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READING THE LAYERS AND TRACES OF WAVES INTERVAL: DESIGN INFORMED BY THE DYNAMIC PATTERN OF NATURE

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ABSTRAK

Tulisan ini bertujuan untuk mengeksplorasi gagasan interval di alam sebagai dasar metode perancangan arsitektur. Tulisan ini berfokus pada pola interval alami yang diciptakan oleh pergerakan gelombang laut. Pembahasan interval gelombang dalam penelitian ini merupakan bagian dari penyelidikan mengenai wacana arsitektur yang saling berhubungan dengan dinamika alam. Pembahasan pola alam saat ini berfokus pada pola yang terdapat pada fisik makhluk hidup. Makalah ini menyelidiki enam studi kasus gelombang laut di alam dan menjelaskan mekanisme jejak dan penyerapan yang terjadi di berbagai lapisan aliran air sebagai respons terhadap arah angin, hambatan fisik di sekitarnya, dan permukaan topografi bawah air. Lapisan jejak dan penyerapan hadir sebagai mekanisme yang menginformasikan pemrograman arsitektur yang didorong oleh interaksi berbagai konteks pola alam yang dinamis. Penelitian tersebut memanfaatkan pola pergerakan gelombang sebagai cara untuk menghasilkan listrik, menyaring air dan merawat makhluk hidup di sekitar pantai, khususnya berbagai organisme tiram di laut dalam. Interkoneksi antara sistem-sistem ini menghasilkan berbagai kemungkinan komposisi ruang arsitektural yang bertujuan untuk memanfaatkan dinamika alam, sekaligus mendorong pertumbuhan makhluk hidup. Kajian ini menunjukkan bagaimana pola-pola alam tidak hanya ada dalam bentuk makhluk hidup yang statis, namun juga muncul secara dinamis melalui berbagai kekuatan yang ada dalam lingkungan.

Kata Kunci: pola interval, gelombang laut, tiram, listrik, hidup dan tidak hidup

ABSTRACT

This paper aims to explore the idea of interval in nature as the basis of architecture design method. This paper focuses on the natural interval pattern created by movement of ocean waves. The discussion of the interval of waves in this study is part of an investigation regarding architectural discourse that is interconnected with the dynamic of nature. Current discussion of pattern of nature focuses on the pattern found in the physicality of living being. This paper investigates six case studies of ocean waves in nature and annotates the mechanisms of traces and absorption which occur in different layer water flow in response to the wind direction, physical obstacles around them, and underwater topographical surfaces. The layers of traces and absorption exist as mechanisms that inform architectural programming driven by the interaction of various context of dynamic natural patterns. The study utilizes the movement pattern of waves as a way to produce electricity, filter water and care for living beings around the seashore, particularly the various oyster organisms in the deep ocean sea. The interconnection between these systems produces various possibilities of architectural spatial composition that aims to harvest the dynamic of nature, and in doing so foster the growth of living beings. This study demonstrates how patterns of nature exist not only in static forms of the living, but also dynamically emerge through various existing forces within the environment.

Keywords: *interval pattern, ocean waves, oyster, electricity, living and non-living*

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INTRODUCTION

This study explores the interval pattern of ocean waves as the basis of architectural programming. This study is part of the continuous theoretical discussion of the interconnection between nature and architecture that began twenty years ago. The discussion argues between architecture defined neither as nature nor is like nature, existing as the mimetic or mimesis of nature (Forty, 2000). At that time, nature was the primary foundation for architectural thought. Through the shape of huts or tents, architecture has been described by Vitruvius as nature's imitation (Forty, 2000). However, imitation can exist through analogy of a natural object, or instead governed by the principles of order and harmony found in natural objects (Forty, 2000). However, many of the concepts of nature explored by Forty are disappearing – both in contemporary theory and in more violent ways among melting glaciers and burning forests (Gissen, 2019).

The one who rejected the doctrine about architecture's tie to imitation of nature was Semper, because rather than looking for the origin of architecture in architectural form, Semper located it in human action (Hvattum, 2001). Semper's rethinking of mimesis in the Greek tradition was not copying of something is already there, but a creative interpretation of reality as a whole (Hvattum, 2001). Nature is no longer used as an organizing category in thinking about architecture in the modern era, and nature that is understood as the visible surface of things. The more intimate way of reading nature is celebrated, with appreciation that nature changes and animates, creating contingencies in the way living activities can be conducted (Paramita, Atmodiwirjo, & Yatmo, 2024). Explorations of architecture and nature in critical forms of architecture theory then migrated into histories and theories of landscapes and gardens, the landscape architecture practice of 'landscape urbanism', and into the theories and design strategies of green and sustainable design (Gissen, 2019). Thus, it is important to view architecture as a creative interpretation of human existence and action rather than as a formal or aesthetically pleasing phenomenon.

