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Bren School of Environmental Science & Management

UNIVERSITY OF CALIFORNIA
Santa Barbara

Surf Protected Areas: Bridging Conservation, Communities, and Sustainable Development in Western Sumatra, Indonesia

by

Miranda Scalzo - Project Manager
Manuela Diaz - Project Manager
Sofia Gutierrez - Research Manager
Ryan Anderson - Data Manager & Financial Manager
Emma Tao - Communication Manager

Committee in charge:
Hunter S. Lenihan - Professor, Applied Marine and Fisheries Ecology

Clients:
Marissa Miller - Conservation International, Surf Conservation Senior Coordinator
Scott Atkinson - Conservation International, Surf Conservation Senior Director

March 2025

A Group Project submitted in partial fulfillment of the requirements for the degree of Master of Environmental Science and Management for the Bren School of Environmental Science & Management, University of California, Santa Barbara

Surf Protected Areas: Bridging Conservation, Communities, and Sustainable Development in Western Sumatra, Indonesia

As authors of this Group Project report, we archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

Ryan Anderson

Manuela Diaz

Sofia Gutierrez

Miranda Scalzo

Emma Tao

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

Faculty Advisor: Hunter S. Lenihan

Date

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To-Do Abstract

Acknowledgements

This Group Project was made possible by the unwavering support of many individuals and organizations. We are grateful to our clients, Scott Atkinson and Marissa Miller, for their collaboration and guidance throughout this process. We also extend our sincere thanks to our faculty advisor, Hunter Lenihan, and our external advisors, Andrew Plantinga and Ana Manero, for their expertise. We are especially appreciative of the knowledge and support of the Konservasi Indonesia team. Furthermore, we would like to acknowledge the additional support of Christopher Costello, Mauricio Collado and the many other Bren faculty and staff who helped us along the way. We would also like to thank Brian R. Crawford from the University of Rhode Island for generously sharing his data for use in this project. And of course, we are grateful to the Bren School of Environmental Science & Management at UC Santa Barbara for providing the foundation, resources, and community that made this work possible.

Crawford et al. Data:
Historical data from North Sulawesi provided by the University of Rhode Island and collected with funding support from the US Agency for International Development.

List of Acronyms

CI	Conservation International
KI	Konservasi Indonesia
SPA	Surf Protected Area
SPAN	Surf Protected Area Network
SCI	Surf Conservation Index
MPAs	Marine Protected Areas
LMMA	Locally Managed Marine Area
ILMMA	Indonesia Locally Managed Marine Area Foundation
KBAs	Key Biodiversity Areas
TEV	Total Economic Value
WTP	Willingness To Pay

Project Objectives

1. **Objective 1 | Current Value of Surf Ecosystems:** Identify and map surf ecosystems in western Sumatra, Indonesia. Characterize the current state and natural value of these areas using the Surf Conservation Index (SCI) and associated values.

2. **Objective 2 | Multidimensional Costs Analysis:** Quantify multidimensional costs of protecting surf ecosystems, including a) financial costs for establishing and maintaining surf protected areas and b) broader non-market costs.

3. **Objective 3 | Multidimensional Benefits Analysis:** Analyze and quantify the environmental, social, and economic benefits of protecting the surf ecosystems in western Sumatra.

4. **Objective 4 | Comprehensive Business Case for Surf Ecosystem Management:** Develop a business case for establishing surf protected areas in western Sumatra that can be expanded to a global action plan. The business case will synthesize the first three objectives and identify potential funding mechanisms.

Background and Significance

Since 2019, Conservation International's (CI's) Surf Conservation program–in partnership with Konservasi Indonesia (KI), the Indonesia Locally Managed Marine Area Foundation (ILMMA), Save The Waves Coalition (STW), and other global and local collaborators–has worked to protect surf breaks and the critical marine and coastal ecosystems that sustain them. These ecosystems, which include coral reefs, mangroves, and seagrass meadows, provide invaluable ecosystem services—such as storing irrecoverable carbon—while also supporting significant economic, social, and cultural benefits.

Surf ecosystems, defined as the as "the land-to-sea interface that create the conditions for breaking, rideable waves, and the flora and fauna and human communities that are dependent upon it" (Save the Waves Coalition), are not only valuable to the surfing community but also play a key role in supporting biodiversity and climate change adaptation. Research has shown that many "of the world's high quality surfing waves occur within or close to marine biodiversity hotspots and key biodiversity areas (KBAs)" (Reineman et al., 2021). Bukoski et al. (2024) also found that surf ecosystems store 88.3 million tonnes of irrecoverable carbon, with 17.2 million tonnes stored in KBAs that lack formal legal protections. While designations such as marine protected areas (MPAs) and locally managed marine areas (LMMAs) have proven to be effective in preserving coastal ecosystems, many ecologically significant surf ecosystems

remain unprotected. Despite their high value, surf breaks are under threat from global climate change and coastal development, which have led to impacts ranging from rising sea levels to decreased coastal water quality (Reineman et al., 2021).

Surf ecosystems offer a unique angle from which to approach conservation, serving as a nexus between ecological and social priorities. They provide a focal point from which to address the relationship between land-based activities, marine resources, and community needs. Recognizing the inherent value of surf ecosystems to both people and nature, CI is working to protect these resources by supporting community based conservation in the form of Surf Protected Areas (SPAs). SPAs leverage legally enforceable regulations and local policy frameworks to protect surf breaks and the surrounding resources that make them ecologically significant.

One of the primary legal frameworks for marine and coastal protection in Indonesia are LMMAs. On-the-ground initiatives led by the Indonesia Locally Managed Marine Area Foundation (ILMMA), along with supporting research, have demonstrated that LMMAs offer a cost-effective, legally enforceable model that balances conservation with community livelihoods. By fostering collaboration and local stewardship, LMMAs empower coastal communities to take an active role in marine resource management. Given their success, surf conservation efforts in Indonesia have adopted the LMMA approach as a local policy framework to establish SPAs.

CI's surf conservation work originated in the idea that surfing can be a powerful motivator for conservation. This is due to the fact that "the world's surfing population is estimated at 50 million with the demand continuously rising, partly accelerated by surfing's inclusion as an Olympic sport in 2021" (Manero, 2023). Additionally, the surfing industry generates $50 billion USD annually, with each surf site generating between $18-25 million USD annually, depending on their quality (McGregor & Wills, 2016; Mach & Ponting, 2021). The surfing community plays an important role in economic diversification in Indonesia and other countries. A study by CI and Save The Waves found that surf tourism in Uluwatu generates about $35.3 million USD annually (Margules et al., 2014). Additionally, surf ecosystems have been linked to accelerated economic growth leading to benefits including increased employment opportunities and improvement in local infrastructure (Manero, 2023).

To date, the CI Surf Conservation team, in collaboration with KI, ILMMA, Save The Waves Coalition, and other partners, has established 30 legally enforceable SPAs in Indonesia, with active projects in Morotai, Sumba, and the Biak Islands. There are also ongoing efforts to expand protections to other areas, such as western Sumatra, the focal region of this project. We analyzed the viability of multiple surf breaks for implementing surf protections within western Sumatra. These breaks encompass the islands of Simeulue, Banyak (Tuangku), and Telos, which are known for their high biodiversity, cultural significance, and exceptional waves. They are also less traveled than popular surf spots in South Nias and the Mentawai Islands, which serve as comparative models due to their higher level of development.

Our analysis considered varying levels of development to integrate tourism's impact on conservation, while prioritizing lower-development areas where protection is more cost effective than restoring heavily impacted sites. However, as Indonesia's surf tourism industry grows, many surf breaks face increasing threats from unsustainable development and environmental degradation, reinforcing the importance of mechanisms like SPAs. Our project aims to develop an action plan that balances conservation, surf tourism, and sustainable development in the focal region. In doing so, we contribute to building the business case for SPAs as a part of CI's efforts to protect coastal ecosystems on a larger scale.

The Environmental Kuznets Curve (EKC) hypothesis is useful in framing the theoretical basis for understanding the relationship between tourism, economic growth, environmental degradation, and conservation. The hypothesis predicts that as an economy develops, environmental degradation initially increases but eventually declines once a certain level of income and development is achieved, then society begins to prioritize and invest in environmental protection (Yandle et al., 2004). However, without proactive policies and community engagement, unregulated tourism can accelerate degradation before this turning point is reached, threatening both coastal ecosystems and the communities that rely on them.

Tourism, especially surf tourism, depends on healthy coastal ecosystems that provide services such as clean water, wave production, and ecological diversity (Singh et al., 2018). Indonesia, home to some of the most famous surf breaks in the world, relies heavily on these natural assets to sustain its tourism-driven economy. Without sustainable development and coordinated regulation, unchecked tourism growth can lead to negative impacts for ecosystems, as well as local communities. CI can position SPAs as an effective, community-driven model for balancing economic growth with long-term ecosystem protection by integrating surf conservation with other coastal management efforts.

