SPATIAL EVALUATION OF NATURAL AND BUILT AREA PROPORTIONS IN CORAL REEF ECOTOURISM AT PANTAI PANDAWA, BALI

I Gusti Agung Bagus Mahesha Tista Cahyanta[a] and Yusuf Ariyanto[b]
[a/b]Architecture Department, School of Creative Industry, Universitas Ciputra, Surabaya, Indonesia
Corresponding Email: yusuf.ariyanto@ciputra.ac.id[b]

ABSTRACT
Indonesia's coral reef ecosystems, particularly in Bali, are facing a degradation issue caused by climate change, pollution, and unregulated tourism, which threatens marine biodiversity and local economic resilience. Although several conservation programs have been initiated, the spatial balance between natural and built areas in coral reef ecotourism remains poorly defined, resulting in inconsistent design approaches that often overlook ecological capacity. This study addresses evaluating the optimal spatial composition and architectural features within coral reef ecotourism through a comparative case study framework. The research evaluates three international precedents: Hanauma Bay Marine Education Centre (Hawaii), Lady Elliot Island Eco Resort (Australia), and Cape d'Aguilar Marine Reserve (Hong Kong), which are selected for their preserved ecological success and effective spatial management strategies. A mixed-method analysis combining spatial quantification and qualitative evaluation was applied to identify patterns in area allocation, facility typology, and ecological integration. Results show that successful projects consistently allocate more than 70% of their total land to conservation areas and less than 30% to build facilities, with a focus on research, education, and community participation. The findings provide an evidence-based framework for developing the proposed Coral Reef Conservation Centre at Pantai Pandawa, Bali. By linking spatial proportion and ecological function, this study offers both academic and practical contributions to sustainable coastal architecture and ecotourism strategies in Indonesia.

Keywords: *Conservation Architecture, Coral Reef, Ecotourism, Spatial Proportion, Sustainable Design*

ABSTRAK
Ekosistem terumbu karang di Indonesia, khususnya di Bali, mengalami degradasi yang semakin cepat oleh sebab perubahan iklim, pencemaran laut, dan aktivitas pariwisata yang tidak terkelola dengan baik. Kondisi ini mengancam keanekaragaman hayati laut serta ketahanan ekonomi masyarakat pesisir yang bergantung pada sumber daya laut. Meskipun berbagai program konservasi telah dilakukan, keseimbangan spasial antara area alami dan area terbangun dalam ekowisata terumbu karang belum memiliki pedoman yang terukur, sehingga pendekatan desain yang dihasilkan sering kali tidak mempertimbangkan kapasitas ekologis wilayah. Penelitian ini berupaya menjawab kesenjangan tersebut dengan mengevaluasi komposisi spasial dan peran arsitektur yang optimal dalam ekowisata terumbu karang melalui pendekatan studi kasus komparatif. Tiga studi kasus internasional dipilih berdasarkan keberhasilan ekologis dan strategi pengelolaan ruangnya, yaitu Hanauma Bay Marine Education Center (Hawaii), Lady Elliot Island Eco Resort (Australia), dan Cape d'Aguilar Marine Reserve (Hong Kong). Analisis dilakukan dengan metode campuran antara kuantifikasi spasial dan evaluasi kualitatif terhadap pola zonasi, tipologi bangunan, serta integrasi ekologis. Hasil penelitian menunjukkan bahwa proyek ekowisata yang berhasil umumnya mengalokasikan lebih dari 70% luas kawasan untuk zona konservasi dan kurang dari 30% untuk intervensi bangunan yang berfokus pada edukasi, penelitian, dan partisipasi masyarakat. Temuan ini memberikan kerangka berbasis data untuk pengembangan Pusat Konservasi Terumbu Karang di Pantai Pandawa, Bali, serta menawarkan kontribusi akademik dan praktis dalam perencanaan arsitektur pesisir berkelanjutan di Indonesia.

Kata Kunci: *Desain Berkelanjutan. Ekowisata, Konservasi Asitektur, Proporsi Spasial, Terumbu Karang*

INTRODUCTION

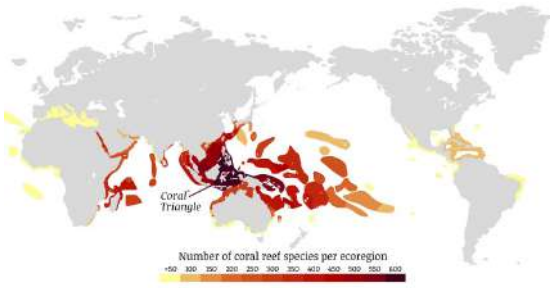

Figure 1. Indonesia As World Coral Triangle Area
Source: bluecornerconservation.org

Indonesia has abundant natural resources, one of which lies in its marine ecosystems, particularly its coral reefs, located in the world's strategic Coral Triangle, as shown in Figure 1. As one of the world's largest archipelagos, with more than 17,000 islands and a coastline exceeding 81,000 km (Ginting, 2023), Indonesia's warm tropical climate provides an ideal environment for coral growth. These reefs, formed by calcium carbonate structures produced by coral polyps, serve crucial ecological functions as habitats, breeding grounds, and feeding areas for marine organisms, while also regulating carbon dioxide levels and preventing coastal abrasion (Brandl et al., 2019; Ginting, 2023). However, these reefs are increasingly threatened by climate change, marine pollution, and oil waste (Nama et al., 2023). Coral reefs provide critical ecosystem services, supporting marine biodiversity, protecting shorelines from wave energy, and underpinning fisheries and local livelihoods. Since early 2023, the world has experienced an extreme global coral bleaching event driven by elevated sea surface temperatures. Large-scale bleaching has affected reefs across ocean basins, increasing the risk of coral mortality. In Bali, over 50% of the coral reefs are expected to be damaged by 2024, which will significantly impact marine biodiversity and the local livelihoods that depend on fishing. Pantai Pandawa, one of Bali's key coastal areas, faces both coral reef degradation and seasonal coastal erosion. Furthermore, tourism in the area has declined due to infrastructure deterioration and limited visitor facilities (Utama et al., 2024). These conditions underscore the pressing need for an infrastructure response that integrates environmental restoration with local economic revitalisation. In this context, architectural intervention should not only serve as a functional facility but also act as a mediator between human activity and ecological restoration. The challenge lies in how built environments can coexist and even contribute to natural recovery processes, an issue that calls for a deeper spatial and design evaluation.