While traditional perceptions of space were based upon fixed and frozen patterns and geometries, or static visual images, some spatial systems exist dynamically in nature as defined by the social sciences (Allen, 2012). These patterns are typically formed through simple, local interactions between many components of a natural system that give rise to self-organization and emergent structures and behaviors (Ball, 2012). The interactions of such systems challenge the old assumption that "nature" and "culture" are separate categories and instead emphasized that they are part of a single system (Forty, 2000). The following discussion proposes to investigate dynamic patterns of nature, particularly intervals of ocean waves and its potential as the basis of programming in architecture.

Architecture and Dynamic Patterns of Nature

Most conversations regarding patterns in viewing nature typically focus solely on visual aspects. However, some occurrences are challenging to directly observe due to their occurrence on multiple time scales. As a result, these events are commonly viewed in a static manner. From this perspective, natural patterns can either be static or dynamic, depending on the context and the underlying processes. In specific settings, natural patterns appear to remain unchanged over brief periods in certain environments. For example, the branch arrangement of a tree may appear at first to be stationary to human sight. However, Ecologists have long understood that findings on the underlying mechanisms causing a pattern can be greatly influenced by the scale of observation such as temporal, spatial, or level of organization (Felton & Smith, 2017). The component of scale at which a natural pattern is observed also affects the perception of its dynamic or static form. For instance, a glacier may appear static when observed over brief periods, but it becomes dynamic when observed over extended periods, exhibiting movement and change. Consequently, it is necessary to change the surrounding landscape, which is typically done in an indeterminate and loose manner (Suryantini, Atmodiwirjo, Yatmo, & Harahap, 2021).

Furthermore, dynamic patterns in nature are often the result of interactions and feedback loops between various components within ecosystems. For example, predator and prey relationship in an ecosystem. Since every organism is an "observer" of its surroundings and since life cycle adaptations like dormancy and dispersion change the species' perceptual scales and the perceived variability, this has fundamental evolutionary

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importance (Levin, 1992). In consequence, architecture can serve as an extension of the earth, hosting all beings by providing a place for them and allowing them to live and move (Rahman, Paramita, & Atmodiwirjo, 2023). Considering the scale of observation and how human perception influences our understanding of dynamic aspects, the complexity of nature may reveal the dynamic of natural patterns in different ways.

Understanding Intervals as Natural Patterns

Intervals are patterns that occur at a certain time repeatedly. Many definitions arise from the word interval. Schelling (1982) discusses architecture as spatial music where he contrasted the interval in music as an interval of time, to the interval in architecture as an interval in space. In Japanese culture, this concept of interval is also stated as Ma. Ma is space as a time and mood-structured process (Delagaye, 2018). It is void, emptiness or interval in space that allows reflection and integration to better address modern life's contradictions or tensions (Delagaye, 2018). The word Ma does not describe the West's recognition of time and space as different serializations, rather, in Japan, both time and space have been measured in terms of interval (Okamoto, 2000). Relative interval of time can be measured by natural phenomena such as the sun, the weather, the seasons, the tide, weathering and decay, life and death (Okamoto, 2000). Interval is an opening, a distance between two points in space or time (Montalbetti, 2020). The interval can be interpreted mathematically or figuratively. In reality, 'interval' frequently implies a pause or break between two occurrences. However, this reading is irrational when attempting to define architecture.

In nature, there are various interval patterns found, produced by seismic waves, light waves, electrocardiogram / ECG, sound waves, ocean waves, and so on. This study finds studying interval to be a necessary exploration of natural pattern, as pattern formation is not a static thing but arises from growth; everything is what it is because it got that way (Ball, 2012). Ocean waves create unpredictable patterns of movement behavior depending on the boundary conditions, the appearance of defects, and path-dependent transitions between patterns (Ball, 2012). The variety of patterns can be stripes, spiral, hexagonal, or random (Ball, 2012). These elements can include the movement of particles, the presence of obstacles, and the influence of external forces in the surrounding context of the waves. The resulting patterns can be complex and diverse, ranging from simple ripples on the surface of the water to large-scale wave systems. When a liquid environment, like the ocean, is considered as an integral aspect of a dynamic entity, it alters our comprehension of the natural world and our methods of engaging with it (Suryantini, Saginatari, & Yatmo, 2022). By studying how these patterns emerge and evolve, scientists can gain valuable insights into the dynamics of the ocean and its impact on the world around us. Waves are changed by actions, which trigger another action. This continuous chain of actions creates a dynamic and ever-changing environment in the ocean.