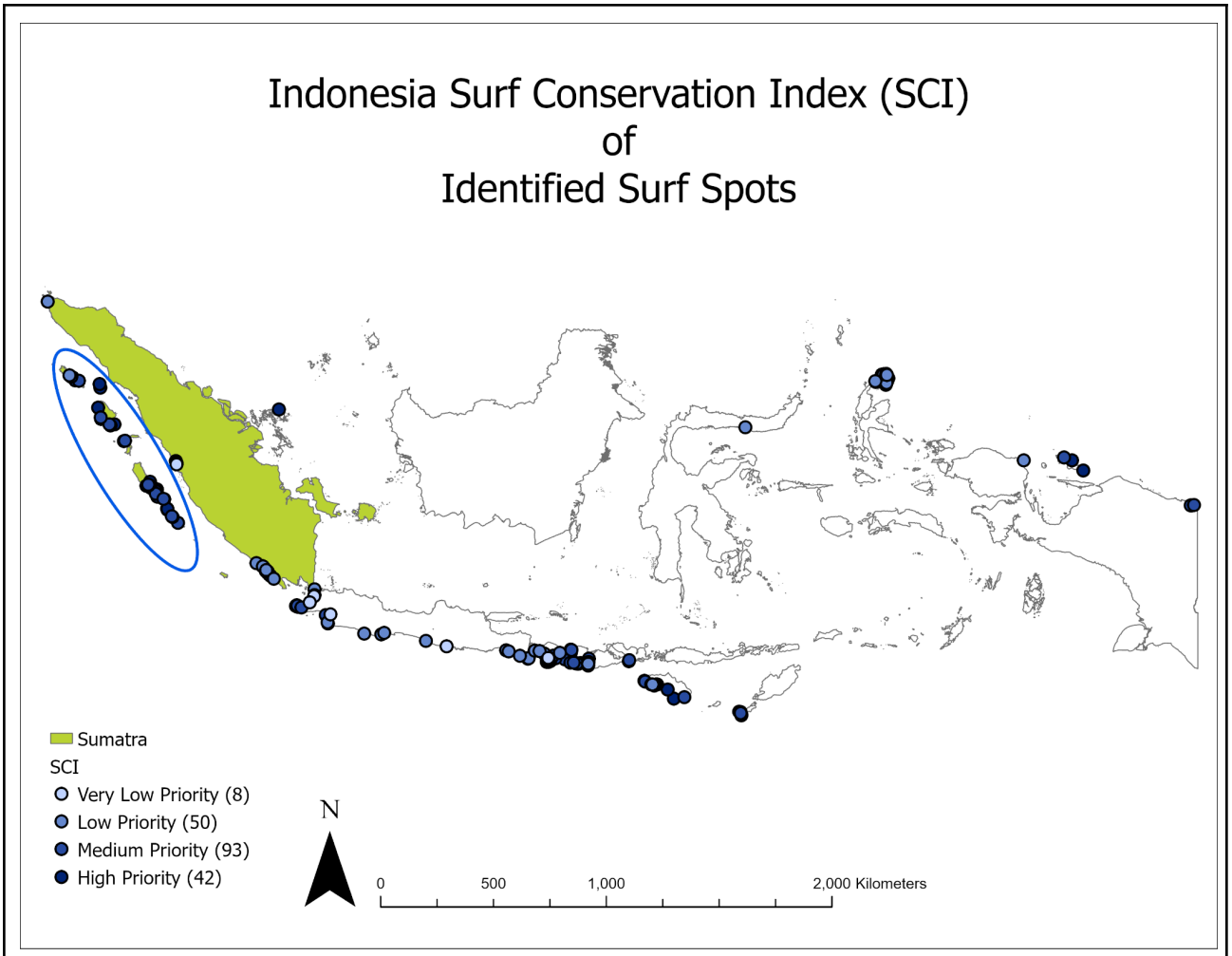


Figure 1: Map of Indonesia with the calculated surf conservation index values split into categories of high, medium, low, and very low based on human pressure and ecosystem value. The area circles in blue include the surf spots that were analyzed as candidate SPAs for this report.

Methods

Our analysis was divided into three primary activities: 1) Development of a Surf Conservation Index (SCI) for Indonesia, aimed at identifying and mapping the current value of surf ecosystems; 2) Estimating the costs associated with establishing SPAs/LMMAs in Sumatra; and 3) Execution of a multidimensional benefits analysis for establishing SPAs in western Sumatra. This included a financial assessment, an analysis focusing on coral ecosystem services, and an evaluation of the environmental, social, and economic benefits and costs associated with surf conservation in Sumatra using a survey. The final objective focused on formulating a business case for implementing Surf Ecosystem Management in the region.

Objective 1 | Current Value of Surf Ecosystems

Identification and mapping

Objective 1 aimed to identify and map surf ecosystems across Sumatra, determine their natural value, and assess which surf ecosystems in Sumatra have the highest surf conservation potential based on the SCI approach. To do so, we used ArcGIS to identify surf breaks, map them, and then characterize them based on their overlap with regions of high biodiversity, ecological processes, and high-carbon ecosystems in order to support decision-making in site selection.

We used data in **Appendix A** to calculate the SCI value for each surf break in the study area based on the pressure-state-response framework. The pressure-state-response framework was used to identify areas of prioritization based on the linkage between pressure placed on the environment by human actions (pressure), condition of the environment (state), and human actions intending to mitigate adverse human impacts (response). Pressure data included population density, population change, road length, and port presence. State data was split into 4 categories: biodiversity (terrestrial and marine biodiversity, tree cover, seagrass, coral, mangroves), climate (coastal vulnerability, carbon storage), surf, and social (hotel, airports). Response data included protected areas, OECMs (Other Effective area-based Conservation Measures), UNESCO World Heritage Sites, and Ramsar Sites.

We mapped each surf spot and the index categories with vector or shapefile data using ArcGIS and used presence/absence or amount of area of each index category intersecting with a 5 km radius around the surf spots to quantify value. We re-projected the intersecting areas from the WGS1984 datum to the Sphere Equal Area Asia Pacific datum in order for the area to be measured in kilometers instead of degrees while still maintaining the same size. The values were normalized on a scale from 0 to 1, with 0 indicating less ideal conditions (e.g., low biodiversity) and 1 indicating more ideal conditions (e.g., high biodiversity), using the formula: (original value-minimum value)/range. Areas with greater ecological services and lower in human pressure were assigned higher values compared with areas with less ecological services and higher in human pressure. Higher index value was assigned to low human pressure because of the lower financial requirements of conserving a not yet exploited environment compared to one that is already highly developed by humans. The normalized value for all of the index categories was averaged and normalized to find the overall SCI value. We ranked them as being high (0.75-1), medium (0.5-0.75), low (0.25-0.5), or very low (0-0.25) priority, with high meaning the area is of potentially higher priority for conservation. We repeated this process for only the selected surf spots in western Sumatra. Communication materials were produced to highlight SCI information for relevant stakeholders.

While the SCI is used to assess the condition of the environment through quantifiable values of state, response, and pressure, it is not the sole determining factor of where SPAs should be implemented. The SCI serves as a general guide for where conservation efforts could prove beneficial. In order to determine where they should actually be implemented, further analysis of

each individual surf break and surrounding ecosystem should be conducted. This would include assessing local legal frameworks, government support, stakeholder interest, and localized environmental pressures.

Objective 2 | Multidimensional Costs Analysis

Cost Components and Budgeting

The most successful approach used to establish SPAs in Indonesia has been to work directly with local communities and governments to create LMMAs–promoting local ownership and ensuring that protected areas are community led and benefit local people.

To estimate the costs associated with the LMMA approach, we focused on three primary components: (1) staffing salaries for outreach and facilitation, (2) costs for LMMA training workshop materials, and (3) time requirements. We chose these elements because they were the most straightforward to estimate and likely to be transferable across different locations. From there, we used the staffing salaries and workshop costs to develop a set of equations to aggregate these components into a final cost estimate. Combined with our estimate of time required to establish an SPA, this provides a real-world view of what it may take to scale up SPA implementation.

Staffing Cost Estimation

Staffing salaries were estimated using data from SalaryExpert.com, a database maintained by the Economics Research Institute. Relevant job titles were identified through a combination of AI generation and human judgment. A computer program was then used to query the online database for available salary data. Whenever data was available, we recorded the mean salary for each job title and categorized them into predefined staff categories. Mean salaries and 95% confidence intervals were then computed for each category.

The specific staff roles included in this estimation are detailed in **Appendix G**. Salary data was only available at the national level, meaning regional variations between Sumatra and the rest of Indonesia could not be accounted for.

Workshop Materials Cost Estimation

The cost of materials for workshops was estimated by identifying essential items needed for training sessions and community meetings, as well as items that CI had provided for a previous event. These materials were identified through a close review of official guides provided by LMMA International, an NGO that supports LMMA development in Pacific Island communities. A list of materials can be found in **Appendix F**.

Prices were sourced from online marketplaces such as Amazon, with a focus on bulk pricing to reflect the likely scale of purchases. Costs were estimated for five workshops conducted over 6 months with 100 attendees based on data from Crawford et. al. (2006). The following assumptions were made: some attendees would participate in multiple workshops; items like

notebooks and tshirts would be kept and reused by attendees; and reusable materials–such as pens, markers, and leftover supplies–would be collected after each workshop and brought to the next one. We also assumed costs would be in U.S. dollars, and materials would be transported by the Surf Conservation program team during travel. As a result, the first workshop would incur the highest cost, with costs decreasing for subsequent sessions due to reuse of supplies.

Time Requirement Estimation

The time estimates are primarily based on data from Crawford et al. (2006), which studied the progress of LMMA development in the Likupang region of North Sulawesi, Indonesia. This study tracked various predictors of LMMA progress, but for our purposes, we focused on village population and the number of meetings implemented over a three-month period. We hypothesized that the ratio of meeting frequency to village population would serve as a good predictor of LMMA development progress, as measured in the study by milestone scores.

The study identified eight key milestones as indicators of LMMA success (**Appendix C**). We followed the assumption that once a village reached all eight milestones, further external support would no longer be required. Using observed milestone scores over three months, we projected the expected time required for full LMMA completion under the assumption of a linear progress rate. The resulting data distribution resembled an exponential decay function. An exponential model was then fitted to the data, allowing us to predict LMMA completion time based on per capita meeting frequency. A visual representation of the exponential model, along with its statistical summary, is included in the results in **Figure 4** and **Table 4**. The LMMA approach has not been as widely and successfully implemented in this western region of Indonesia as it has in the East. Therefore, the time required to work with communities to effectively establish these SPAs/LMMAs might end up being a little longer.

Cost Aggregation

The total cost estimation was calculated using the following equations:

$$Staffing\ Cost\ = \frac{1}{Pop.\ to\ Staff\ Ratio} \times\ Village\ Pop. \times\ Time\ (months)\ \times\ Salary\ per\ Staff\ (monthly)$$

$$Salary\ per\ Staff\ =\ Cost\ per\ Workshop\ \times\ Per\ Capita\ Meeting\ Frequency\ (meetings/person/month)\ \times\ Village\ Pop. \times\ Time\ (months)$$

The key assumptions in these calculations include:

- Staffing and workshop costs are the only cost components considered.
- External NGO support ceases once all eight milestones (or a similar threshold) are achieved.

To simplify the analysis, we assumed a per capita meeting frequency of 2 meetings per month per thousand people—beyond the plateau point shown in **Figure 4**. We used a conservative 9-month timeline for budgeting, providing a margin of safety beyond the model's 7-month mean estimate.

A sensitivity analysis was conducted to explore how varying assumptions impact total costs. A subset of these variations is presented in **Figure 5**, and a full table is provided in **Appendix B.**

Addressing the Funding Gap

To address funding gaps, the project modeled revenue potential by estimating tourist willingness-to-pay (WTP) for SPAs. The Surf Tourism Survey (See **Appendix D)** provided average WTP values, which were multiplied by projected tourist numbers to estimate revenue. Stakeholder analyses were used to analyze available resources, potential funding sources (e.g., conservation fees, private-sector partnerships, public grants), and viable funding mechanisms tailored to the socio-economic and governance context of the region.