Global and regional conservation efforts have advanced coral restoration techniques and community-based stewardship, and sustainable tourism guidelines are in place for protected and heritage sites. While many studies have discussed the environmental and economic benefits of ecotourism, limited research has addressed the spatial relationship between natural areas and built interventions within coral reef ecotourism

sites. The lack of quantitative evaluation on how architectural interventions interact with or impact natural restoration zones represents a significant research gap. Existing literature rarely explores the balance between built infrastructure and preserved ecological zones as a measurable parameter for sustainable design. Consequently, there is little guidance for architects and planners on how to proportionally allocate land use that supports both conservation and tourism goals. Addressing this gap can help define architectural strategies that are both ecologically sensitive and socially beneficial, especially in contexts where natural restoration is the foundation of tourism appeal.

This study aims to evaluate the land use of coral reef ecotourism facilities at Pantai Pandawa by assessing the proportional relationship between natural and built areas. The objectives are to identify the optimal ratio of natural preservation to architectural intervention, to propose integrated artificial ecosystems that support coral regeneration and erosion control, and to develop a design model that enhances visitor engagement through eco-marine learning activities. Academically, this study contributes a framework for evaluating and designing ecotourism spaces that balance environmental and spatial considerations. Practically, it serves as a reference for architects, policymakers, and local stakeholders in developing sustainable coastal tourism that supports both ecological conservation and community empowerment.

Definition and Principles of Ecotourism

Ecotourism is widely defined as a form of sustainable tourism that emphasizes the preservation of natural environments while enhancing understanding, appreciation, and conservation awareness among visitors (Patil, S., & Pattanshetti, M., 2024). It integrates environmental protection with socio-economic improvement by involving local communities as key beneficiaries. Five core elements define ecotourism: it is nature-based, ecologically sustainable, educational, economically beneficial to local communities, and capable of providing visitor satisfaction. According to Ariyanto (2020), the development of ecotourism can be categorised into two complementary approaches: first, conservation, which aims to protect and restore ecosystems; and second, utilisation of natural beauty as a tourism asset that supports local economic activities. The synergy between these two approaches is typically realized through zoning systems that spatially connect conservation and recreation areas. Through such integration, spatial design and circulation can be arranged to minimize environmental disturbance while maintaining functional accessibility. This principle aligns with the *International Ecotourism Society* (TIES), which emphasizes that practical ecotourism must balance the protection of natural resources with sustainable economic development through careful planning and zoning.

Typology and Architectural Characteristics of Ecotourism Buildings

Buildings in preserved ecotourism focus on both support facilities and environmental mediators. They differ from conventional tourist structures by embedding ecological, educational, and socio-cultural values in their form, materiality, and function. Sofian et al. (2017) identify several design characteristics essential to ecotourism architecture: minimising negative environmental and cultural impacts, raising visitor awareness of conservation, utilising existing infrastructure, reducing fossil energy consumption, adapting to local ecological and cultural contexts, and generating direct economic benefits for the community. In addition, Yu and Abola (2023) argue that such architecture should embody harmony with its surroundings through passive design strategies that respond to climate and landscape characteristics. Similarly, Van der Ryn & Cowan (1996) introduce the concept of *ecological design*, emphasizing five key principles: design should emerge from local context, ecological considerations must form the foundation of the creative process, natural systems should guide design logic, community participation is essential, and the design should express natural character visibly and conceptually.

Recent studies have expanded these ideas into built projects that function as both architectural and ecological systems. For example, the Green School in Bali demonstrates how vernacular materials and passive ventilation can create a low-impact educational environment (Astuti & Shania, 2024). In marine settings, reef conservation centres in Australia and the Philippines integrate elevated walkways, permeable structures, and open learning spaces to minimise interference with coastal habitats (Hobman et al., 2025). These examples demonstrate how design can extend beyond shapes to serve as an operational framework that supports ecosystem recovery, energy efficiency, and environmental education — an approach essential for coral reef ecotourism facilities.

Spatial Composition and Area Allocation in Ecotourism

Understanding the spatial balance between conservation and development areas is fundamental to sustainable ecotourism. Birawa & Sukarna (2016) conducted a study of coastal ecotourism in Katingan Kuala District, Central Kalimantan, identifying four subzones: ecotourism (15.83%), buffer (31.30%), core conservation (29.55%), and production-economic zones (23.31%). This zoning model illustrates that nearly half of the total area is dedicated to conservation-related purposes, demonstrating how spatial planning can effectively align ecological preservation with local economic needs. Zhou et al. (2025) later reinforced this finding by recommending that conservation areas should occupy the most significant possible proportion of ecotourism sites to maintain ecosystem integrity. However, they also note the importance of allocating sufficient support areas for community

welfare. Similarly, a comparative study by Blanton et al. (2024) on marine ecotourism in Malaysia and Thailand found that sites with over 60% preserved natural zones achieved higher biodiversity recovery and visitor satisfaction, illustrating that spatial ratios have a direct influence on ecological and social outcomes.

These examples demonstrate that a precise determination of area proportions, supported by policy, local management, and architectural adaptation, provides a solid foundation for successful ecotourism. In each case, the consistency between conservation zoning and built infrastructure has enabled both ecological restoration and sustained visitor engagement. This approach demonstrates that ecotourism can become a regenerative system when the scale of architectural intervention is carefully balanced with the preservation of natural zones. Applying similar strategies in Indonesia, particularly in coral reef destinations such as Pantai Pandawa, could therefore strengthen both environmental outcomes and community-driven tourism development.

