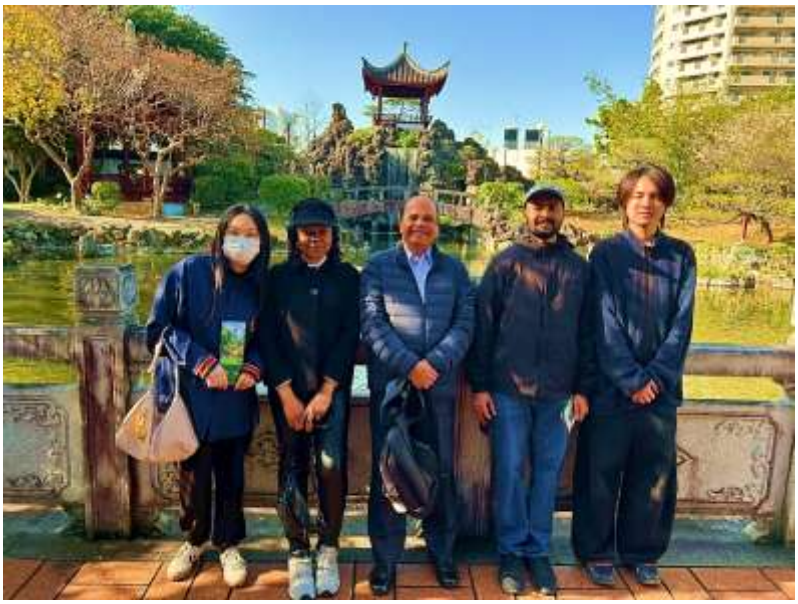
Report of the Research Retreat at Okinawa, January 26-29, 2026

I. Introduction

This field visit to Okinawa was designed to explore the dynamic relationship between environment and development within an island context shaped by ecological vulnerability, tourism dependence, and resource constraints. Over the course of the research retreat we engaged in our thesis progress presentations, visited TRIM Co., Ltd., Bise Fukugi Tree Road, Gangala Valley, and Okinawa Churaumi Aquarium. The presentations offered us a chance to understand each other's work, engage in dialogue based on our study and deepen our clarity and focus. Each site provided a distinct perspective on how environmental systems intersect with economic activity, cultural heritage, and technological innovation.

At TRIM, we examined an industrial model of circular economy in which waste glass is transformed into Supersol, a value-added construction material that addresses landfill pressures and supports infrastructure development. The Bise Fukugi Tree Road illustrated community-based environmental adaptation, where traditional windbreak forests serve both ecological and socio-cultural functions. At Gangala Valley, we observed the conservation of a limestone forest ecosystem and archaeological landscape that has been integrated into eco-tourism without extensive ecological disturbance. Finally, The Churaumi Aquarium offered insight into marine biodiversity conservation, environmental education, and the economic role of large-scale tourism infrastructure.



Together, these sites represent complementary dimensions of the environment–development nexus: industrial innovation, ecosystem conservation, tourism-based development, and traditional ecological knowledge. The visit provided an opportunity to critically assess our research progress, and to understand better how Okinawa balances environmental stewardship with economic growth, particularly within the constraints of island geography and climate exposure.

II. TRIM Co., Ltd., Glass Recycling Factory

The visit to the TRIM Co., Ltd. provided a valuable opportunity to observe how industrial ecology principles are implemented in practice within an island economy facing spatial and resource constraints. The facility's production of *Supersol*, a lightweight porous construction

material derived entirely from recycled waste glass, offers a case study of how environmental challenges can be transformed into development opportunities. This report documents the production process, applications, and sustainability implications of Supersol, while also analyzing the broader environment–development nexus embodied in this model. It further examines the feasibility of scaling such a system to other countries where similar recycling infrastructure does not yet exist.

