being in the same space as the animals, further enhancing the dynamic aspects of the sensory experience. Together, these other stimuli would foster connection and appreciation for the natural world.

As for somatosensory experiences, it could be applied by making visitors interact with spatial elements symbolizing animal habitats, such as water and grass, and implementing cage-free zones that allow visitors to touch and interact directly with the animals. This would help deepen the connection by letting the visitors physically experience the habitats and interact with the animals. Olfactory designs could be realized through the application of plants within the exhibition and open habitats allowing natural scents to be detected by visitors. Color stimuli may also be applied to stimulate the gustatory sense. These would also give the visitor a more hands-on experience of the place.

The biomorphic aspect of the design complements the sensory design aspects by using both patterns and materials inspired by natural ecosystems. The process involves selecting organisms that are symbolic or iconic in the eyes of the public, in line with the aquarium space program, or choosing organisms that match the location of the site. Afterwards, the basic morphological forms and identifying key descriptive words for the fundamental forms of organisms, which can later be applied to the design would be observed and analysed. The growth factors of the organisms and translating them into the design process based on the conditions of the site should also be considered in the design. This is so that the buildings would be able to integrate well with the surrounding environment as per the characteristics of biomorphic design. Furthermore, Biomorphic design could also be applied to the interiors of the building, and not just the exterior. This application could be in the form of interior decors of the space and the animal habitats itself.

To close the gap between people and nature, this study redraws the boundaries of aquatic life in an urban setting. The study demonstrates how sensory and biomorphic design approaches can be used to enhance the human experience by permitting meaningful interactions and immersion with natural components. This creative perspective finds support in a design development process that integrates the tactics described earlier to ensure the final designs both meet functional demands and evoke an intense feeling of harmony, empathy and belonging between humans and nature.

While this research provides some insights, it certainly has its limitations. The focus of this research was primarily on theoretical and design developments. Insightful as it may be, this research did not touch on the real-world applications of the proposed methods. Future studies could build on this research and involve testing these design strategies within real-world projects to assess their impact on visitor experiences. Further, the technological approaches towards the design could also be studied, such as the integration of augmented reality.

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