The Role of Architecture in Environmental Conservation

Architecture, as part of the broader environmental system, has both a responsibility and an opportunity to foster relationships between human needs and the natural world. Other notes that architectural design must accommodate both human activities and the habitats of different species. Rechner Dika (2025) ecological design theory reinforces this idea, proposing that architecture should regenerate rather than deplete natural systems. Recent architectural research supports this argument: Kumar et al. (2025) highlight the role of *regenerative architecture*, which not only reduces negative impacts but also actively restores ecological conditions. In coastal contexts, buildings can function as artificial ecosystems by integrating coral nurseries into underwater structures, utilising porous retaining walls that reduce erosion, and incorporating floating pavilions that promote water flow.

Architecture in coral reef ecotourism, therefore, operates at the intersection of environmental, social, and educational domains. It must provide facilities for visitors while directly contributing to restoration processes through the selection of materials, structural design, and landscape integration. As La Monaca (2025) suggest, architectural intervention should be measured by its ecological performance as much as its aesthetic or economic value. For Pantai Pandawa, this perspective implies that the design of conservation and tourism facilities must establish a symbiotic relationship between the built form and the marine ecosystem it seeks to protect.

METHODS

Frameworks

This study adopts a case study and comparative research method to evaluate the design of the Coral Reef Conservation Center at Pantai Pandawa, Bali. The objective is to assess

the spatial allocation between natural and built zones by referencing successful models of coastal ecotourism design in developed countries. The methodological framework in Figure 2 is adapted from precedent-based design evaluation, which includes six main stages: identifying issues, reviewing theories, selecting case studies, analysing spatial percentages, conducting comparisons, and performing assessments (Creswell & Creswell, 2018).

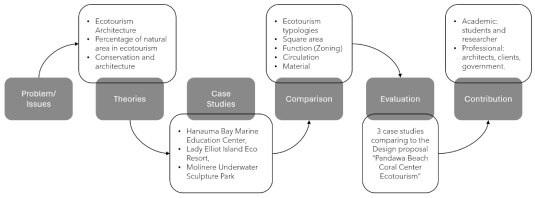

Figure 2. Research Structure
Source: Researcher's Analysis, 2025

The first stage identifies the central issue related to the spatial proportion between preserved natural areas and new architectural interventions within coral reef ecotourism projects. This phase focuses on understanding how design decisions can influence ecological balance, visitor experience, and educational outcomes in conservation-based tourism settings. The second stage involves reviewing theoretical approaches that support the design of conservation and ecotourism facilities. Theories of sustainable coastal planning, environmental carrying capacity, and restorative landscape design provide the conceptual basis for analysing the case studies. These theoretical perspectives guide the interpretation of how built environments can coexist with natural systems while maintaining ecological resilience. The third stage selects international case studies of successful coastal ecotourism projects that demonstrate effective spatial and functional balance between conservation and tourism. The selected projects include the Hanauma Bay Marine Education Centre in Hawaii, the Lady Elliot Island Eco Resort in Australia, and the Molinere Underwater Sculpture Park in Grenada. Each of these projects exemplifies different strategies in integrating architecture, education, and marine conservation within a sensitive ecological context. In the fourth stage, spatial analysis is conducted to determine the proportion of natural areas and built facilities within these case studies. This quantitative assessment focuses on measurable parameters, including land-use ratios, building coverage, and open-space percentages. The results form the basis for identifying optimal spatial thresholds for coral reef ecotourism facilities. The fifth stage compares the findings from international cases with the spatial characteristics of Pantai Pandawa. The comparison considers total site area, proportion of conservation zones, and the extent of built interventions. This step is crucial for contextualising global best practices within Indonesia's regulatory and environmental framework. The final stage evaluates the suitability of the proposed design for the Coral

Reef Conservation Center at Pantai Pandawa. The evaluation highlights how spatial allocation can improve ecological performance, enhance visitor accessibility, and foster educational engagement. The findings are expected to contribute both academically and practically, providing design recommendations for future conservation-based ecotourism projects in Indonesia.

RESULTS AND DISCUSSION

Site Context

The study will evaluate the site in the Pantai Pandawa Tourism Area, Kutuh Village, South Kuta District, Badung Regency, Bali, covering an area of 13,900 m². Geographically situated at 8.829000°S and 115.190000°E, the site is positioned between limestone cliffs and the coastline. The topography consists of hard, rocky soil with relatively flat contours. The coral reef conservation zone is located approximately 200 meters offshore, at a depth of 2–3 meters, and covers around 2.5 hectares. The site complies with spatial and building regulations as stated in *Peraturan Bupati Badung Nomor 59 Tahun 2021* concerning the Detailed Spatial Plan of South Kuta District. The regulations define maximum building coverage (KDB 30–60%), green open space (KDH minimum 30–50%), height limits (4–15 meters), and requirements for traditional Balinese architectural expression. These parameters form the physical and regulatory boundaries within which the proposed ecotourism facility will be analyzed and evaluated.

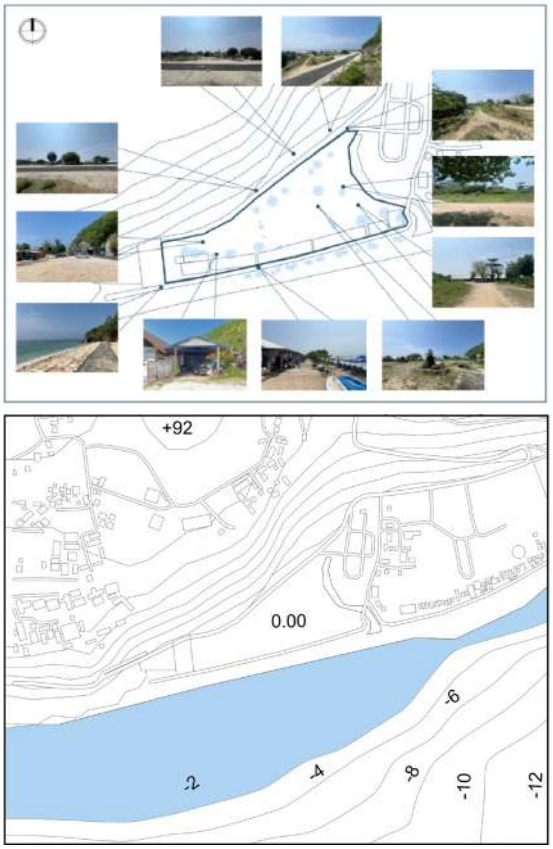

Figure 3. The Pandawa Coral Center location in Bali Island
Source: Researcher's Analysis, 2025

Case Studies

Several coastal ecotourism projects in developed countries serve as comparative references in this study, including the Hanauma Bay Marine Education Centre in Hawaii, Lady Elliot Island Eco Resort in Australia, and the Molinere Underwater Sculpture Park in Grenada. These projects were selected for their proven ability to integrate conservation and tourism through spatial and programmatic balance.