Regional Context and Waste Management Challenges

Okinawa's geographic position as a remote island prefecture presents structural challenges for waste management. Limited landfill capacity, high transportation costs to mainland Japan, and increasing urbanization intensify pressure on disposal systems. Glass waste, though chemically stable, is bulky and non-biodegradable, occupying valuable landfill space without decomposing. Rather than treating waste glass as a terminal by-product, TRIM has transformed it as a secondary raw material. This shift reflects a broader transition from a linear use and dispose model to a circular production framework. In an island context where importing construction aggregates and exporting waste are both costly, the localization of material cycles becomes economically and environmentally strategic. The facility thus addresses two development imperatives simultaneously: reducing environmental burdens and strengthening regional industrial capacity.

Supersol Production Process and Technological Innovation

The Supersol production process is both technically sophisticated and conceptually simple. Waste glass collected from municipal and industrial streams is first sorted to remove contaminants such as metals or ceramics. The glass is then crushed and pulverized into a fine powder to ensure uniform particle size. The powdered glass undergoes high-temperature heating in a controlled furnace environment. During this stage, a proprietary foaming mechanism introduces gas bubbles into the molten material, causing it to expand and form a porous internal structure. Upon cooling, the material solidifies into a lightweight, foam-like aggregate characterized by closed pores, chemical stability, and high compressive strength relative to its weight. The resulting product – Supersol- is significantly lighter than conventional aggregates. Its structural properties allow it to serve as a substitute for natural gravel and soil in various engineering applications. From an industrial ecology perspective, this transformation of inert waste into high-value infrastructure material demonstrates material upcycling rather than simple recycling.

Applications and the Environment–Development Nexus

The visit highlighted multiple applications of Supersol in civil engineering, urban development, and environmental management. In infrastructure projects, its low density reduces load pressure on weak or unstable soils, making it particularly useful in embankments, bridge approaches, and coastal constructions. In a region susceptible to typhoons and heavy rainfall, such characteristics enhance infrastructure resilience. Supersol is also used in green roofs, landscaping, and soil improvement due to its porous structure, which supports drainage and root aeration. These applications integrate built environments with ecological considerations, illustrating how development interventions can incorporate environmental design principles. Additionally, the material has potential use in filtration systems and agricultural soil conditioning and acting as maintenance materials during disasters.

The environment–development nexus is clearly visible in this case. Environmental protection is achieved through waste reduction and reduced reliance on virgin aggregate extraction. Simultaneously, economic development is supported through technological innovation, job creation, and the establishment of a specialized materials industry. Rather than positioning environmental regulation as a constraint on growth, the Supersol model demonstrates how ecological limits can stimulate innovation-driven development. While the environmental benefits are evident, a full evaluation of the system requires attention to lifecycle energy use and economic viability. The high-temperature heating process consumes energy, and its overall carbon footprint depends on the energy mix powering the facility. If fossil fuels dominate the electricity supply, emissions reductions from avoided landfill use must be carefully quantified to assess net benefits.

However, several factors strengthen the lifecycle case for Supersol. The reduced weight of the material lowers transportation emissions in construction projects. The avoidance of virgin aggregate extraction reduces ecological degradation and embodied energy in mining. Additionally, the diversion of glass waste from landfills avoids long-term storage impacts. The economic viability of the model depends on market demand for lightweight construction materials and supportive procurement policies that encourage recycled material use. In Okinawa, the specific geotechnical conditions create natural demand, enhancing feasibility.

Contribution to Sustainable Development Goals

During our discussion in the evening, we looked into how the Supersol system aligns with several global sustainability objectives. By promoting recycling-based industrial innovation, it supports the goals of sustainable industry and infrastructure development. Its contribution to

waste reduction and material circularity directly advances responsible consumption and production patterns. Through its application in resilient construction and green urban systems, it indirectly contributes to sustainable cities and climate adaptation efforts. Moreover, the reduction of landfill waste and the decreased extraction of natural aggregates reduce pressure on terrestrial and marine ecosystems. In an island context where ecological carrying capacity is limited, these contributions are particularly significant.

Scalability and Replicability in Other Countries

We also studied the scalability of this model in countries where similar facilities do not exist. Replication potential varies according to several structural conditions.