METHODOLOGY

This study has been conducted using research "through" design methodologies (Verberke, 2013). The project aims to utilize layering mechanisms along traces and absorption of ocean waves to develop an architectural proposition to convert pollutants into fresh water through oysters and create electricity for electric ship chargers in a deep ocean sea. This paper begins by identifying the movement of waves in six different time intervals with different boundaries to investigate each situation that is necessary for the design foundation. These mappings include waves breaking on rough surfaces, waves refracting around obstacles, waves in the middle of the sea, waves in the bay, island waves, and waves among the stones. The selection of these several waves aims to explore the potential for diverse forms of motion in different contexts. Then, this study employs traces and absorption mechanism through layering system. Layers are defined as the fragments of the whole. Traces are a mechanism that can produce spatial compositions (Nabawi, Paramita, & Yatmo, 2022). As the waves move closer to the coast, the movement of the waves that were left behind becomes a trace. This trace depends on the medium and the wind movement in each mapping. This mechanism is then utilized to generate spatial system that can serve as the basis for design programming.

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RESULT AND DISCUSSION

Exploration of Ocean Waves Interval

In this study, the development of intervals as dynamic patterns of nature begins with exploring the movement of waves in six distinct time intervals with various boundaries to examine each scenario that is required for the design basis. First, all waves are analyzed from the aerial view to capture the interval timing and arrange them with five layers, such as: (1) Traces; (2) Absorption; (3) 1st Wave; (4) 2nd Wave; and (5) 3rd Wave. Wave's type 1, 2, and 4 are mainly located on the seashore where the land meets the ocean. Traces are the perceptible changes made in the medium by actions, which can trigger subsequent actions as they carry information about the actions that produced them (Nabawi, Paramita, & Yatmo, 2022). The sea water is trapped in various barriers due to the existence of sand and rock that stop the water and return it to the sea. Waves 3 and 6 are located in the middle of the sea. Figure 1 shows that type 1 waves in the bay were spreading, while type 2 waves were coming off with suppression. Type 3 emphasizes the disappearance of the rock impediment, while wave type 6 continues uninterrupted. Although there are five layers, not all of them occur in every scenario. It is evident that, given a consistent time interval, the wave images undergo variations with each successive leap second, and various scenes produce distinct layers. Subsequently, after the layering process throughout the 2-dimensional picture has been identified, it is crucial to examine the projected depth and length that impact each individual wave in three dimensions. The sea is dynamic because it moves as a fluid body, exhibiting both horizontal and vertical non-flat dynamics (Suryantini, Saginatari, & Yatmo, 2022; Steinberg & Peters, 2015). Consequently, I classify those six wave cases as containers. The classification of those six wave cases as containers helps in analyzing and deepen understanding their pattern and properties.