1. Hanauma Bay Marine Education Center

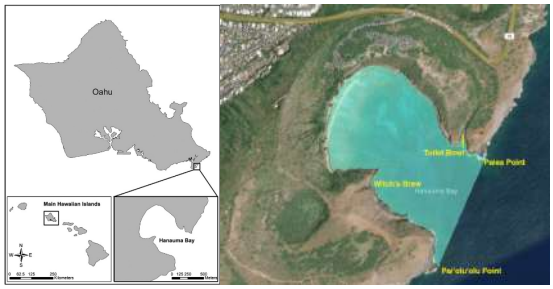

Figure 4. Hanauma Bay Marine Education Center
Source: sah-archipedia.org

The Hanauma Bay Marine Education Centre is a marine education facility located within the Hanauma Bay Marine Conservation Area, Hawaii, covering approximately 408.732 square meters. Designed by 70 International Architects, the main building occupies 753 m² and accommodates various functions, including a ticket office, gift shop, training rooms, offices, a theatre, and interpretive display areas. Additionally, a 152 m² auxiliary building provides food concessions and restrooms. The actual total area for human activities or facilities is approximately 12% total area of Bay Marine. The centre's design minimises built intervention while focusing on educational development and ecological conservation, showing a highly efficient spatial ratio between the built and natural environment. This area attracts over one million visitors annually and is the most visited marine park in the world (Beukering & Cesar, 2004). The bay was formed by two breached volcanic craters, with the seaward opening of the bay as the result of wave abrasion. The marine park features extensive coral reefs and sandy-bottom habitats, offering a diverse range of structural complexity and ecosystem types. Hanauma Bay represents a distinctive location to evaluate the relationship between a relatively intact fish assemblage and its associated habitat (Wedding et al., 2008).

2. Lady Elliot Island Eco Resort

Figure 5. Lady Elliot Island Eco Resort
Source: travelonline.com

The Lady Elliot Island Eco Resort is located at the southernmost point of the *Great Barrier Reef*, Australia. It is widely ecognized for its strong commitment to sustainability and reef conservation. The island covers approximately 450,000 square meters, consisting mainly of coral formations that support over 1,200 marine species. Built facilities occupy about 25% of the island's total area. Beyond accommodation services, the resort conducts several conservation programs, including reef health surveys and marine monitoring, which integrate tourism activities with environmental stewardship. The resort exemplifies a successful model that directly supports coral reef protection and community-based education (Piola & Johnston, 2008).

3. Cape d'Aguilar Marine Reserve, Hongkong

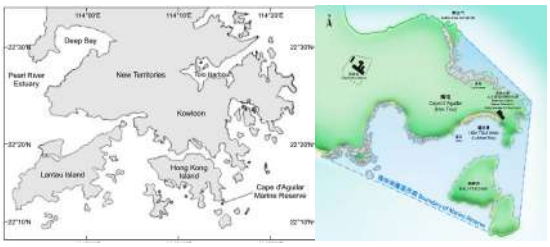

Figure 6. Cape d'Aguilar Marine Reserve Location and Area
Source: .wordpress.com, 2015

Cape d'Aguilar Marine Reserve is the only marine reserve in Hong Kong, officially designated on 5 July 1996. The reserve encompasses 20 hectares (200,000 m²) of marine and coastal environments on the southeastern tip of Hong Kong Island. Managed by the Agriculture, *Fisheries and Conservation Department* (AFCD), the site supports coral communities, rocky and sandy shores, and intertidal pools that harbour a wide diversity of marine organisms (Morton & Harper, 1995). Within or adjacent to the reserve is the *Swire Institute of Marine Science* (SWIMS), a research facility operated by the University of Hong Kong. The institute serves as the primary centre for marine biology and ecology research in the region, featuring wet laboratories, aquaria, classrooms, and accommodation for visiting researchers. While exact data on the built area is not officially published, the estimated footprint of the SWIMS complex, including the main laboratory building and associated facilities, is approximately 12.000 m², representing roughly 6% of the total reserve area.

Identification of Area Functions and Zoning in Ecotourism Sites

In coastal ecotourism, the relationship between spatial zoning and facility function determines how effectively a site supports both conservation and visitor experience, in terms of tourism or education. The architecture in such settings is not merely an addition to nature but a mediator between ecological processes and human activity. Each facility, whether for teaching, research, or recreation, has a distinct function that shapes how visitors engage with the ecosystem and how conservation goals are maintained. The success of these projects often hinges on how design and zoning align with the site's ecological sensitivity and management objectives.

At Hanauma Bay Marine Education Centre in Hawaii, the built facilities occupy a minimal percentage of the area. They are located at the entrance to control visitor flow before access to the marine reserve. The functions include ticketing, interpretation, and educational spaces that prepare visitors for responsible behavior in the protected bay. This zoning strategy minimizes physical disturbance to the coral ecosystem while maximizing its academic impact. Similarly, the Cape d'Aguilar Marine Reserve in Hong Kong places its research facilities and monitoring stations inland, away from direct interaction with coral habitats. This separation enables continuous observation and data collection without disrupting marine life, exemplifying a model of non-intrusive

ecotourism infrastructure. In contrast, the Lady Elliot Island Eco Resort integrates accommodation, educational facilities, and research labs within a compact zone that occupies about a quarter of the island's land area.

From these examples, spatial zoning and facility function in ecotourism are guided by ecological sensitivity and programmatic intention. Low-impact zones, such as those in Hanauma Bay and Cape d'Aguilar, prioritize education and monitoring, ensuring that the environment remains largely undisturbed. Mixed-use zones, such as Lady Elliot Island, however, demonstrate how controlled tourism and architectural creativity can directly support conservation through engagement and revenue generation. Therefore, facility design and zoning in ecotourism should not be viewed as competing interests, but rather as interdependent systems where built forms reinforce both ecological and educational goals.