First, waste stream composition and collection systems are crucial. In many Global South contexts, informal recycling networks already collect valuable materials such as metals and plastics, but glass often has low resale value. Establishing a Supersol-type facility would require reliable and clean glass supply chains. Formal–informal integration models could play a role here, ensuring both material flow and livelihood support.

Second, energy infrastructure matters. The heating process requires stable electricity or fuel supply. In countries with unreliable power systems, production costs could increase significantly. However, coupling such facilities with renewable energy systems could enhance sustainability and reduce operational costs over time.

Third, construction sector demand is essential. Regions facing rapid urbanization, weak soils, coastal vulnerability, or landfill scarcity may find strong utility in lightweight recycled aggregates. Policy instruments such as green procurement standards, landfill taxes, or recycled content mandates could stimulate market uptake.

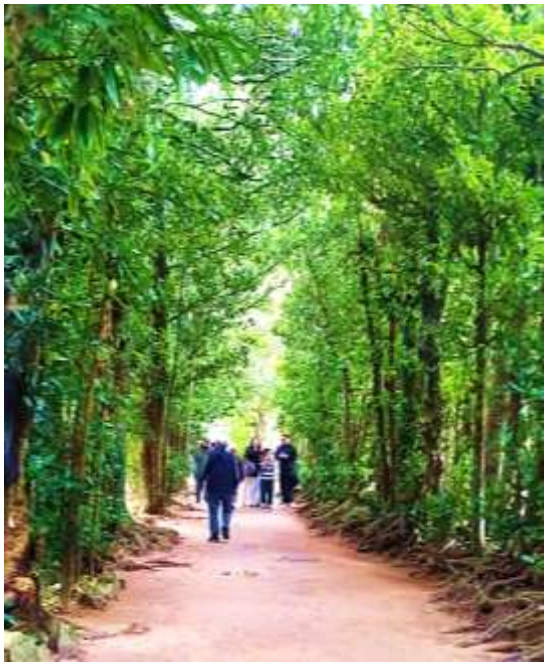
Fourth, initial capital investment and technological expertise may pose barriers. Public–private partnerships, concessional financing, or technology transfer agreements could support implementation. Pilot-scale facilities could test feasibility before large-scale rollout.

Despite these challenges, the model holds strong relevance for small island developing states and rapidly urbanizing coastal regions. Where landfill space is limited and aggregate extraction causes ecological damage, converting waste glass into construction material offers a dual environmental and developmental solution.

Essentially, the field visit to TRIM Co., Ltd. demonstrated how innovative recycling technologies can bridge environmental protection and economic development. By transforming waste glass into Supersol, the company exemplifies circular economy principles in action within an island context marked by spatial constraints and ecological sensitivity. The case illustrates that environmental limitations can catalyze industrial innovation rather than inhibit growth. Supersol's applications in resilient infrastructure, green urban design, and soil stabilization reveal how waste management strategies can contribute to broader development objectives. While replication in other countries would require careful adaptation to local institutional, energy, and market conditions, the model offers significant promise particularly for regions facing landfill scarcity and construction material shortages. Ultimately, the Supersol system provides an instructive example of how environmental challenges, when approached through technological innovation and policy alignment, can become engines of sustainable development rather than obstacles to it.

III. Bise-Fukugi Tree road

A visit at the bise-fukugi tree road, a very popular scenic spot in the village of Bise situated close to the Okinawa Aquarium provided us with a comprehensive understanding of sustainable coexistence between environmental conservation, culture, and tourism. We learned that the fukugi tree (*Garcinia subelliptica*), an evergreen tropical tree first identified in the Philippines, was introduced to Okinawa from Southeast Asia more than three hundred years ago.



The Planting structure as a touristic attraction

The tree road runs into the village with fukugi trees planted in rows that delineate the limits of each homestead, which joins up to create a criss-cross pattern of row upon row of trees known as "fukugi namiki". This pattern shapes into a natural tunnel with a dense cold shade canopy of the trees which offers a special beautiful and unique walking space for tourists. During our visit, the in-and-out flow of visitors was true evidence of this attraction site.