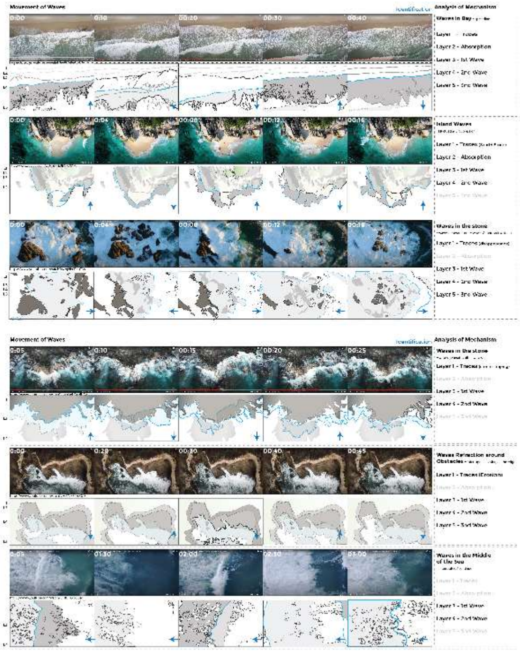

Figure 1. Exploration of Waves in Context
Source: Author, 2023

Analyzing the layering pattern in depth for interval begins with wave type 1, which is described as shallow seawater with numerous sand traces along the beach. As it enters deeper water, the hues get darker. In contrast to type 1, obstacles in wave type 2 significantly impact the border and traces along the shore, resulting in a collision of water orientations and the generation of a greater amount of passive foam. Meanwhile, wave type 3 involves collisions between the waves. Nevertheless, the presence of erratic winds and numerous obstruction rocks intensifies the turbulent nature of the breaking waves. These elements drive the water to crash with heightened intensity, leading to the production of more waves. Upon impact, the rock disappears from its original position, as seen from above.

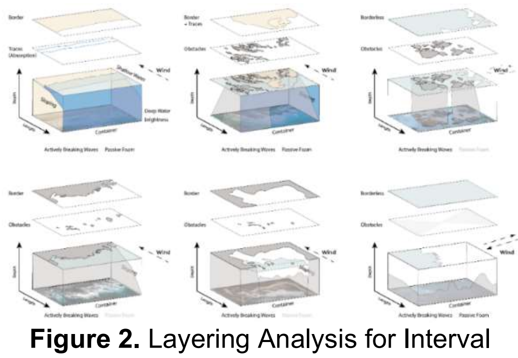

Figure 2. Layering Analysis for Interval Pattern in Nature
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Wave types 4 and 5 exhibit parallel movement with the wind, even in the presence of little obstacles. As they approach the coast, they modify their direction in accordance with the surrounding environment, resulting in the absence of passive foam. Wave type 6 exhibits alternating wind directions, causing the container below to seem empty both from below and above. Consequently, the water may flow freely in either direction without obstruction, producing both actively breaking waves and passive foam. Based on these analyses, everything occurring under the surface is related to the occurrences happening above the surface. The direction of the wind and the surrounding environment have an impact on the waves' motion and the presence of foam with different interval type of waves. This interconnected relationship between above and below creates a dynamic and ever-changing marine ecosystem.

Architecture Programming in Response to Ocean Waves Interval

After learning about the features of seawater movement and seeing the overall pattern, the project's objective is to employ those layering mechanisms to construct an architectural concept. In this paper, architectural programming is created by the combination of Living and Non-Living System. This system is discussed by Christopher Alexander (2002) that everything has its degree of life, and this broader concept of life is trying to make world alive. Since nature is impacted by the results of the majority of human actions, human societies have developed close relationships with it. Humans have still become a designated center of architecture, animals require significant attention to preserve the balance of the environment (Nabawi, Paramita, & Yatmo, 2022). The living system in this study is pointing out how Oyster can be the medium for filtering water, while the repeated motion from the wave become the potential for generates electricity as the notion of the Non-Living System. The deep ocean sea is considered become the context.

The dynamic motion of water proves advantageous for some organisms, particularly Pacific oysters. Oysters are beneficial to marine ecosystems from an ecological standpoint because they can convert pollution into fresh water by using their gills (Loxahatchee River District, 2009). This water movement is so vital to Oysters because they rely on currents to deliver food to them and prevent them from becoming buried (Loxahatchee River District, 2009). The movement process of oysters in the underground water also can trigger providing habitat for small organisms, and their reefs provide stabilization for the shorelines (Loxahatchee River District, 2009).

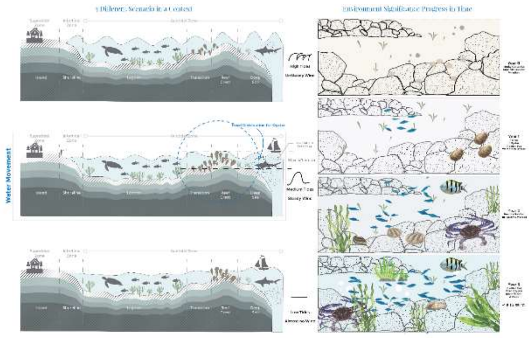

Figure 3. Scenario of Oyster in Different Water Movement
Source: Author, 2023

Next, I searched for three possible situations in three different contexts can be seen in the diagram in Figure 3. With unsteady wind, the water tide tends to be high. An optimal location would be characterized by consistent wind patterns and moderate tidal conditions, since these factors contribute to a favorable mineral flow that supports the growth of oysters. The environmental significance is evident from Year 0, when the water state was murky and harmful for fish, and contaminated. However, within 3 years or later, the water transformed into a cleaner blue sea with abundant oxygen, resulting in an increase in fish population and coral growth. Thus, the research does not need a particular site; any region with a plentiful supply of oysters would suffice. Implementing the context into the scenario.