Comparison of Natural and Built Area Proportions

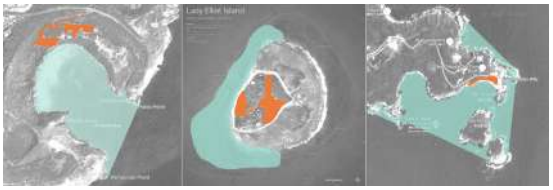

Figure 7. The Natural and Support Facilities Areas of Each Case Study
Source: Researcher's Analysis, 2025

The following table presents a comparison of spatial allocation between natural areas (cyan colour) and built interventions (orange colour) among the selected case studies, as presented in Figure 7. These proportions illustrate how successful ecotourism projects in developed countries maintain a dominant natural environment while integrating essential built facilities at a minimal scale to support education, tourism, and conservation management. To determine the boundary area of each zone, it will be easier to compare those boundaries and identify the percentage, as well as mention the type of function, in Table 1.

Table 1. Comparison of The Natural Conservation and Support Facilities Area

Case Study	Natural/ Conservation Area (%)	Built/ Facility Area (%)	Total Area	Primary Function
Hanauma Bay Marine Education Center (Hawaii)	88 %	12 %	408,732 m²	Visitor education & marine conservation
Lady Elliot Island Eco Resort (Australia)	75 %	25 %	450,000 m²	Sustainable accommodation & reef monitoring
Cape d'Aguilar Marine Reserve (Hong Kong)	94 %	6 %	200,000 m²	Marine research & ecological conservation

Source: Researcher's Analysis, 2025

In the case of Hanauma Bay and Cape d'Aguilar, the small built-up proportion demonstrates a strict conservation approach, where visitor access is highly regulated and educational functions are concentrated in compact zones. This design logic supports both ecological protection and efficient management, as controlling movement reduces direct human impact on sensitive marine environments. Conversely, Lady Elliot Island adopts a more integrated model, where a larger built portion accommodates overnight stays and actual conservation activities. This model demonstrates that slightly higher built ratios can still align with sustainability goals when development supports ecological awareness and funds ongoing restoration. The comparative data suggest that the relationship between built and natural areas is not fixed but context-dependent. Ecotourism design must respond to environmental capacity, visitor management strategies, and the expectations of the goals. However, all cases indicate that maintaining a high proportion of conserved land generally above 70% is critical to ecological resilience. The built environment's zone, therefore, is not to occupy space but to mediate understanding, serving as a bridge between human experience and natural systems. Through controlled design interventions, architecture in ecotourism becomes a form of stewardship, reinforcing rather than diminishing the value of the natural landscape.

Evaluation of the Proposed Design

Based on comparative analysis of international case studies, the proposed design of the Coral Reef Conservation Centre at Pantai Pandawa adopts a spatial and philosophical approach that integrates environmental preservation, education, and community-based tourism. The main principle drawn from successful coastal ecotourism models such as Hanauma Bay Marine Education Centre, Lady Elliot Island Eco Resort, and Cape d'Aguilar Marine Reserve is the prioritisation of natural zones over built structures. These precedents demonstrate that sustainability in ecotourism is achieved not through the scale of architecture, but through the proportionate relationship between natural ecosystems and human intervention. The proposed site planning at Pantai Pandawa reflects this principle by allocating most of its 13.900 m² area to coral reef conservation, open educational landscapes, and low-impact facilities that harmonise with the surrounding ecology.

Figure 8. The Observation of Natural Issues
Source: Researcher's Analysis, 2025

The design process begins with an on-site observation of existing physical and ecological conditions. The coastal area currently serves as a coral habitat, though parts of it have been damaged by coastal abrasion. Despite this, the site continues to support a diverse array of marine life, including mangroves and fish populations that sustain the local fishermen's livelihoods.

The *South Badung Government, Bali Province*, has expressed a commitment to conserving marine biodiversity in this region through the establishment of an ecotourism conservation initiative. However, this effort requires careful assessment because the site is also a place of community activity where fishermen dock, auction their catch, and sustain their families. The design therefore aims to improve both environmental quality and socio-economic vitality, transforming the area into a site that supports coral research, education, and tourism while maintaining the traditional livelihoods of local people.

Figure 9. Trilogi Research Aims
Source: Researcher's Analysis, 2025

The proposed development emphasises the coexistence between natural conservation and local livelihoods. Through spatial programming, the design provides distinct yet interconnected zones: a conservation zone that serves as the ecological core, an educational and research zone that facilitates knowledge exchange, and a community and tourism support zone that encourages visitor participation in sustainable activities. This tripartite division reflects a modern recontextualization of *Tri Hita Karana*, a Balinese philosophical concept that emphasises harmony among the divine (*Parahyangan*), humanity (*Pawongan*), and nature (*Palemahan*) (Irina (Mildawani et al., 2024). Within this framework, the project aspires to embody spiritual and ecological balance, representing architecture not merely as construction, but as a cultural mediator between humans and nature.