Environmental protection and conservation

We understood that the row planting characterised by compact upright form of straight trunks and dense clusters of its elliptical thick leathery glossy leaves forms a protective barrier which has been used by local residents as a longstanding tradition for centuries to protect their homes from strong winds and salt damage from the nearby ocean. This protective function has in turn fostered an active historical usage which has contributed to the conservation of this tree and like other trees, have a high potential for biomass accumulation, carbon sequestration, and climate change mitigation.

The cultural connection

However, the Fukugi trees not only serve as a touristic, protective or environmental conservation function but also portrays a deep historical and cultural depth of this settlement as the trees are a tangible sign to the traditional Okinawan way of life, which is closely connected to nature and sustainability. Moreover, we also learned that the heartwood and bark of these trees are used to extract the yellow dye essential to Okinawa's traditional Ryūkyū bingata stencilled textiles and tsumugi silk which is a strong cultural aspect of the people.

Fukugi dyeing class for the aged people group

Source: Bixia Chen and Hikaru Akamine (2021)

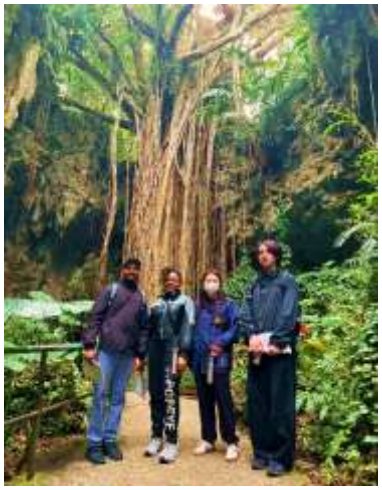
IV. The Gangala Valley

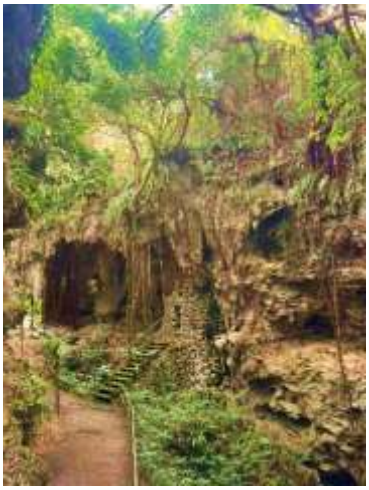
During this Okinawa research trip, we visited Gangala Valley in the Nanjo City area. This site is not merely a tourist attraction; rather, it is an integrated field where limestone caves and a collapsed valley landform, subtropical forest ecology, and human-history narratives related to cave sites are interwoven into a single spatial experience. Its research significance lies in the fact that visitor experiences are organized through a fully reservation-based guided tour system, and "interpretation and communication" functions as the core mechanism of the tourism product. In this way, the site achieves a relatively sustainable reconciliation between tourism use and nature conservation.

The tour begins inside a cave, where the guide first explains the geological and geomorphological background before leading participants along a fixed route into the valley forest. Because the environmental system here is relatively enclosed and sensitive, how visitors enter and how they move constitutes an essential part of the conservation mechanism itself. Once inside the valley, the route, group pace, and stopping points are all controlled by the guide, making the visit closer to an organized field interpretation rather than a free-form sightseeing experience. This tour structure and content also correspond to descriptions in related studies: guided tours typically start with geological and geomorphological interpretation in the cave,

continue with observations of flora and fauna and visits to sites associated with local folk beliefs, and finally connect at the terminal cave to traces of Paleolithic habitation and relevant research findings.

Regarding the site's opening and management background, the guide noted that Gangala Valley has not always been open in its current form; it was reopened to the public only after a period of closure and environmental recovery. The literature likewise states that the site was once closed due to river environmental problems, and that it was reopened in August 2008 under a fully reservation-based guided tour model. Therefore, reservations, controlled group entry, and fixed routes should not be understood merely as service designs to enhance visitor experience; they can also be interpreted as institutionalized management choices that control ecological externalities and environmental risks.