Oyster farming requires planting new oyster seeds each year, and production begins in hatcheries and nurseries with parent oysters releasing eggs and sperm into a marine environment (Revell, 2021). According to Revell (2021), the fertilized egg develops into an oyster larva, which then develops into "spat"—tiny baby oysters—that oyster farmers use as the "seed" to grow into a marketable crop or product. Therefore, the oyster hatchery requires a controlled environment for the early stages of the oyster life cycle with controllable water salinities and temperature. As a result, obtaining this seed directly from a hatchery or nursery is the most effective technique since it can manage the

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number of young oysters. Among the several oyster breeding procedures, off-bottom culture is selected. Therefore, these requirements will be the basis for architectural programming. The combination of forces due to the gravity, sea surface tension, and wind intensity are the main factors of origin of the sea waves (Rodrigues, 2008).

In addition to the oyster's ability to purify contaminated seawater, the movement of the sea may also be used to generate power. According to Veerabhadrappa et al. (2022), wave energy can be observed as a possible clean energy resource that can be exploited for power generation purposes. This wave energy has gained more attention as a potential solution to reduce our dependence on fossil fuels. As technology continues to advance, harnessing the power of the ocean's waves could become a viable and sustainable energy source in the future. This innovative approach not only benefits the environment but also offers a reliable and consistent energy supply for communities around the world. Due to the increase of renewable energy especially for clean marine mobility, incorporating that electricity current into electric ship charger and lighting system can actually support the oyster production activity actions and also complement each other processes. Oyster shell waste may be utilized as battery material because of the calcium oxide concentration in oyster shells, which is one of the future energy sources that is extensively employed as an energy source for electric vehicles (Sabarudin, et al., 2023). In addition to the energy from the wave, among the most cutting-edge technologies now under development is *Wave Star Energy*, which harnesses the kinetic energy of moving water to generate power. The Wave Star converter generator was considered the most optimal scenario because it has the lowest cost of energy (COE) and net current cost (NPC) (Jahangir, Alimohamadi, & Montazeri, 2023). The power production is mainly influenced by the wave height, wave period, and wave direction (Marquis, Kramer, & Frigaard, 2010). When the wave is high, the period becomes short, and then the direction becomes more dynamic.

The Wave Star device, a marine energy system, has buoyant legs attached to a central connector attached to the ocean floor. It operates at depths over 50 meters (O'Connor, Lewis, & Dalton, 2013) and has a 600-kW power capacity (Jahangir, Alimohamadi, & Montazeri, 2023). The device's components are positioned higher than water levels to ensure safety during bad weather. The power capacity may be determined by the number of rows in the main section of the device and the number of floating rows. The energy stored by the device can be transferred to an electric ship charger using the Aqua Superpower Machine, which has capacities of 25 kW, 75 kW, and 150 kW (Marquis, Kramer, & Frigaard, 2010). Thus, a single leg machine from Wave star Energy is equivalent to a single spot charging station of the Aqua Superpower Machine. The integration of these components in Figure 4 creates a comprehensive and integrated system, demonstrating the extensive scope of the project.

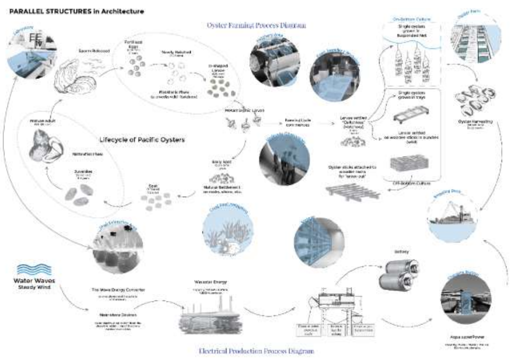

Figure 4. Process and Architectural Elements of Programming
Source: Author, 2023

After understanding the underlying correlation between the oyster and electricity, it is appropriate to proceed with the design process by exploring form compositions, as seen in Figure 5. The potential for the building form is reliant upon the frequency of water flow, which allows the oyster to effectively filter the polluted seawater. Additionally, the device's leg can be aligned in the same direction as the water movement. This synchronization of processes enhances the overall performance and effectiveness of the design, making it a sustainable solution for water purification and electricity generation.