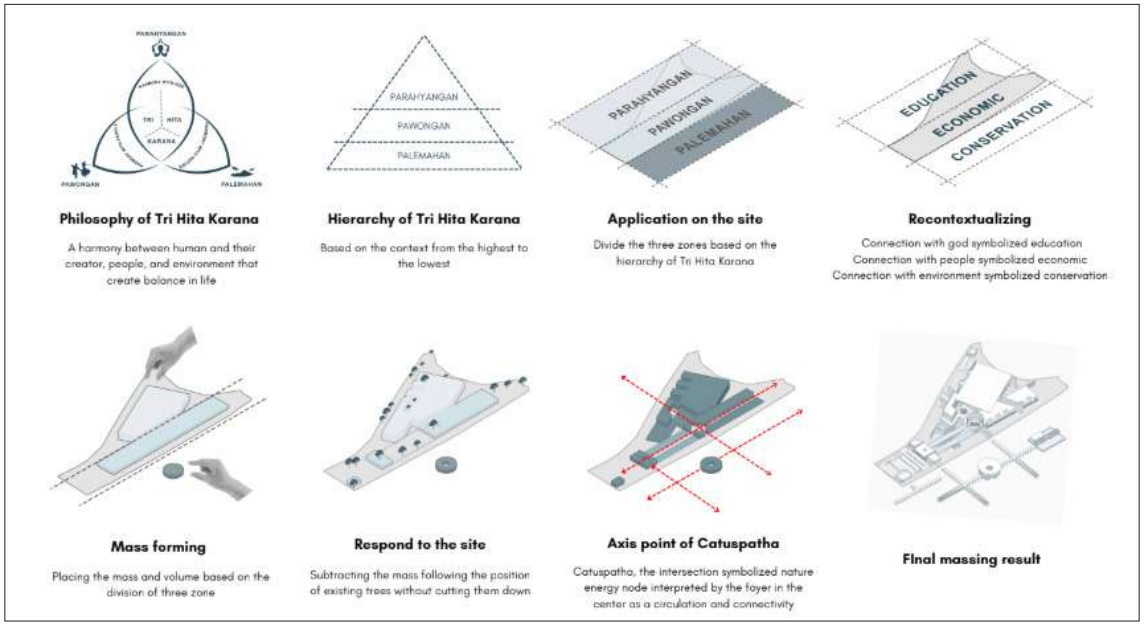

Figure 10. The Project Proposal Consept
Source: Researcher's Analysis, 2025

In applying this philosophy, the design recognizes that conservation must be accompanied by education and economic benefits. Educational programs and interpretive displays aim to raise public awareness of coral reef ecosystems and the threats they face. Tourism activities will be carefully managed to minimize ecological disturbance, utilizing controlled pathways, designated snorkelling zones, and renewable energy-based infrastructure. The built elements, estimated at around 30% of the total site area, exceed the average built proportion of the international case studies (which range between 0.22% and 25%). This difference reflects a localized adaptation, acknowledging that Pantai Pandawa serves not only as a conservation site but also functions as an educational hub and livelihood centre for nearby communities. Nevertheless, further design refinement is needed to ensure that this higher built ratio does not compromise ecological sustainability.

The evaluation results indicate that spatial optimisation will play a critical role in maintaining environmental equilibrium. Facilities such as research laboratories, interpretation centres, and tourism services must adopt low-impact construction methods, including lightweight structures, modular materials, and porous surfaces, to enhance groundwater absorption. Moreover, the architectural layout should maximise natural ventilation and daylighting to reduce energy demand, consistent with ecological design principles. The proposed artificial coral installations serving as both research media and wave barriers represent a form of adaptive design that supports reef regeneration while mitigating the effects of wave energy and abrasion. This innovation aligns with global practices seen in Lady Elliot Island's reef health monitoring systems, where architecture and ecology merge as mutually reinforcing agents of conservation and tourism.