Sustainable Tourism through Conservation & Historical Exploration

Based on our field experience, we discussed in the evening on Gangala Valley's distinctive feature that its tourism experience relies on interpretation as a core mechanism, rather than depending solely on the visual appeal of the landscape. When the significance of the site is clearly explained, visiting rules are more likely to be internalized as visitors' self-regulated behaviors (e.g., not crossing boundaries, not separating from the group, and not lingering excessively in sensitive areas), thereby embedding conservation objectives within the experience itself.

From a broader perspective, however, there is a structural gap in Okinawa between resources being recognized, organized, and protected. Research indicates that information on natural environmental resources in northern Okinawa has long been fragmented and requires systematic organization and database development. After compiling and de-duplicating multiple sources, the researchers identify a total of 143 natural environmental resources, yet only 12 have been officially designated by the national government, prefecture, or municipalities as historic sites, places of scenic beauty, or natural monuments. This result suggests that the difficulty of sustaining protection for many natural resources is not simply a matter of low public visibility; it is also related to whether their value-related information is effectively organized, interpreted, and communicated. In this sense, Gangala Valley's guided tour functions, to some extent, as an on-site integrative device that translates dispersed

knowledge - geology, ecology, and human history - into a comprehensible narrative framework, thereby improving public understanding and strengthening conservation motivation.

In conclusion, Gangala Valley illustrates a relatively ideal pathway for conservation-oriented tourism. Rather than relying on large-scale development to generate attractiveness, it integrates conservation objectives into the visitation process through a reservation-based guided tour system and narrative design. By structuring geological, ecological, and human-history information into an accessible experiential framework, the site enhances public recognition and reinforces conservation incentives. This case suggests that, for tourism development in environmentally fragile settings, the key lies in reducing externalities through institutionalized management and high-quality interpretive mechanisms, and in ensuring the consistent realization of conservation principles at the level of visitor experience.