Modeling Potential Revenue from Conservation and Crowd Management Fees: **Fee Structures Considered**

Revenue for conservation efforts and crowd management in a SPA/LMMA could be generated through various fee mechanisms. These include:

- **Accommodation-based fees**, where a small surcharge is added to lodging prices.
- **Charter boat mooring fees**, requiring operators to pay for the right to anchor near the surf break.
- **Direct surf access fees**, where surfers pay for a pass (usually a wristband) allowing them to surf designated waves.

For a detailed explanation of how we assess the economic impact of implementing these fees, see the section "**Analysis of Economic Difference Between Scenarios".**

Objective 3 | Multidimensional Benefits Analysis

Cost-Benefit Analysis

We conducted an ex-ante, cost-benefit analysis using a benefit-transfer approach to determine if establishing an SPA could increase the value of ecosystem services provided by coral reefs. This analysis contributed to understanding potential ecological and economic outcomes of protecting surf ecosystems, including their role in promoting sustainable tourism and local economic development.

Wee based our valuation on data from a study of the West Buleleng Conservation Zone (WBCZ), a MPA off Siberut Island, which estimated the Total Economic Value (TEV) of coral reefs to be $18,602 ha/yr (Windayati et al., 2022). We focused on coral reefs for this ecosystem service valuation because Indonesia is part of the Coral Triangle, a region renowned for its biodiversity of coral reefs. These ecosystems not only serve as the foundation of tropical marine biodiversity but also directly support roughly 80% of Indonesia's population.

Coral reefs play a crucial role in shaping waves, protecting shorelines, and serving as a key ecosystem for surf breaks in the tropics (Ogden-Fung et al., 2021). This makes them essential

for both conservation and surf tourism. Conserving coral reefs is also a core objective of CI's surf protection work, and our analysis based on the SCI further reinforced their importance in sustaining productive surf ecosystems. However, 95% of coral reefs are threatened by global and local disturbances, including increased tourism development, pollution, and destructive fishing practices (Ogden-Fung et al., 2021).

As a next step, we applied the TEV estimate to the Siberut UNESCO-MAB Biosphere Reserve (**Figure 2**), located in the Mentawai Islands Regency, Indonesia. We selected this site due to its ecological similarities, its location within our project's focus area–Siberut lies off the west coast of Sumatra–and its formal designation as a protected area. As the largest island in the Mentawai archipelago, Siberut serves as a key site for marine conservation and community-based resource management (UNESCO, 2024).

These comparable factors led to the determination that a benefit-transfer approach provided a reasonable valuation without requiring a full primary assessment. Furthermore, this method was chosen because all SPAs established using the LMMA approach in Indonesia are less than five years old, and thus lack long-term data. In contrast, established MPAs like the WBCZ offer more data, making them the best available reference for an analysis in this area.

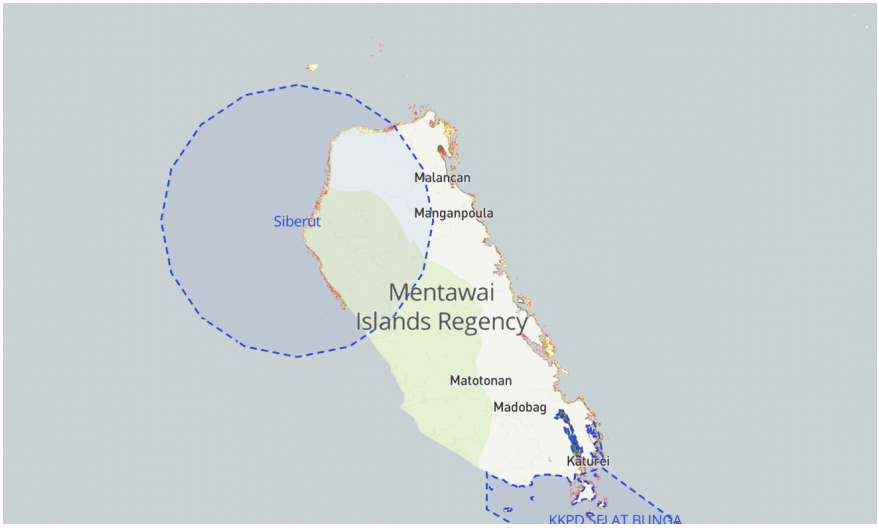


Figure 2: Map of Siberut Island, a UNESCO-MAB Biosphere Reserve, sourced from the Allen Coral Atlas by Arizona State University (circle: 5 km radius around surf spot).

The cost-benefit analysis followed several stages: (1) identifying stakeholders with standing for the study, (2) reviewing literature to find data enabling estimates for the ex-ante analysis, (3) selecting cost and benefit values from studies for benefit-transfer, (4) defining the impact categories to be analyzed, (5) utilizing transferred values to establish two scenarios for comparison: an MPA scenario, providing a proxy to a SPA, and a Business-as-Usual (BAU) scenario, used as the counterfactual, and (6) discounting benefits to determine the Net Present Value (NPV) under each scenario.

The first step in this CBA was to determine who has standing, which involved identifying the groups that would benefit from or bear the costs of establishing an SPA and those who would be directly impacted. For this project, the main stakeholders with standing included surf tourists, local communities, local businesses in and around surf ecosystems, the Indonesian government, and NGOs, such as CI, KI, and the ILMMA Foundation.

The study by Windayati et al. (2022) assessed the TEV of coral reefs by calculating the value of multiple benefit categories. These included: (1) direct use values (DUV), including tourism and fisheries production; (2) indirect use values (IUV), which account for coastal protection and the role of coral reefs as fish habitats; (3) option values (OV), representing potential future uses of coral reefs; (4) existence values (EV), reflecting the intrinsic value of coral reefs regardless of use; and (5) bequest values (BV), which capture the value of preserving reefs for future generations. **Table 1** provides an overview of these value classifications, along with the formulas and economic valuation methods applied by Windayati et al. (2022) to estimate TEV. **Table 2** presents the estimated TEV for the WBCZ in 2019, expressed in present value.

To structure the cost-benefit analysis, we adopted the same benefit categories in **Table 1** and valuation framework used by Windayati et al. (2022) as our impact categories. This provided a way for us to capture a wide range of ecological, economic, and social impacts associated with coral reef conservation. Additionally, we recognized that they reflect market and non-market values relevant to our study area. Because our analysis utilized benefit-transfer from the WBCZ, we also applied the benefit categories in assessing coral reef ecosystem services. This allowed for establishing our BAU scenario as the counterfactual and MPA scenario for comparison. Subsequently, a 23-year time horizon (2023–2045) was used to align with Indonesia's Marine Protected Area Vision 30x45, which aims to expand conservation areas to cover 30% of national waters by 2045, and a discount rate of 6.82% based on the Bank of Indonesia's interest rate.

Table 1: Value of benefits assessed, formulas, and methods adapted from Windayati et al. (2022).

No.	Value of benefits	Formulas	Methods
1	DUV a) Tourism b) Fisheries production	a) Number of visits = f(travel expenses, others factor x_1, x_2…) b) Fish cost/kg x total of production/year (kg)	*a) Travel cost method* *b) Effect on production*
2.	IUV a) Coastal protection b) Fish habitat	a) Length of the coastline (m) x Cost of breakwater making per meter b) Percentage of coral cover x Total area of coral reefs (ha) x Cost of making a pond	*Replacement cost method*
3	OV	The value of selected coral reefs (IDR) x Total area of coral reefs (ha)	*Benefit transfer method*
4.	EV Tourists and local communities	Existence benefit of respondent x The number of the population	*Contingency valuation method*
5.	BV	Bequest benefit of the respondent (local communities) x The number of the population	*Contingency valuation method*
6.	TEV	DUV + IUV + OV + EV + BV	*Total economic value*

Table 2: Estimated Total Economic Value (TEV) in 2019 (present value) for WBCZ from Windayati et al. (2022).

No.	Value of benefits	Economic value per year (US$)
1	DUV	9,096,391
	a) Tourism	115,179
	b) Fisheries production	
2.	IUV	1,737,431
	a) Coastal protection	272,431
	b) Fish habitat	
3	OV	524,491
4.	EV	229,933
	Tourists and local communities	
5.	BV	138,552
TEV		12,114,408

To analyze and model the two scenarios we used RStudio to graph: coral coverage over time, ecosystem services value under each scenario, and cumulative ecosystem services value for

each scenario. In order to model coral coverage we used spatial and ecological data sourced from the Allen Coral Atlas for the Siberut MPA. Values included: an area of 4,050.7 km², 48.969 km² of reef extent and 17.54 km² (1,754 hectares) of coral/algae cover (Arizona State University, 2024). These values provided the baseline for modeling changes in coral coverage and ecosystem services under both BAU and MPA scenarios.

After obtaining the necessary data, the first step was to calculate coral coverage over time under both scenarios. To model future changes in reef coverage, an exponential decay model was used to estimate coral degradation under BAU. Based on historical data from Bruno & Selig (2007), coral loss was assumed to occur at an annual rate of 0.72%, reflecting Indo-Pacific trends where coral cover declined by 1% per year over the past two decades and by 2% annually between 1997 and 2003. The coral loss projection follows:

$$C_{BAU}(t) = C_0 \times e^{-\lambda t}$$

Where:

- $C_{BAU}(t)$ = coral cover under BAU at time *t*,
- C_0 = Initial coral cover (1,754 hectares),
- λ = annual coral loss rate (0.0072 or 0.72%),
- *t* = number of years (23 years, 2023-2024).

For the MPA scenario, we assumed a 0% annual coral loss rate, based on findings by Bruno and Selig (2007), who observed that coral cover within MPAs remained stable over time. This assumption reflects the expectation that conservation measures would prevent further coral degradation and offset the 0.72% annual loss rate, resulting in stable reef coverage. While this provides a useful baseline for comparison, these projections do not account for the stochastic nature of coral distribution and recovery. As such, although this analysis is useful, there are limitations to its application. The equation used to estimate coral coverage under the MPA scenario is as follows:

$$C_{MPA}(t) = C_0 = 1,754\ ha$$

Following the coral cover projections, the next step was to estimate ecosystem service values (ESV) under both scenarios using the TEV per hectare, allowing us to quantify the economic implications of coral reef changes over time and compare the benefits of conservation versus continued degradation. The ecosystem service values were calculated as follows:

$$E_{BAU}(t) = C_{BAU}(t) \times TEV$$

$$E_{MPA}(t) = C_{MPA}(t) \times TEV$$

Where:

- $E_{BAU}(t)\ and\ E_{MPA}(t)$ = ecosystem service values under each scenario,
- TEV = Total Economic Value per hectare ($18,602/ha/year, Windayati et al., 2022).