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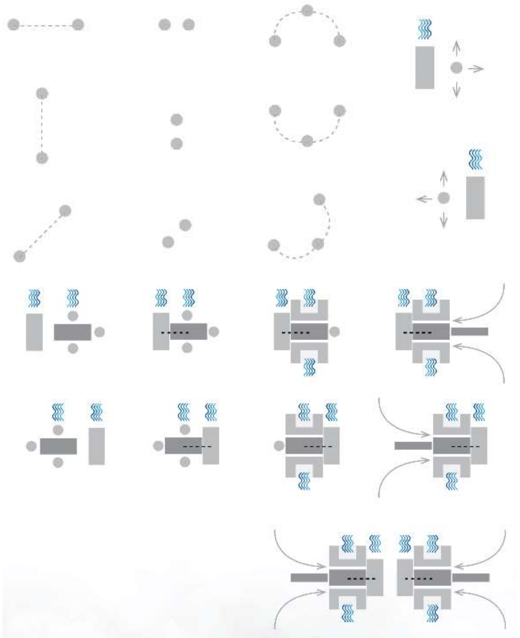

Figure 5. Process and Architectural Elements of Programming
Source: Author, 2023

The procedure of form development proceeds to integrate all the components as can be seen in Figure 6. The structural support column ensures the stability of the overall system, particularly under turbulent water conditions. The lighting system is crucial for nighttime activities, guaranteeing visibility and safety when refueling. Electric chargers are essential for providing electricity to electric ships, hence advancing sustainable and environmentally friendly transportation. The elevator enables seamless and efficient vertical transportation, providing convenient and effortless mobility between various levels of the system. The underwater conduit efficiently distributes energy from the main machine to various components throughout the system, allowing for seamless operation. Lastly, the dock protector acts as a shield, preventing any potential damage to incoming ships and ensuring a secure refueling process. These components work in synergy to reduce the system's carbon footprint and minimize environmental impact. By utilizing renewable energy sources and safeguarding incoming ships, this architecture sets a precedent for a greener and more sustainable future in transportation.

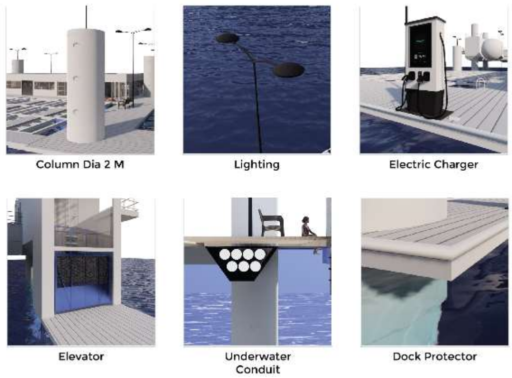

Figure 6. Design Scenario Elements in Context
Source: Author, 2023

The design should incorporate the three stages of oyster farming stated in Figure 7. The initial stage is the hatchery, which serves as the central location for conditioning the brood stock, larval rearing, and spat rearing. Algae cultivation is carried out at this location to provide a food supply for the growth and production of tiny oysters, known as spat. In addition to the hatchery, there are other facilities available for a pearl workshop program, storage, and an underwater observatory. The second step, known as the nursery phase, involves the cultivation of medium-sized oysters using a *floating upwelled system*. These oysters are placed in a location where they may immediately get nourishment from the water. The oysters that have undergone the nursery phase are then transferred to the off-bottom rearing area at the back of the hatchery. Here, they are carefully sorted one by one to ensure optimal growth. Once they have reached their final size, the oysters can be distributed to an electric ship, which is equipped to transport them to various locations. This allows for the oysters to be distributed and utilized in different areas, whether for further cultivation or for commercial purposes. The change in the arrangement and composition of this interval-based architecture produces a novel comprehension of how to create architectural designs that incorporate both living organisms and nonliving things. Additionally, this buildup can be progressively increased over time, leading to a more sustainable and dynamic architectural environment.