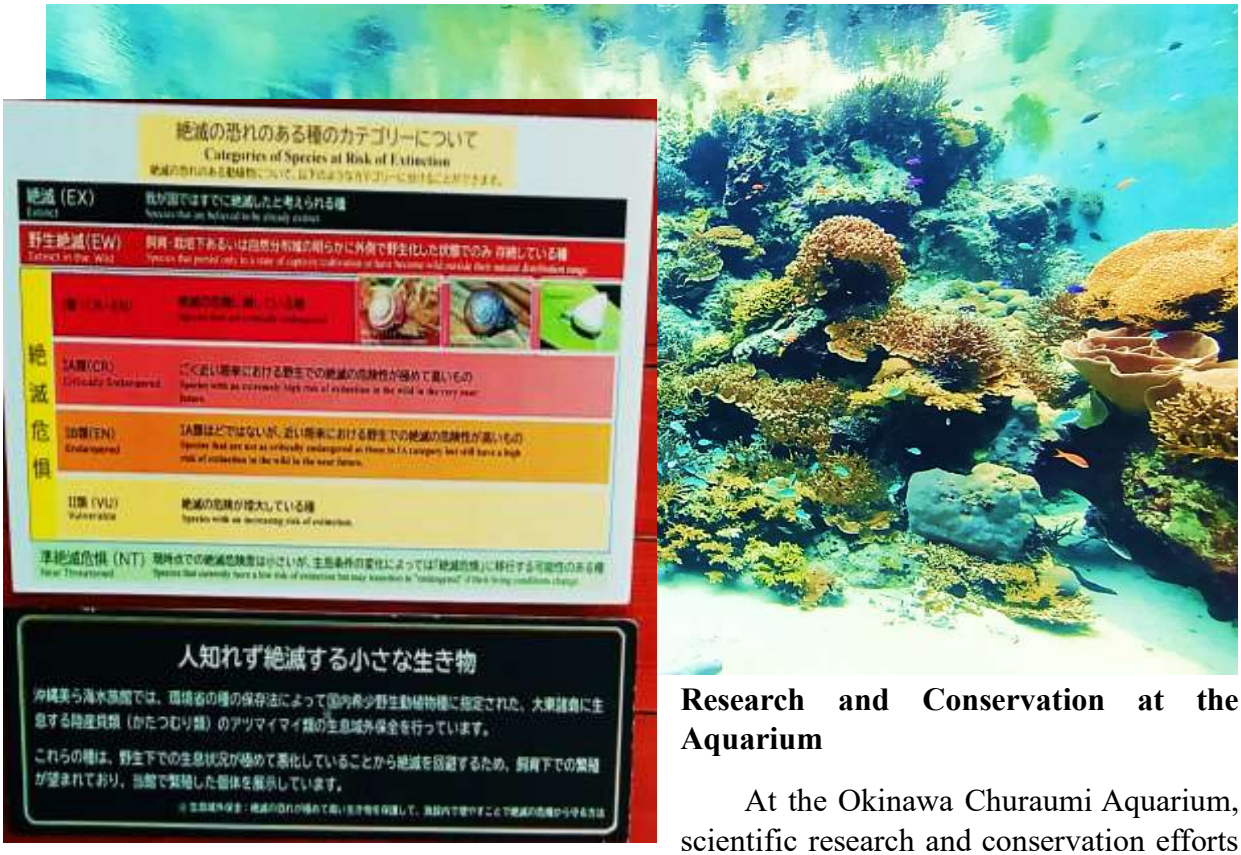
V. The Churaumi Aquarium

The Okinawa Churaumi Aquarium, located in the heart of the Ocean Expo Park in Motobu City, Okinawa Prefecture, is a centre of marine conservation and environmental education. It is undoubtedly an architectural marvel boasting the world's second-largest acrylic panel aquarium. This enormous aquarium, reaching a depth of 7.5 meters and holding 750,000 litres, provides a natural habitat for the largest fish on Earth - the majestic whale shark.

We were fortunate to observe these magnificent creatures up close, deepening our understanding of the delicate balance of marine life and ecosystems. The aquarium's design simulates the natural marine environment, including proper water circulation, temperature control, and lighting, ensuring the health of these whale sharks.

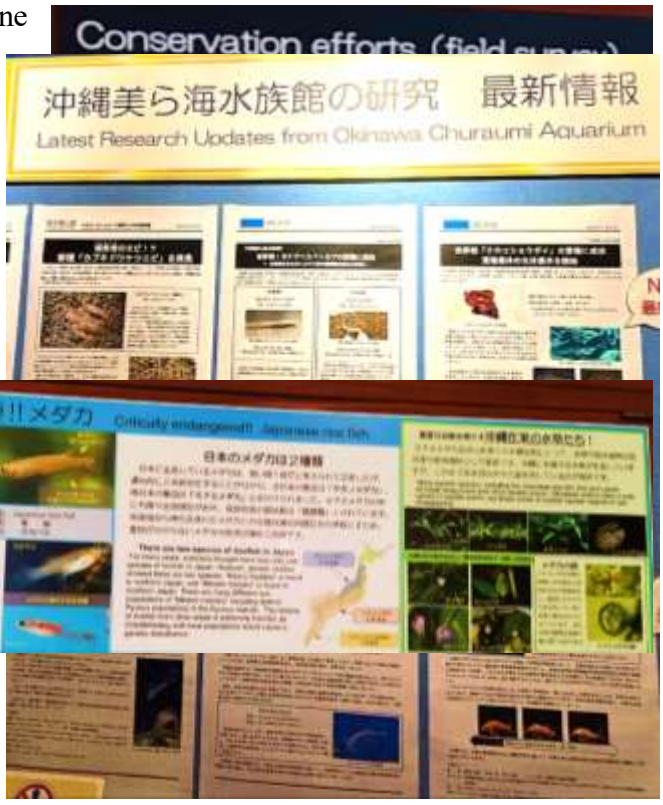
Furthermore, the aquarium showcases extensive marine biological research, contributing to endangered species breeding programs and actively participating in global conservation efforts. We gained a deeper understanding of sustainable fishing practices and the impact of climate change on marine ecosystems particularly on the coral reefs. We also

gained a better understanding of the crucial role the ocean plays in maintaining the Earth's ecological balance and the positive actions we, as individuals, can take to contribute to it.