To compare the economic benefits of the MPA and BAU scenarios, future ecosystem service values were discounted to calculate their NPV using a social discount rate of 6.82%, based on the Bank of Indonesia's interest rate (Kementerian Kelautan dan Perikanan et al., 2024). The discounted ecosystem service value for each year was calculated as:

$$E_{discounted}(t) = \frac{E(t)}{(1+r)^t}$$

Where:

- $E_{discounted}(t)$ = discounted ecosystem service value at time t,
- $E(t)$ = non-discounted ecosystem service value at time t,
- r = discount rate (6.82%)

Lastly, to determine the cumulative discounted benefits over the 23-year period, the sum of discounted values was computed. This step was necessary to account for the fact that economic benefits from ecosystem services accrue over time but their present-day value diminishes due to discounting. By summing these discounted values, we can assess the total economic benefits of coral reef conservation under the MPA scenario compared to the BAU scenario, providing a more comprehensive understanding of the long-term financial returns of protection efforts. The cumulative discounted benefits were calculated as follows:

$$Cumulative\_E(t) = \sum_{i=1}^{t} E_{discounted}(i)$$

Where:

- $Cumulative\_E(t)$ = cumulative discounted benefits over time,
- $E_{discounted}(i)$ = discounted ecosystem service value for year i.

Our methodology enables a direct comparison between a BAU scenario in which there are no formal protection measures and a scenario in which marine protections are implemented. This provides a way to assess the long-term financial returns of conservation interventions like SPAs that help to prevent the loss of ecosystem services provided by natural resources such as coral reefs.

Surf Tourism Survey

We conducted a semi-structured online survey to collect data on surf tourists' perceptions, experiences, and willingness to pay for conservation and crowd management in western Sumatra.

We collected responses online from adults worldwide who have surfed or hope to surf in western Sumatra. We anticipated a diverse range of ages and backgrounds, reflective of the global surfing community. Participants were primarily recruited from groups that have previously been involved with CI's surf conservation activities and tourists who have been to Indonesia or might visit in the future. The results were compared with previous scientific studies on surf tourism in the local area such as Towner, N., & Milne, S. (2017).

Survey Design and Objectives

The survey aimed to gather quantitative and qualitative data among surf tourists visiting or intending to visit Sumatra. Specifically, the objectives were:

1. To estimate the spending patterns of surf tourists, including total trip expenditures and budgeted costs.
2. To assess WTP for conservation efforts around surf breaks and determine whether this willingness depends on specific locations.
3. To assess WTP for crowd management as a service that could be provided by local communities managing their own surf resources.
4. To understand the demographic profiles of surf tourists who have or would travel to Sumatra.
5. To evaluate perceptions of key issues surrounding sustainable surf tourism development.

The survey design was inspired by previous studies on surf tourism, conservation and coastal management, including Margules et al. (2014) in Bali and Ogden-Fung (2021) in Morotai. A key distinction, however, is that unlike these studies, this survey did not sample respondents directly at the beach. We aim to use these survey results to inform management strategies for SPAs in Sumatra. While no specific policies were targeted, the findings could assist communities in determining appropriate prices for conservation fees or accommodation levies to support sustainable tourism.

Target Population and Recruitment

The target population consisted of surfers who have previously traveled to Sumatra or have an interest in visiting. Recruitment efforts leveraged both direct outreach and social media networks, with respondents categorized based on how they found the survey. The recruitment channels included: CI's surf conservation team network, social media outreach, CI's Australian Surf Conservation Advisory Group, CI's US board, and attendees of past CI events. We offered four $100 USD gift cards (redeemable at Patagonia, Rip Curl, Billabong, or Amazon) as incentives, selecting winners through a random drawing of completed survey responses.

Survey Implementation

The survey was conducted online, with responses collected between February 4 and February 28, 2025. It was open to adults (18 years or older) who met the eligibility criteria of either having surfed in Sumatra or expressing an intent to visit for surfing in the future.

Data Quality and Analysis Plan

No formal data validation techniques were applied beyond standard survey logic. However, responses were reviewed to identify potential duplicates and incomplete submissions. Given the recruitment strategy, sampling bias is a recognized limitation, as certain groups—such as members of the CI network—may have stronger pro-conservation biases than the general

surfing population. Responses from non-CI-affiliated surfers may provide a less biased view on conservation-related spending and surf tourism development.

Data analysis was primarily conducted using standard quantitative and qualitative methods. Quantitative data from Google Forms was processed using Excel and RStudio, while qualitative data was analyzed through techniques such as triangulation and saturation (Figueroa et al., 2017), and word clouds to identify key topics.

Stakeholder Priorities and Engagement Strategies

We conducted a stakeholder analysis to address Objective 3—identifying potential benefits from SPAs—and to inform the business case. Understanding the needs and expectations of the individuals who most influence a project or initiative—in this case, surf conservation efforts such as SPAs in Indonesia—is essential for building a strong business case. It also helps identify whether the strategic objectives of CI's surf conservation program and its local partners are aligned with key stakeholders while identifying potential sources of contribution or support for the initiative (Sheen & Gallo, 2015).

This analysis assesses stakeholder perceptions of the benefits and costs of surf conservation and surf development in Indonesia, their willingness to contribute financially or otherwise, and their potential impact on the establishment of SPAs. Insights gained from this process informed the content of the business case.

The first step of the stakeholder analysis was identifying and mapping the project's main stakeholders and their level of influence on surf conservation in Indonesia. To achieve this, both primary and secondary data sources were used. Conservation International's internal case studies and documentation served as the main source of information, while other published stakeholder analyses of West Sumatra and Indonesia were used to validate the findings. The ecosystem map technique (Figueroa et al., 2017) was applied to identify and visualize key stakeholders, as well as map their relationships, influence, and contributions to SPAs in Indonesia. This approach helped assess their roles, potential impact, and engagement strategies to align the business case with their interests and expectations.

The second step involved understanding stakeholders' perceptions of the costs and benefits associated with surf conservation and development. We obtained primary data from the surf tourism survey we developed (see **Appendix D,E**). Surf tourists were identified as key stakeholders and as a significant potential source of revenue through surf tourism, conservation, and crowd management fees. Direct feedback from tourists on their perceptions of the benefits and costs of surf conservation and surf development in Indonesia was gathered using a Likert scale to measure different levels of agreement for statements on various potential costs and benefits, along with open-ended questions that were analyzed qualitatively. The statements were developed using templates from the California Marine Sanctuary Foundation's (CMSF) Ocean Access Survey and previous stakeholder analyses to enable triangulation and comparative analysis (CMSF, 2024).

The quantitative data obtained from the survey was analyzed using charts generated in Excel and Google Forms, while the qualitative data was analyzed using qualitative tools and techniques, including coding and visual word clouds for data visualization. For the secondary data, CI's internal sources from its existing work in Indonesia, local government reports on tourism development, and previously published stakeholder analyses and case studies of Indonesia were utilized.

Finally, we assessed stakeholder interests, project impact, and priorities to improve engagement, refine messaging, strengthen the business case, and recommend effective SPA engagement strategies.

Objective 4 | Comprehensive Business Case for Surf Ecosystem Management

Comprehensive Business Case

To address Objective 4, we developed a business case for establishing SPAs in western Sumatra. This product synthesizes findings from the first three objectives to create a framework for SPA implementation in the study area, with the potential to inform CIs global action plan and broader surf conservation strategies.

The business case synthesizes our findings to present a compelling argument for implementing SPAs through the LMMA framework in Sumatra. By integrating our ecological, social, and economic findings, it provides a clear picture on how to scale up SPA implementation. It focuses on identifying critical funding gaps and proposing viable, sustainable funding sources to support the work long-term. Additionally, the business case develops a narrative that highlights the multidimensional benefits of SPAs to build stakeholder and donor support. It also provides recommendations for aligning SPA conservation goals with local community priorities, stakeholder aspirations, and relevant policy frameworks.

To structure this process, the Harvard School of Business' guide to building a Business Case (Sheen & Gallo, 2015) was used as a reference and adapted to our project as follows:

1. Refining and scoping the problem/opportunity of establishing SPAs in Indonesia.
2. Identifying and considering alternative solutions, policy frameworks, and regulatory approaches, such as MPAs, blue carbon, and other conservation strategies.
3. Gathering information from Objectives 1, 2, and 3 to ensure a data-driven approach.
4. Consolidating information to further evaluate costs and benefits by integrating the financial and non-market costs identified in Objective 2 with the quantified environmental, social, and economic benefits from Objective 3 to assess the net benefits of SPA implementation compared to a BAU scenario.
5. Designing implementation recommendations, specifying the resources required, and identifying stakeholders who would bear costs and receive benefits, while aiming to ensure that a portion of the benefits remains within local communities.

6. Communicating the approach, and designing a Business Case Report that compiles all previous steps into a structured and actionable document.

This process combined the financial and non-market costs from Objective 2 with the quantified environmental, social, economic benefits assessed in Objective 3 to estimate the net benefits of SPA implementation relative to a BAU scenario. We also conducted a qualitative policy analysis to explore strategies for keeping economic benefits within local communities. In addition, we included a comparative analysis of surf tourism regulations to compare successful frameworks from other regions to Sumatra and evaluate enabling conditions. From this analysis, recommendations were developed regarding optimal practices and relevant policy mechanisms which would enable SPA implementation and expansion.

Results

Mapping of surf breaks in Sumatra for Objective 1

Of all the surf spots in Indonesia, those in Sumatra tended to rank higher in terms of SCI value (**Figure 1**). There were 63 surf spots identified within Sumatra, from which we selected 41 for further analysis in identifying candidate SPAs. These selected surf spots ranked higher in priority compared to other surf spots in Sumatra. When compared to each other, of these 41 surf spots, 9 of them ranked highly in terms of their SCI value, 20 ranked medium, 8 ranked low, and 4 ranked very low in conservation priority (**Figure 3**). Surf spots that ranked highly generally had higher ecological value and lower human pressure, with the opposite being true for those that ranked low. High ranking surf spots tended to be located in Siberut Island, Sipura Island, and Tuangku Island. The SCI value for the SPA target locations (A, B, D) generally appeared to be lower than surf spots with more human development (C, E, F, G).