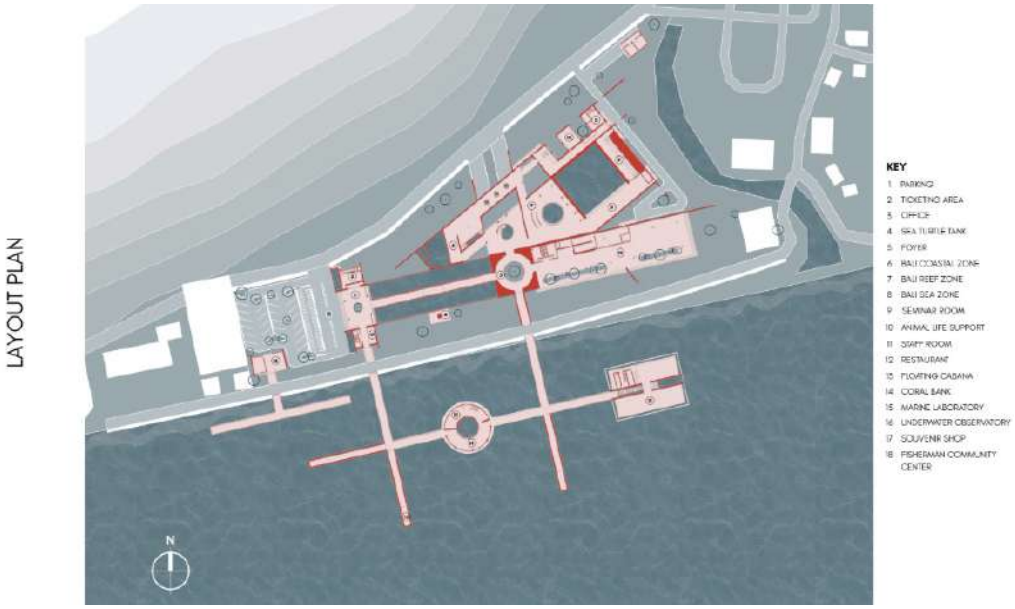

Figure 11. The Project Proposal Layout Plan
Source: Researcher's Analysis, 2025

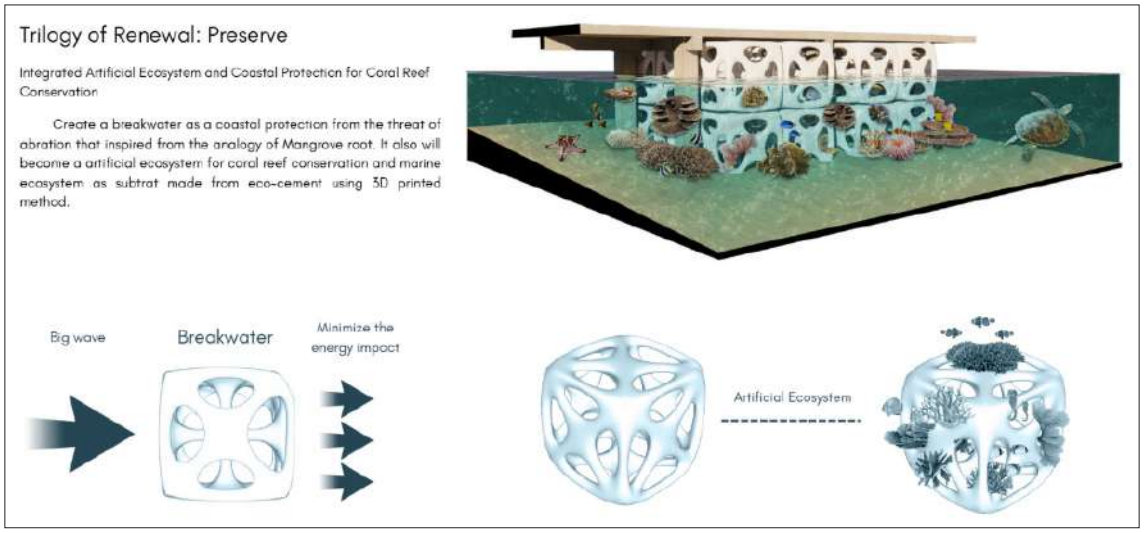

Figure 12. The Artificial Reef Concept In Natural Environment
Source: Researcher's Analysis, 2025

From a socio-cultural perspective, the proposed design reinforces the integration of local values and traditions. The architectural expression draws from Balinese vernacular elements, employing natural materials such as limestone and bamboo, which not only reduce environmental impact but also preserve visual harmony with the coastal landscape. Public spaces are envisioned as learning and gathering zones, where community members can participate in reef planting activities and environmental education, strengthening their role as custodians of the marine environment. This participatory approach ensures that the conservation project is not an external imposition, but a community-driven transformation.

Figure 13. The Research Center and Seasight Corner Design
Source: Researcher's Analysis, 2025

Economically, the design aims to revive tourism in Pantai Pandawa by establishing the site as a model of eco-educational tourism. The integration of research, tourism, and conservation is expected to diversify income sources for local people, providing opportunities in eco-guiding, craft production, and environmental management. Like international examples, economic resilience emerges when the natural environment is seen as a long-term asset rather than an exploitable resource. The Pantai Pandawa proposal, therefore, situates itself within a global discourse on sustainable coastal development, adapting international best practices to local environmental, cultural, and social conditions.

The evaluation of the proposed *Coral Reef Conservation Centre* highlights that architectural success in ecotourism hinges on contextual design. The project at Pantai Pandawa demonstrates how spatial balance, cultural philosophy, and community engagement can merge into a holistic model for marine conservation and sustainable tourism. By grounding design decisions in ecological logic and cultural identity, this proposal offers a replicable framework for future conservation developments in Indonesia and beyond.

CONCLUSION

Indonesia's coral reefs, particularly those in Bali, are facing accelerated degradation due to climate change and coastal development. Pantai Pandawa, one of Bali's premier beach tourism destinations, although ecologically rich, has experienced coral damage and economic decline due to a decrease in tourism activity. This condition establishes the contextual background for the research, which addresses a critical gap in architectural and spatial evaluation within coral reef ecotourism. Previous studies have focused on ecological or managerial aspects, but few have quantified the relationship between natural preservation and architectural intervention. The study aims to identify an optimal spatial balance that supports both coral conservation and community-based tourism.

The research adopts a comparative case study framework that encompasses international ecotourism models, including Hanauma Bay in Hawaii, Lady Elliot Island in Australia, and Cape d'Aguilar in Hong Kong. Through quantitative analysis of land-use ratios and qualitative evaluation of design strategies, the study identifies a consistent trend: successful projects maintain a dominant natural zone (75–95%) and restrict built areas to minimal, multifunctional facilities. These facilities, education centres, research labs, and low-impact accommodations demonstrate how architecture can act as a mediator between human activity and ecological regeneration. Applying these insights to Pantai Pandawa, the proposed *Coral Reef Conservation Centre* adopts a 30% built area proportion, justified by its dual role as an educational and livelihood hub, aligning international best practices with local needs.

The evaluation results indicate that spatial

optimisation and cultural integration are crucial to achieving sustainable design outcomes. Incorporating the *Tri Hita Karana* philosophy, the proposed design frames ecological zones (*Palemahan*), community spaces (*Pawongan*), and educational or spiritual facilities (*Parahyangan*) as interrelated components. This framework not only ensures environmental protection but also reinforces social participation and economic revitalisation. The architectural strategy integrates coral reef restoration infrastructure, renewable energy systems, and community learning facilities, creating a resilient model that connects design performance to measurable ecological and social benefits.

Practically, this research contributes to the development of ecotourism by providing a spatial recommendation for balancing conservation and built interventions. Academically, it advances architectural discourse on regenerative coastal design, offering a replicable analytical framework for integrating environmental metrics into spatial decision-making. The Pantai Pandawa case demonstrates that ecotourism can serve as a living system where design, culture, and ecology converge to sustain both the natural landscape and the community that depends on it.

REFERENCES

Ariyanto, Y. (2020). Sinergi Perancangan Zona Konservasi Dan Rekreasi Pada Kawasan Mangrove Pulau Galang, *Buana Sains*, 20(1), 67–74. https://doi.org/10.33366/bs.v20i1.1933

Astuti, F., & Shania, N. (2024). Penerapan Prinsip Arsitektur Berkelanjutan pada Green School Bali, *Venus: Jurnal Publikasi Rumpun Ilmu Teknik* , 2(6), 01–17. https://doi.org/10.61132/venus.v2i6.615

Beukering, P., & Cesar, H.S.J.S.J. (2004). Ecological Economic Modeling of Coral Reefs: Evaluating Tourist Overuse at Hanauma Bay and Algae Blooms at the Kihei Coast, Hawai'i. *Pacific Science* 58(2), 243-260. https://dx.doi.org/10.1353/psc.2004.0012

Birawa, C., & Sukarna, R. M. (2016). Zona Ekowisata Kawasan Konservasi Pesisir di Kecamatan Katingan Kuala, Kabupaten Katingan, Provinsi Kalimantan Tengah Melalui Pendekatan Ekologi Bentang Lahan, *Jurnal Ilmu Kehutanan*, 10(1), 19. https://doi.org/10.22146/jik.12628