Research and Conservation at the Aquarium

At the Okinawa Churaumi Aquarium, scientific research and conservation efforts are integral to its mission of protecting marine biodiversity and promoting sustainable use of the surrounding natural environment. Staff and affiliated researchers from the Okinawa Churashima Foundation conduct long-term ecological studies on tropical and subtropical marine organisms, focusing on species diversity, physiological and ecological processes, and population dynamics of coral, fish, sea turtles, sea grass, sharks, and other marine fauna in the Okinawan region. These programs include both in-situ field surveys and ex-situ research such as captive breeding, genetic analysis, and behavioural tracking, which have yielded peer-reviewed publications on species such as Hydrophis Sea snakes and reproductive ecology of green and loggerhead turtles, among others, contributing to broader conservation science. Comprehensive monitoring of sea turtles' ingestion of marine debris and coral reef habitat assessments informs ecosystem management and public awareness campaigns about human impacts on marine life.

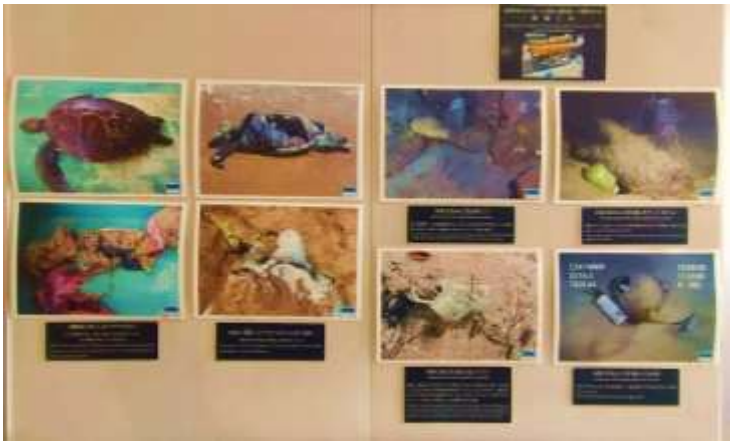


In addition, collaborative research on large elasmobranchs (e.g., whale sharks and manta rays) and marine mammal health using tagging and physiological measurements support both species conservation and global understanding of endangered marine taxa. Through this multifaceted research portfolio – including surveys, genetic and physiological studies, and long-term monitoring – the aquarium plays a vital role in linking empirical science to conservation policy and education in the region.

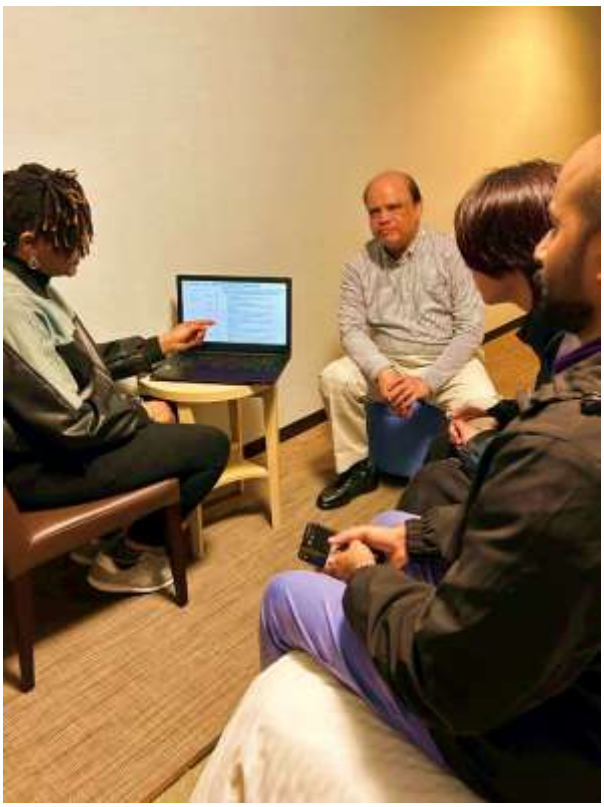
The aquarium also engages with the Sustainable Development Goals in its own unique way. It contributes to Goal 14: Underwater Life – through conservation efforts, research, and public education on marine ecosystems; Goal 4: Quality Education – providing immersive learning experiences to foster environmental awareness; Goal 13: Climate Action – raising public awareness of the impacts of climate change on the marine environment; Goal 12: Responsible Consumption and Production – promoting sustainable tourism practices and responsible resource use; and Goal 17: Partnerships to Achieve Goals – collaborating with global organizations to advance marine conservation.