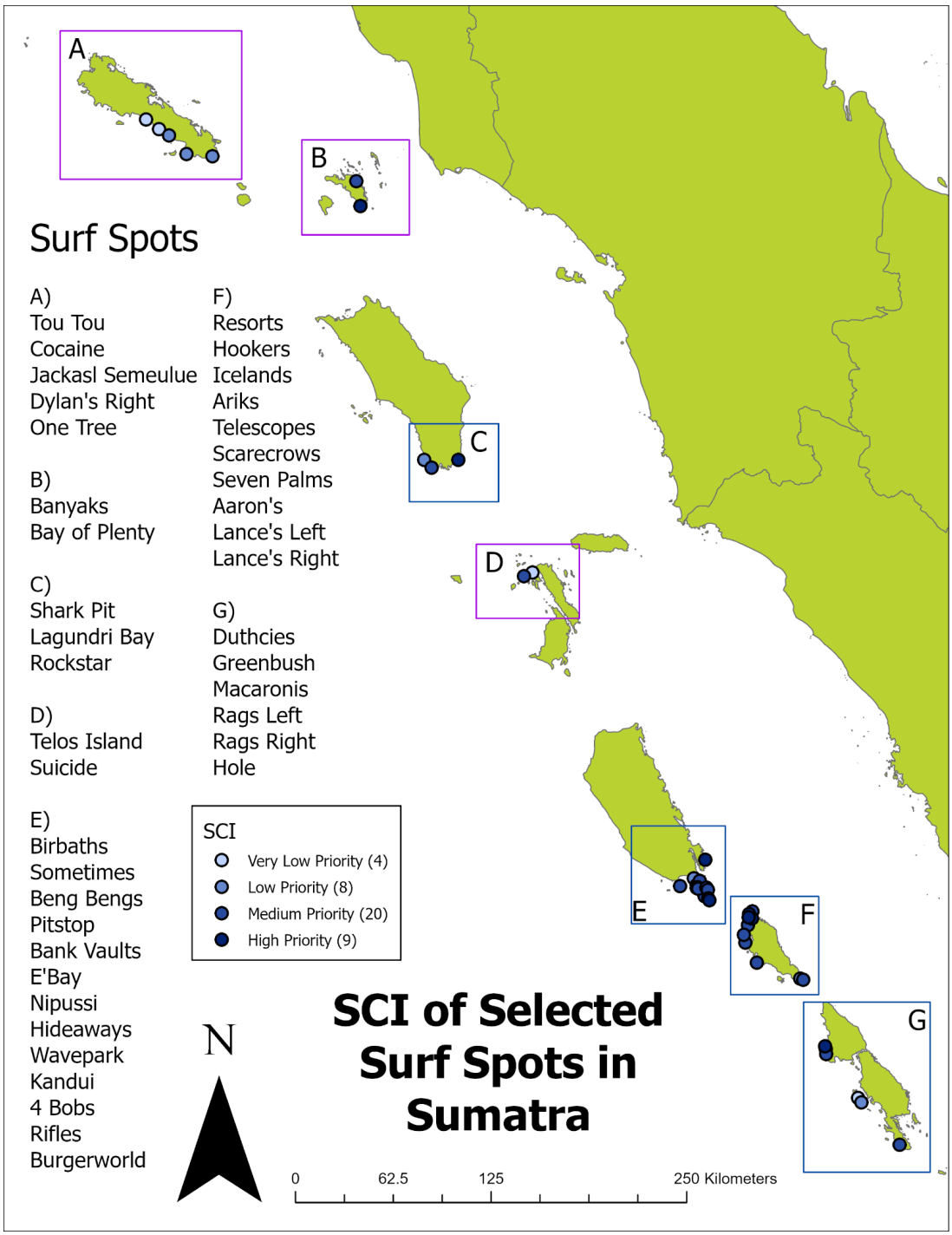


Figure 3: Map of selected surf spots in western Sumatra and the associated surf conservation index values. Groups A, B, and D (purple) were used to analyze the impacts of recently implementing surf protection, using groups C, E, F, and G (blue) as a baseline because of their more extensively developed infrastructure and surf network.

Table 3: Top 5 candidate SPAS in terms of existing ecological value

Existing Ecological State/Response

Surf Spot	Irrecoverable Carbon (Metric tons)	Key Biodiversity Areas - KBA (km^2)	Mangrove (km^2)	Seagrass (km^2)	Coral (km^2)	Protected Areas - Terrestrial and Marine (km^2)	Kelola Pesisir - Coastal Management (count)	Other effective area-based conservation measures - OECM (km^2)	Tree Cover
Birdbaths	456140.91	0	8.84	0	2.95	13.42	0	0	31.21
Banyaks	392161.51	0	3.22	0	2.78	65.44	0	65.44	45.41
Macaronis	311613.58	32.16	2.75	0	9.95	0	0	0	26.36
Bay of Plenty	242764.36	0	1.73	0	8.12	78.85	1	78.85	24.82
Greenbush	239427.53	31.72	1.82	0	9.41	0	0	0	29.08

Irrecoverable Carbon Storage

Irrecoverable carbon is defined by CI as “the vast stores of carbon in nature that are vulnerable to release from human activity and, if lost, could not be restored by 2050 — when the world must reach net-zero emissions to avoid the worst impacts of climate change”. Of the 171 surf spots that contained irrecoverable carbon storage within a 5 km radius, 61 (35.3%) of them were located in Sumatra. Birdbaths (456140.91 metric tons) and Banyaks (392161.51 metric tons) were the two highest out of the surf spots selected as potential SPAs in terms of the amount of irrecoverable carbon stored.

Key Biodiversity Areas (KBA)

KBAs are defined as “sites contributing significantly to the global persistence of biodiversity” (IUCN 2016). KBA presence was used to quantify biodiversity, but there are some caveats in using them as a measure of biodiversity. Designation is typically based on more well studied groups of organisms like birds, which can result in an underrepresentation of areas with a high biodiversity of less well studied species. Of the 62 surf spots that contained KBAs within a 5 km radius, 21 (33.9%) of them were located in Sumatra. Hole (34.97 km^2) and Shark Pit (34.55 km^2) were the two highest in terms of area of KBA out of the surf spots selected as potential SPAs.

Mangroves

Mangroves serve as biodiversity hotspots, providing critical habitat for both terrestrial and marine species (Sunkur et al., 2023). They also offer numerous ecosystem services, including carbon sequestration, water purification, and coastal protection by reducing storm wave intensity. However, mangrove extent is declining due to unsustainable human development. This threatens the ecosystems they support as well as the coastal communities they protect. Of the 80 surf spots where mangroves were present within a 5 km radius, 26 (32.5%) of them were located in Sumatra. Ebay (0.019 km^2) and Lance's Left (0.034 km^2) had the highest area of mangroves out of the candidate SPA study sites.

Seagrass

Seagrass supports biodiversity by providing nursery habitat for multiple marine organisms (Valdez et al., 2020). It can also provide other environmental benefits in the form of carbon sequestration and reduction of coastal erosion. Of the 8 surf spots where seagrass was present within a 5 km radius, 1 (12.5%) of them was located in Sumatra. Bintan Lagoon Resort, which was not one of the candidate SPA sites, was the only surf spot that was identified to have seagrass in Sumatra.

Coral

Corals provide numerous benefits to humans and the local environment. They support local fisheries, offer natural coastal protection, and serve as biodiversity reservoirs, with approximately 25% of marine species depending on them for habitat or food (Yuan et al., 2024). Of the 168 surf spots where corals were present within a 5 km radius, 61 (36.3%) of them were located in Sumatra. Hookers (14.42 km^2) and Resorts (14.35 km^2) had the highest area of coral out of the candidate SPA study sites.

Protected Area

Protected areas are so designated by the World Database on Protected Areas because of their perceived economic and scientific benefit, as well as their importance in the preservation of the existing ecological state (Protected Planet 2015). These protected areas encompass national, such as wildlife sanctuaries and marine recreation parks, and international level designation, including Ramsar sites, UNESCO-MAB Biosphere Reserve, and World Heritage Sites. Of the 92 surf spots that had overlap with Protected Areas within a 5 km radius, 28 (30.4%) of them were located in Sumatra. Bay of Plenty (Nature Recreation Park-78.85 km^2) and Burgerworld (Marine Recreation Park-76.55 km^2) had the highest area of Protected Areas out of the candidate SPA study sites.

Other effective area-based conservation measures (OECM)

OECMs refer to any non-Protected-Area geographically defined area that is managed with the intent of sustained conservation of biodiversity (CBD 2018). Of the 21 surf spots with OECM overlap within a 5 km radius, 2 (9.5%) of them were located in Sumatra. Bay of Plenty (78.85

km^2) and Banyaks (65.44 km^2) had the highest area of OECM overlap out of the candidate SPA study sites. Kelola pesisir (coastal management) OECMs refer to a specific type of OECM that focuses on coastal environments. Of the 37 surf spots where kelola pesisir OECMs were present within a 5 km radius, 13 of them were located in Sumatra. Telos Island (2) had the highest amount of kelola pesisir OECMs out of the candidate SPA study sites.

Tree Cover

Trees provide numerous benefits to the surrounding environment and the people living there, ranging from storing and sequestering carbon to improving mental health (Turner-Skoff & Cavender, 2019). Indonesia has lost 25% of its old growth forests and 45% of its intact forest land since 1990, with the majority of deforestation occurring through human action in order to convert the land to palm oil plantations (Parker et al., 2024). Of the 44 surf spots where tree cover was present within a 5 km radius, 42 (95.5%) of them were located in Sumatra. Banyaks (45.41 km^2) and Jackals Simeulue (34.77 km^2) had the highest area of trees out of the candidate SPA study sites.

Estimating the Costs of LMMA Implementation for Objective 2

To estimate the expected time required to reach the eight milestones in LMMA establishment the following model was used. In the model let y be the expected time to reach the 8 milestones, and x be the number of workshops per month per one thousand people living in the village. The model used was:

$$y = ae^{bx} + c$$

Table 4. Likupang exponential model fit parameters. This table presents the model fit parameters for the Likupang exponential model. The parameters *a* and *c* show a significant fit at the 5% level, while *b*, representing the steepness of the exponential decay function, is not statistically significant. This suggests uncertainty in how quickly milestone fulfillment may be achieved. As a precaution, it is advisable to plan beyond the model's projected flattening point to ensure efficient resource allocation and successful LMMA implementation.