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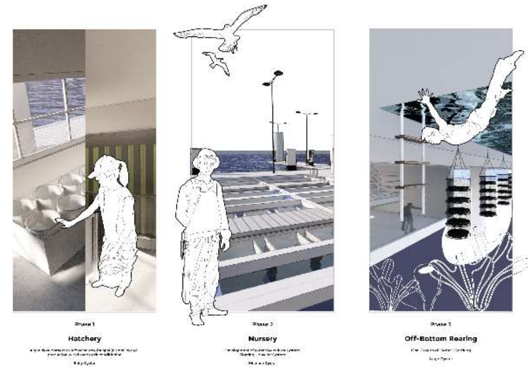

Figure 7. Three Stages of Oyster Farming in a Design Scenario
Source: Author, 2023

Figure 8. Perspectives of Design in Context
Source: Author, 2023

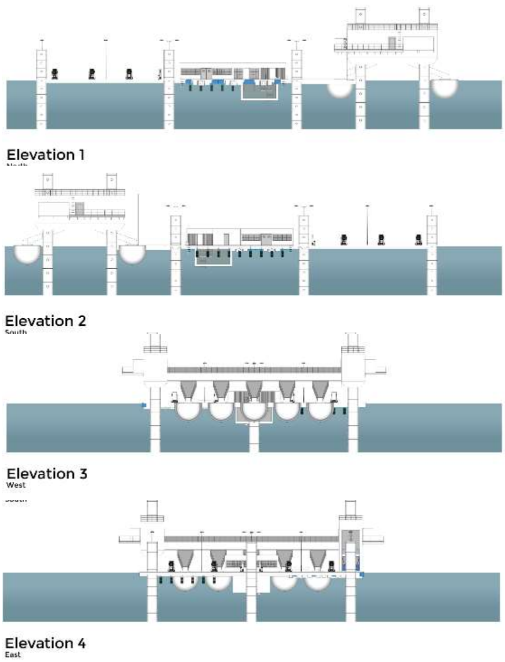

Figure 9. Perspectives and Sections of Design in Context
Source: Author, 2023

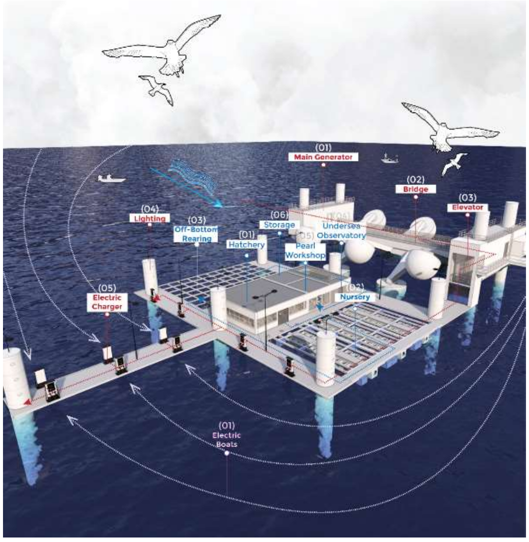

Figure 10. Perspectives of Design in Context
Source: Author, 2023

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study investigates the mechanism of interval pattern as the foundation of the architectural design process that values the dynamics of the environment. In order to determine the spatial characteristics of interval driven architecture, this study examined six case studies of ocean wave motion. The study proposes that the mechanisms of traces and absorption as layer processes are examined as the basis for reading the emergence of natural dynamics. The study found that the pattern of interval is produced through the interrelationship of the top and bottom physical terrain of the ocean, shaping the water movement and the living environment within it. Further architectural programming is offered to utilize such a movement pattern systematically in sustaining particular production needs that support the balance of the environment. Future directions for research in this area, such as additional case studies or experimental investigations, could be proposed based on the conclusions drawn from the current study.

Suggestions/Recommendations

The study limits its discussion to architecture driven by the interval pattern of ocean waves and its possibility of developing a living environment for Pacific oysters through the utilization of seawater filtration.

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More study is needed to discover another form of interval that explores other natural dynamics. Further research could investigate how different interval patterns in nature can be utilized in architectural design to create sustainable living environments for various species. Understanding the relationship between natural patterns and architectural design could lead to innovative solutions for ecological challenges. More quantitative study is also needed to determine the applicability of the design and designated context, particularly exploring the force of the interval so that it can be mapped more accurately. The study creates a contribution to design studies through its way of reading the interval pattern, not only as a form of visual aesthetics but also through the way it operates and influences the dynamics and functions of nature. Taking into account both the visual and operational components of the interval pattern reflectas the possibilities of an architectural design method that appreciates nature as a dynamic and ever-evolving entity instead of solely as a neutral and static background of the built form.

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