While the aquarium and the Ocean park as a whole offer a great tourist attraction complemented with conservation efforts, the ecological footprint and energy usage that contribute to emissions may be a concern. Balancing the developmental initiatives with sustainable conservation strategies is crucial. This visit was not only a close-up experience with marine ecosystem for us, but also a rare opportunity to delve deeper into ecological conservational practices at the aquarium and understand the delicate ecological equilibrium that sustains life under water.

VI. Thesis Progress presentations and Evening Reflections



During the field visit, each of the four students delivered a structured thesis progress presentation of approximately forty-five minutes, outlining their research questions, conceptual frameworks, methodology, preliminary findings, and key challenges encountered thus far. The presentations created a reflective academic space within the field setting, allowing theoretical work to be discussed alongside real-world observations. Following each presentation, the professor and fellow students provided constructive feedback on research design, data collection strategies, analytical approaches, and theoretical positioning. Particular attention was given to refining research gaps, strengthening methodological rigor, and clarifying the contribution of each thesis to broader environmental and development debates. The session turned out to be a greatly beneficial, collaborative knowledge-sharing platform, enabling peer learning, critical engagement, and clearer direction for the next stages of thesis development.



Along with these discussions we also had a reflective session on the places we visited during the day regarding their ecological, conservational, developmental impacts and how they contributed to the Sustainable Development Goals. These sessions enabled us to critically analyse our experiences in the light of our own theses and broaden our perspectives listening to each other.

VII. Conclusion

The field visits collectively highlighted that sustainable development in Okinawa is not defined by a single model but by a spectrum of approaches responding to different environmental and economic realities. At TRIM, environmental protection emerges through technological innovation and circular production systems that convert waste into infrastructural value. The Bise Fukugi Tree Road reflects long-standing community adaptation strategies, where environmental design- such as windbreak tree planting - serves both protective and cultural purposes. In Gangala Valley, conservation is integrated with tourism in a way that maintains ecological integrity while generating income and environmental awareness. Meanwhile, The Churaumi Aquarium demonstrates how large-scale tourism infrastructure can support marine research, conservation, and regional economic vitality, while also raising questions about energy use and ecological footprint. Taken together, these experiences illustrate that the environment–development nexus operates at multiple scales: from industrial processes to ecosystems, from global tourism networks to localized traditional practices. Okinawa's case shows that environmental vulnerability can become a catalyst for innovation, conservation, and adaptive design rather than merely a developmental constraint. At the same time, the visits underscore the importance of critically evaluating energy use, commercialization pressures, and long-term ecological impacts. The thesis progress presentations enabled genuine sharing of feedbacks, support for further research direction and a certain clarity of overall structure.

Ultimately, the field study reinforced the idea that sustainable development requires integration of technology with ecology, tourism with conservation, and tradition with modern planning. Okinawa offers a nuanced example of how diverse environmental strategies can coexist within a small island context, providing lessons relevant to other coastal and island regions navigating similar environmental and developmental challenges.

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