Term	Estimate	Std. Error	t value	Pr(>|t|)
a	2.75083844647847	0.33016372159001	8.33174048690423	2.98750873284978E-08
b	-7.19139308390586	4.59520900716374	-1.56497627696472	0.131860193316762
c	0.578725801640091	0.124837570078758	4.63583039364658	0.000127685658323166

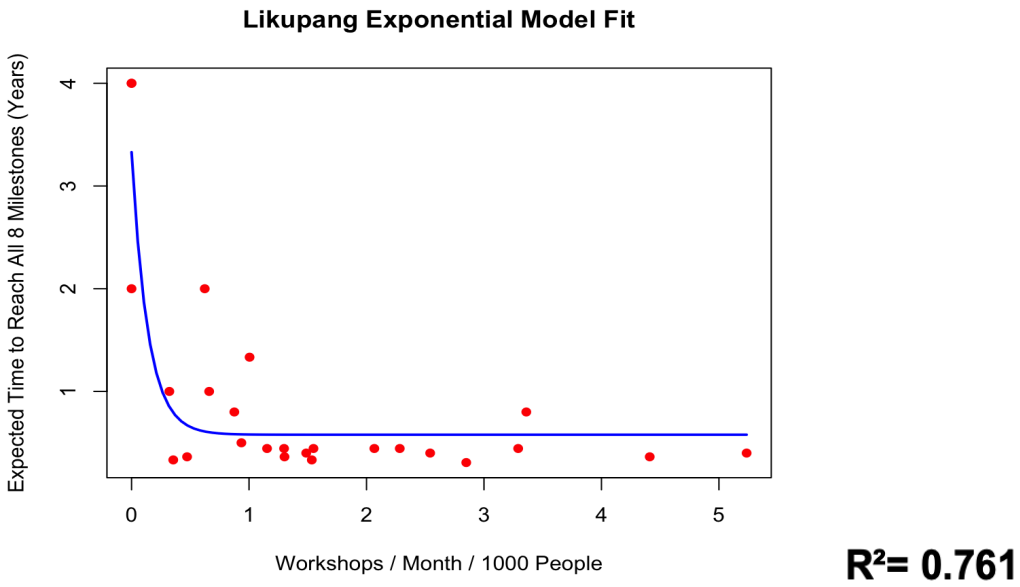


Figure 4. Likupang exponential model fit plot. This figure visualizes the Likupang data alongside the fitted exponential decay model, illustrating the relationship between workshop frequency and the expected time to reach all eight LMMA milestones. The curve flattens quickly before reaching 1 workshop per month per thousand people, indicating diminishing returns on additional workshops. However, given the low confidence in the *c* parameter, a more conservative estimate suggests flattening around x=2. This threshold represents a point where time and resources are allocated most efficiently for milestone completion.

For the sake of simplicity, a per capita meeting frequency of 2 meetings / month / thousand people was used. A number past the point of plateau in **Figure 4.** A time period of 9 months was chosen and incorporated into the budgeting. (The model suggests a mean time period of 7 months, so 9 months constitutes a relatively safe margin).

A sensitivity analysis was conducted to explore how varying assumptions impact total costs. A subset of these variations is presented in **Table 5**, and a full table is provided in **Appendix B.**

Table 5. Cost Scenario Results. This table presents a subset of costing results under varying assumptions for village population, population-to-staff ratio, and cost per workshop. The final cost calculations follow the equations outlined in the *Cost Aggregation* section. For simplicity, all staff salaries were assumed to be $1,500 USD per month, a figure derived from web-scraped data (see Appendix G). A per capita workshop frequency of 2 workshops per month per thousand people was selected as a safe estimate for efficient resource use. The projected duration was set at 9 months as a conservative upper bound, though the Likupang model (Table 4, Figure 4) suggested completion could take as little as 7–8 months. Cost estimates vary widely, primarily due to the strong influence of the population-to-staff ratio on total expenditures.

Village Population (Individuals)	Population to Staff Ratio	Cost per Workshop (USD)	Total Cost (USD)
1000	100	100	136800
		130	137340
		160	137880
	500	100	28800
		130	29340
		160	29880
	1000	100	15300
		130	15840
		160	16380
2000	100	100	273600
		130	274680
		160	275760
	500	100	57600
		130	58680
		160	59760
	1000	100	30600
		130	31680
		160	32760
5000	100	100	684000
		130	686700
		160	689400
	500	100	144000
		130	146700
		160	149400
	1000	100	76500
		130	79200
		160	81900
10000	100	100	1368000
		130	1373400
		160	1378800
	500	100	288000
		130	293400
		160	298800
	1000	100	153000
		130	158400
		160	163800

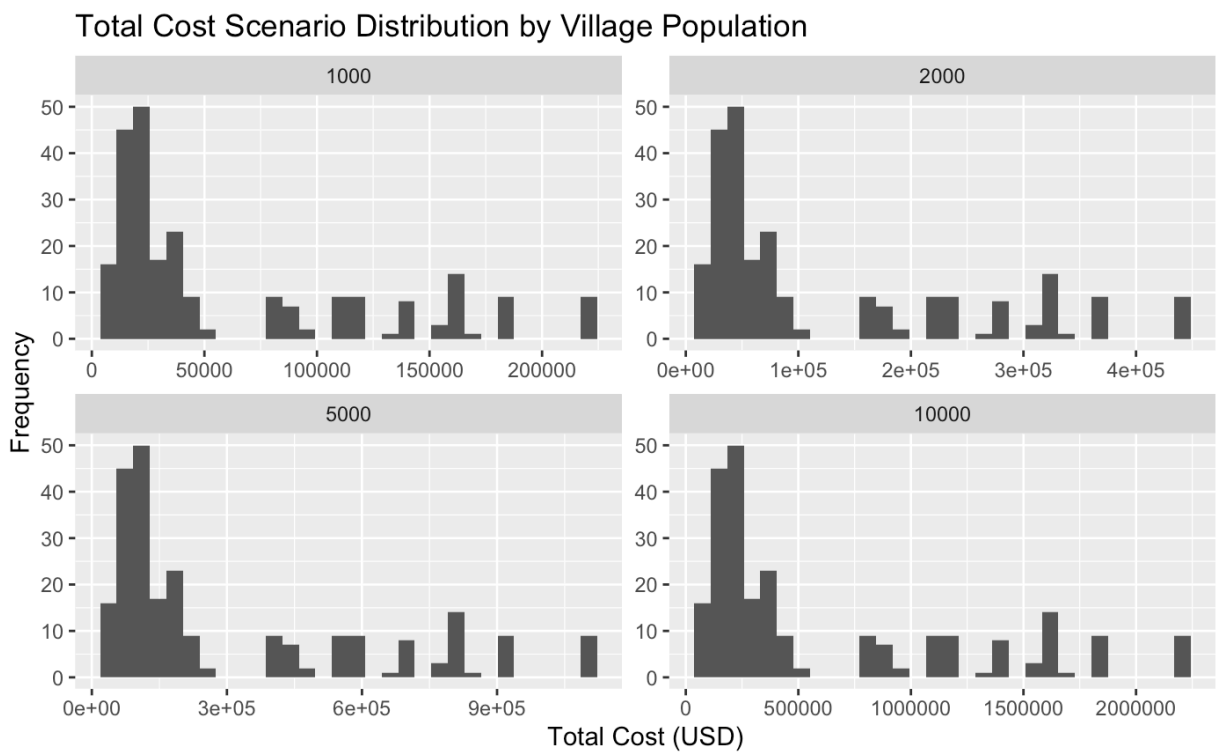


Figure 5. Cost Scenario Distribution by Village Population. This histogram visually represents the cost estimates from Table 5, illustrating the distribution of total costs across different parameter sets. While there is a large spread in the data, the distribution exhibits a right skew with a leftward central tendency. It is important to note that this distribution is based on a selected range of parameter values chosen to capture breadth in scenario testing rather than an empirically derived probability distribution. As such, caution should be taken when interpreting the spread and central tendency of costs.

Table 6. Costing Results Summary Statistics. This table presents the mean and median cost estimates for each village population value, summarizing the costing results from Table 5. A key practical takeaway is that the median cost tends to approximate 30 times the village population in USD. Under the assumptions used in this analysis, this suggests that supporting a village of 1,000 people through the LMMA establishment process would require a median cost of approximately $30,000 USD. This rule of thumb can provide a useful heuristic for estimating LMMA implementation costs at different population scales.

Village Population (Individuals)	Median Cost (USD)	Mean Cost (USD
1000	29340	62140
2000	58680	124280
5000	146700	310700
10000	293400	621400

CBA Results for Objective 3

Coral Coverage Over Time

The analysis of coral coverage over the 23-year period reveals a clear contrast between the Business-as-Usual (BAU) and Marine Protected Area (MPA) scenarios. Under the BAU scenario, where no conservation measures are in place, coral degradation follows an exponential decline at an annual rate of 0.72%. As shown in **Figure 6** (orange line), coral coverage at t_1 = baseline year is 1,754 hectares. However, by the end of the projection period at t_{23}= Year 23, coral coverage has declined to 1,486 hectares, representing a 268-hectare loss over time.

In contrast, under the MPA scenario, conservation measures prevent further degradation, resulting in stable coral coverage at 1,754 hectares throughout the entire time frame, as shown in **Figure 6** (blue line).