Blanton, A., Ewane, E. B., McTavish, F., Watt, M. S., Rogers, K., Daneil, R., Vizcaino, I., Gomez, A. N., Arachchige, P. S. P., King, S. A. L., Galgamuwa, G. A. P., Peñaranda, M. L. P., al-Musawi, L., Montenegro, J. F., Broadbent, E. N., Zambrano, A. M. A., Hudak, A. T., Swangjang, K., Valasquez-Camacho, L. F., Vorenberg, J. H. P., Srinivasan, S., Abdullah, M. M., Charabi, Y. A. R., Wan Mohd Jaafar, W. S., Musa, F., Sidik, F., Al-Awadhi, T., Ali, T., Doaemo, W., & Mohan, M. (2024). Ecotourism and mangrove conservation in Southeast

Asia: Current trends and perspectives, *Journal of Environmental Management*, 365, 121529. https://doi.org/10.1016/J.JENVMAN.2024.121529

Brandl, S. J., Rasher, D. B., Côté, I. M., Casey, J. M., Darling, E. S., Lefcheck, J. S., & Duffy, J. E. (2019). Coral reef ecosystem functioning: eight core processes and the role of biodiversity. *Frontiers in Ecology and the Environment*, *17*(8), 445-454. https://doi.org/10.1002/fee.2088

Creswell, J. W., & Creswell, J. David. (2018). *Research design : qualitative, quantitative, and mixed methods approaches*, SAGE Publications, Inc., 275.

Ginting, J. (2023). Analisis kerusakan terumbu karang dan upaya pengelolaannya. *Jurnal Kelautan dan Perikanan Terapan (JKPT)*, *1*, 53-59.https://doi.org/10.15578/jkpt.v1i0.12066

Hobman, E. V., Dyer, M., Stone-Jovicich, S., Newlands, M., Schultz, T., Maclean, K., Benham, C., Jones, N., and Dean, A. J. (2025). Understanding & monitoring Reef stewardship: a conceptual framework and approach for the Great Barrier Reef, *Australasian Journal of Environmental Management*, 32(1), 65–85. https://doi.org/10.1080/14486563.2024.2439839

Kumar, S., Sakagami, K., and Lee, H. P. (2025). Beyond Sustainability: The Role of Regenerative Design in Optimizing Indoor Environmental Quality, *Sustainability*, 17(6), 2342. https://doi.org/10.3390/su17062342

La Monaca, F. (2025). The Construction Site as Ecological Laboratory, *International Theory and Practice in Humanities and Social Sciences*, 2(7), 155–169. https://doi.org/10.70693/itphss.v2i7.1096

Mildawani, I., Asmiwyati, I. G. A. A. R., Apriyanti, R., Prabawasari, V. W., & Akhirson, A. (2024). The Application of Tri Hita Karana Principles in Landscape Architecture and Urban Planning: A Case Study of Kedonganan Traditional Village, Bali. *EVOLUTIONARY STUDIES IN IMAGINATIVE CULTURE,* 869–878. https://doi.org/10.70082/esiculture.vi.741

Morton, Brian., and Harper, Elizabeth. (1995). *An introduction to the Cape d'Aguilar Marine Reserve, Hong Kong*, Hong Kong University Press, 100.

Nama, S., Shanmughan, A., Nayak, B. B., Bhushan, S., & Ramteke, K. (2023). Impacts of marine debris on coral reef ecosystem: A review for conservation and ecological monitoring of the coral reef ecosystem, *Marine Pollution Bulletin*, 189, 114755. https://doi.org/10.1016/J.MARPOLBUL.2023.114755

Patil, S., & Pattanshetti, M. (2024). The role of ecotourism in sustainable development: A comprehensive systematic review.https://doi.org/10.21203/rs.3.rs-4843585/v1

Piola, R. F., & Johnston, E. L. (2008). The potential for translocation of marine species via small-scale disruptions to antifouling surfaces, *Biofouling*, 24(3), 145–155. https://doi.org/10.1080/08927010801930480

Rechner Dika, I. (2025). Are Ecological Design Principles Becoming the Norm in Contemporary Landscape Design? A Comparative Analysis of Realized Park Projects (2015–2025), *Sustainability*, 17(14), 6620. https://doi.org/10.3390/su17146620

Sofian, T., Sudradjat, I., & Tedjo, B. (2017, October). Sensible architecture: bamboo ecotourism and community development in Indonesia (case study: Ubud, Bali, and Tentena, Poso). In *Proceedings of the 6th International Conference of Arte-Polis: Imagining Experience: Creative Tourism and the Making of Place* (pp. 245-254). Singapore: Springer Singapore.https://doi.org/10.1007/978-981-10-5481-5_24

Utama, I. G. B. R., Suardhana, I. N., Sutarya, I. G., & Krismawintari, N. P. D. (2024). Assessing the impacts of overtourism in Bali: Environmental, socio-cultural, and economic perspectives on sustainable tourism. *TourismSpectrum: Diversity & Dynamics*, *1*(2), 10-56578.https://doi.org/10.56578/tsdd010202

Van der Ryn, Sim., & Cowan, Stuart. (1996). *Ecological design*, Island Press, 201.

Wedding, L. M., Friedlander, A. M., McGranaghan, M., Yost, R. S., & Monaco, M. E. (2008): Using bathymetric lidar to define nearshore benthic habitat complexity: Implications for management of reef fish assemblages in Hawaii, *Remote Sensing of Environment*, 112(11), 4159–4165. https://doi.org/10.1016/j.rse.2008.01.025

Yu, Y., & Abola, M. (2023, August). Ecological Architecture-A Perfect Interpretation of the Harmonious Coexistence of Architecture and Nature. In *2023 2nd International Conference on Urban Planning and Regional Economy (UPRE 2023)* (pp. 302-306). Atlantis Press.https://doi.org/10.2991/978-94-6463-218-7_34

Zhou, J., Li, X., Liu, Y., Niu, J., Wu, N., and Lu, T. (2025): The minimum land areas required for maximizing biodiversity conservation, *Biological Conservation*, 302, 110943. https://doi.org/10.1016/J.BIOCON.2024.110943