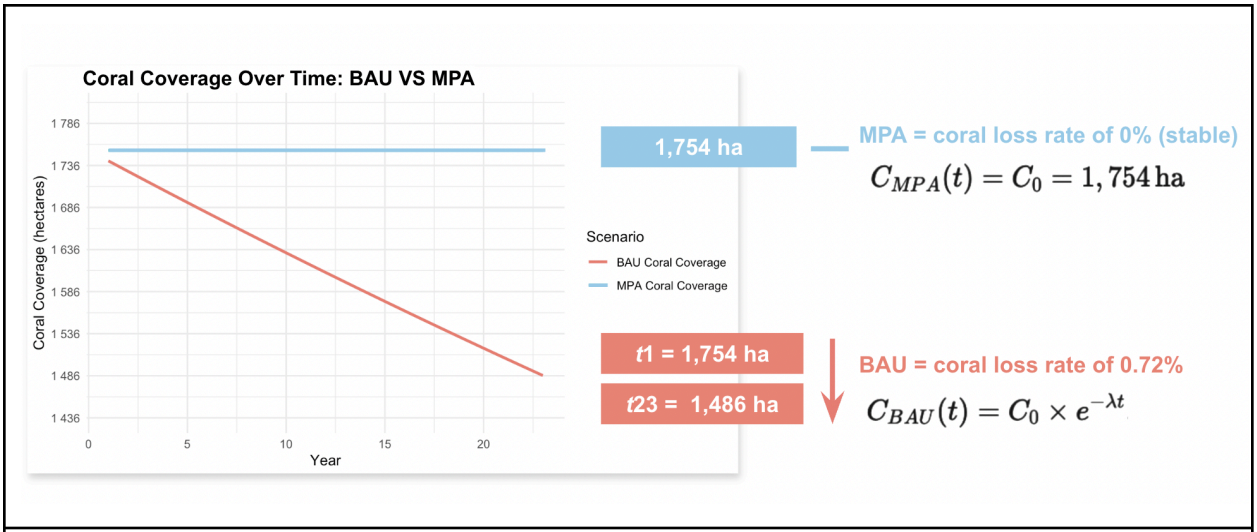


Figure 6: Projected coral coverage over 23 years under BAU and MPA scenarios. The BAU scenario (orange) shows a decline from 1,754 ha at t_1 to 1,486 ha at t_{23} due to a 0.72% annual loss. The MPA scenario (blue) maintains stable coverage at 1,754 ha, highlighting the impact of protection efforts.

Ecosystem Services Over Time

The economic value of ecosystem services (ESV) follows the trend of coral coverage. Since TEV is calculated per hectare, the declining coral cover under BAU leads to a corresponding decrease in ESV, while in the MPA scenario, ESV remains constant.

As shown in Figure 7, at t_1, ecosystem service values under both scenarios are $32,627,908 USD. However, as reef degradation continues under BAU, ESV drops to $27,648,403 USD by t_{23}. This represents a loss of approximately $4.98 million in economic benefits due to coral degradation.

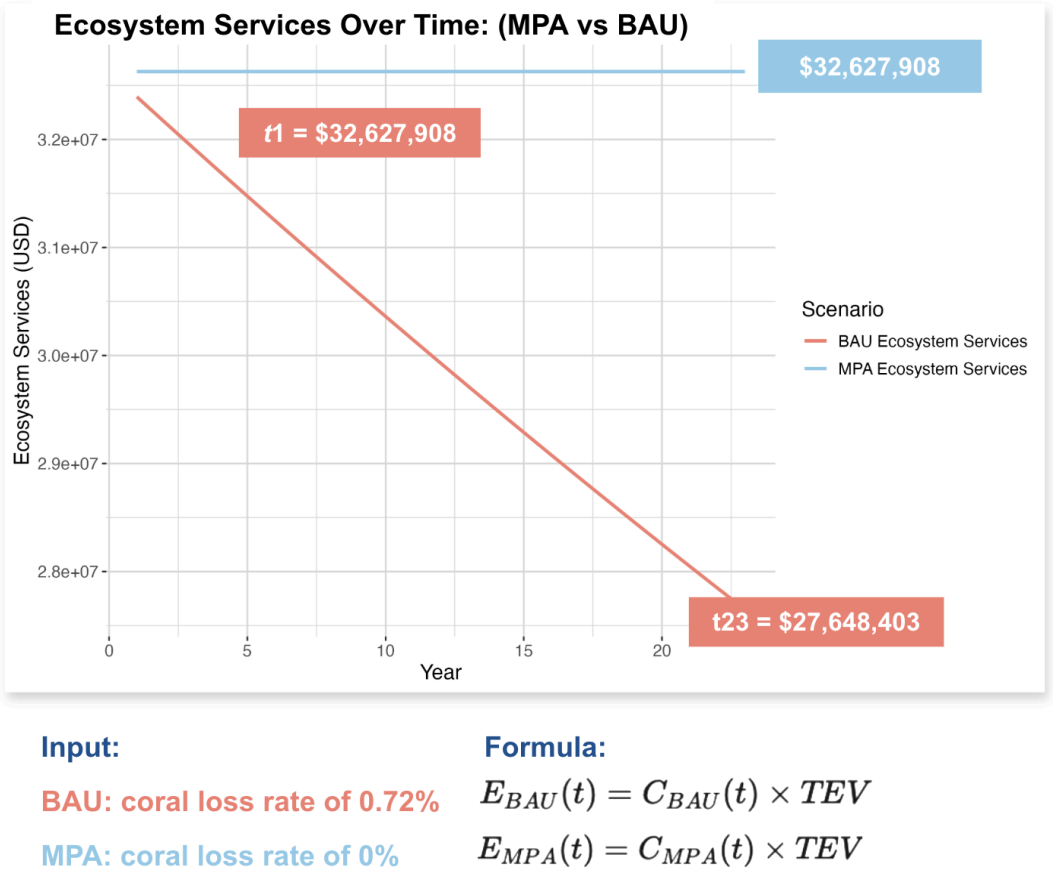


Figure 7: Projected ecosystem service values over 23 years under BAU and MPA scenarios. The BAU scenario (orange) shows a decline in ecosystem services from \$32.6M at t_1 to \$27.6M at t_{23}, while the MPA scenario (blue) maintains a constant value, reflecting stable coral coverage.

Discounted Ecosystem Services Over Time

To incorporate the time value of money, ecosystem services were discounted using a 6.82% social discount rate, based on the Bank of Indonesia's interest rate (Kementerian Kelautan dan Perikanan et al., 2024).

As shown in Figure 8, at t_1, the discounted ecosystem service value under BAU is \$30,325,623 USD, while under MPA it is \$30,544,755 USD. By the end of the projection period at t_{23}, the discounted benefits declined further to \$6,062,627 USD under BAU and \$7,154,512 USD under MPA, widening the gap to \$1,091,885 USD in favor of the MPA scenario.

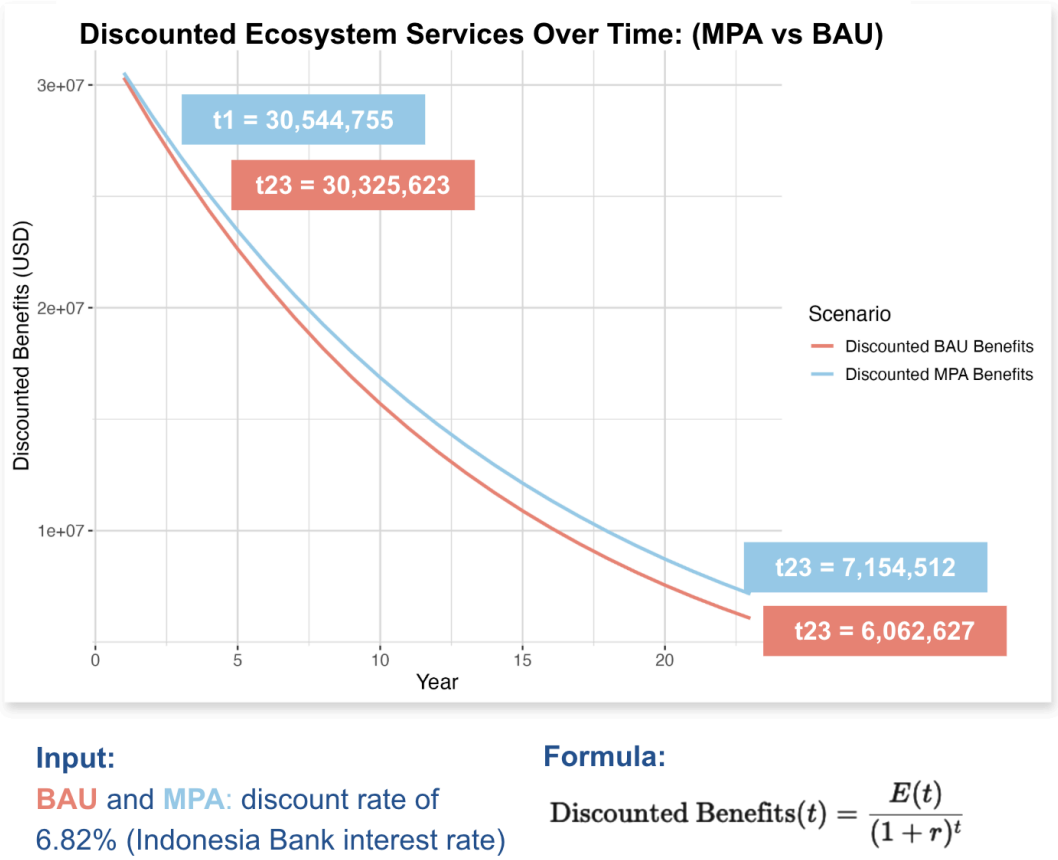


Figure 8: Discounted ecosystem service values over 23 years under BAU and MPA scenarios. The BAU scenario (orange) shows a decline from \$30.3M at t_1 to \$6.06M at t_{23}, while the MPA scenario (blue) maintains higher discounted benefits, decreasing from \$30.5M to \$7.15M.

Cumulative Discounted Benefits Results

To determine the total economic value of coral reef conservation, cumulative discounted benefits were calculated by summing annual discounted values over 23 years.

As shown in Figure 9, cumulative benefits consistently favored MPAs over BAU. The total cumulative ecosystem service benefits under BAU are lower, reflecting the accelerated economic losses from reef degradation. Conversely, MPA cumulative benefits remain higher throughout, emphasizing the cost-effectiveness of protection efforts.

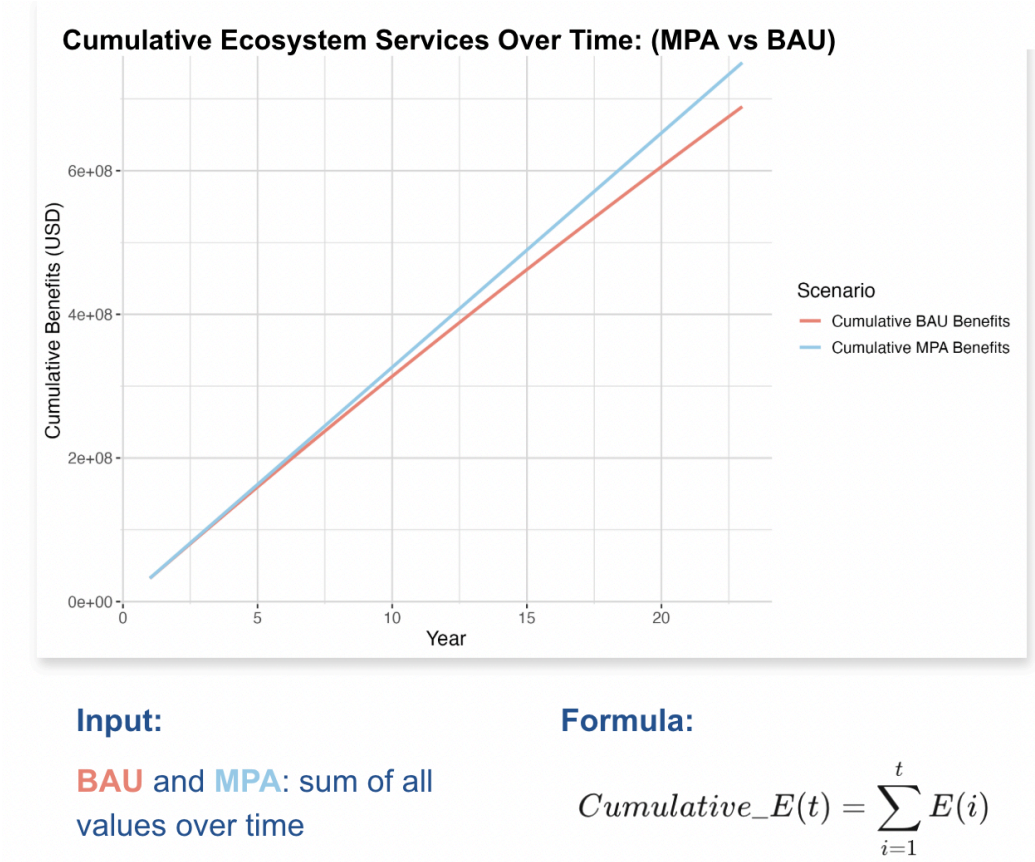
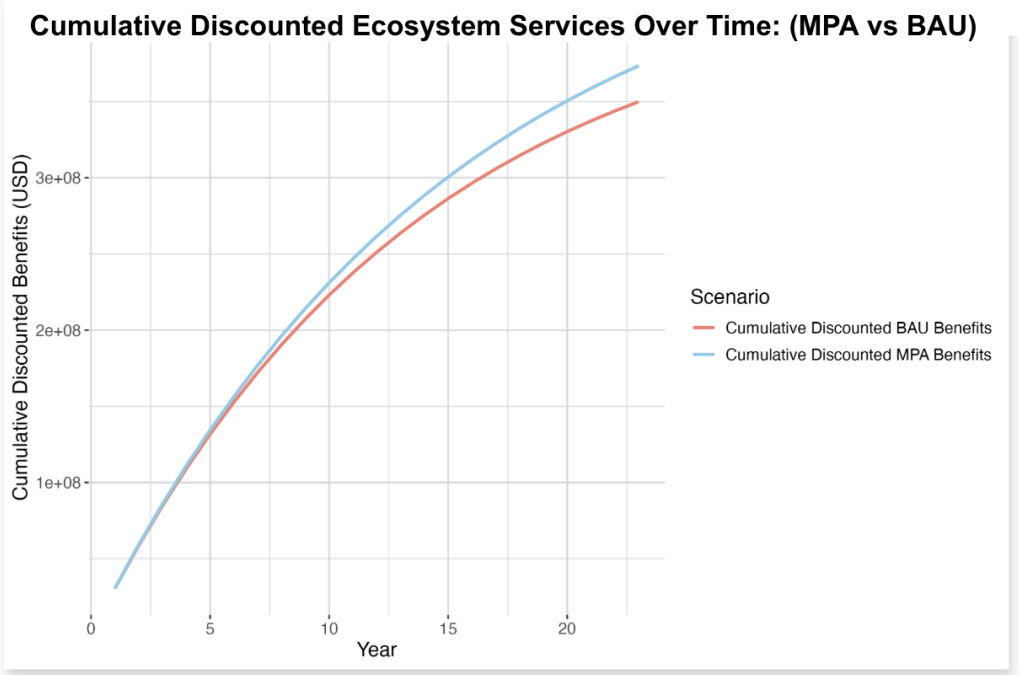


Figure 9: Cumulative ecosystem services value for each scenario over a 23-year horizon.



Input:

BAU and **MPA**: sum of all discounted values over time

Formula:

$$Cumulative\_Discounted\_E(t) = \sum_{i=1}^{t} \frac{E(i)}{(1+r)^i}$$

Figure 10: Cumulative discounted ecosystem services value for each scenario over a 23-year horizon. Further illustrates that cumulative discounted benefits follow the same trend, with the Net Present Value (NPV) of ecosystem services over the 23-year period totaling $34,991,705 USD under BAU and $37,351,020 USD under MPA, as shown in Figure 11. This results in a positive ΔNPV of $2,359,314 USD, demonstrating that MPA implementation yields higher long-term economic returns compared to BAU.

Discussion of CBA results

Overall results showed that in the BAU scenario, coral coverage and ecosystem services would decline. Alternatively, the MPA scenario showed that if we were to utilize protections to keep coral health and coverage stable, ecosystem services could be sustained over time and lead to higher economic benefits. The higher NPA amount under the MPA scenario and the positive ΔNPV of $2.36 million reinforces the long-term benefits of protecting coral.

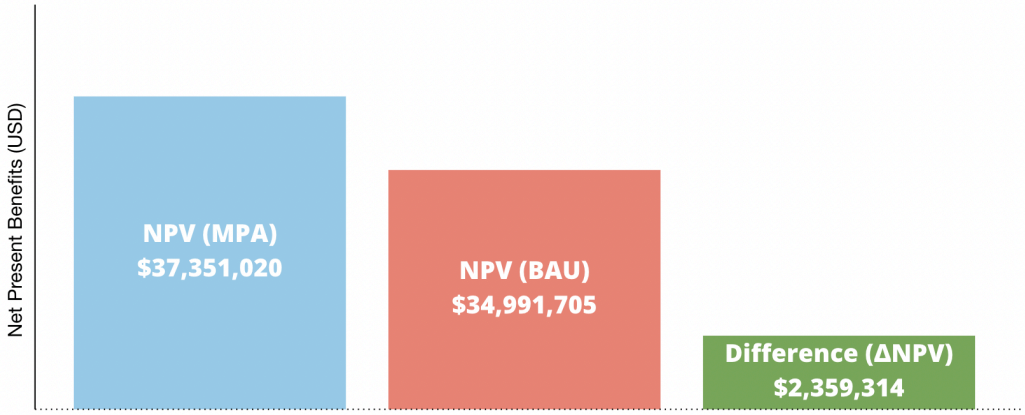


Figure 11: Net present value is higher under the MPA scenario after a 23-year horizon. The $2.36 million positive difference highlights the long-term benefits of protecting corals.

The BAU scenario assumed an annual coral loss rate of 0.72% due to unregulated activity and environmental degradation. This resulted in a steady decline in ecosystem service values over time, reflected in the lower NPV. The MPA scenario assumed no further coral loss, maintaining coral coverage at a stable level. This would allow the ecosystem services to also remain stable, leading to a higher cumulative discounted value over the 23-year horizon. The discount rate of 6.82% reflected the time value of money, reducing the weight of future benefits. While both scenarios were discounted equally, the sustained ecosystem services in the MPA resulted in a higher NPV. The ΔNPV demonstrated a clear economic benefit of $2.36 million in favor of implementing the MPA. This figure quantified the additional economic value generated by preserving coral reef ecosystems through proactive management.

Findings from the Surf Tourism Survey

The data presented in this section reflect the final survey results, with a total of 44 responses collected. While the sample size may still limit data saturation, the findings provide valuable insights into surfer profiles, preferences, and travel patterns. Among the responses, 30 (68%) were from the English survey version, and 14 (32%) from the Spanish survey version.

One concern was the potential for response bias, as respondents might be more supportive of surf conservation due to their involvement with CI, which conducted outreach to gather participants. However, after analyzing the data, results show that 33 out of 44 respondents (75%) reported learning about the survey through social media, friends, or UCSB students, rather than through CI.

Surfers Profiles & Demographics

Among the 44 respondents, 44.5% were from the United States. Participants from Chile accounted for 31.8%, while 6.8% were from the European Union. Additionally, 11.4% were from Australia, and 2.3% from South America and Austria. No responses were recorded from Indonesia.

65.9% of the respondents were male, and 34.1% were female. The majority (43.2%) were between 25–34 years old, followed by 22.7% in the 35–44 age group and 9.1% in the 18–24 group. A smaller percentage were 55–64 years old (13.6%) and 45–54 years old (11.4%), respectively. No respondents were 65 or older.

Employment status varied, with 40.9% identifying as full-time employees, 29.5% as a student, 22.7% as self-employed, 4.5% as part-time employed and 2.3% unemployed. Regarding education, the majority (54.5%) held a graduate degree, 36.4% had a college degree, 4.5% were high school graduates, and 4.5% had some college degree.

The survey results indicate a diverse distribution of household incomes among respondents. The most common income categories were $150,000 and over (20.5%) and $25,000 to $49,999 (20.5%), followed closely by $10,000 to $24,999 (18.2%). 15.9% of respondents reported an annual household income between $100,000 and $149,999, while 6.8% fell into the $50,000 to $74,999 and $75,000 to $99,999 ranges, respectively. A small portion (2.3%) reported earning less than $10,000, and 9.1% chose not to disclose their income.

To compare our survey results with available data, we referenced Towner (2016) and Ogden-Fung et al. (2021), which surveyed surfers in the Mentawai Islands and Morotai Island, respectively. Towner (2016) reported that 25% of surveyed surf tourists had a personal income between $100,001 and $150,000 USD. In contrast, our survey found that 15.9% of respondents fell within the $100,000 to $149,999 range. However, since we asked about household income (the total income of all individuals living in a household) before taxes rather than personal income, this may explain why a larger percentage (20.5%) reported an income of $150,000 and over.

Similarly, Ogden-Fung et al. (2021) surveyed 26 respondents in Morotai Island and found that the most common personal income category was $20,000-$40,000 USD (35%), followed by $40,001-$60,000 USD (15%). These findings are comparable to our results, as the second most common income bracket in our study was $25,000 to $49,999 (20.5%). However, our survey showed a broader income distribution with a higher percentage of respondents in the upper-income brackets. This difference could be attributed to variations in survey locations, the specific surf tourism markets in Mentawai versus Morotai, or the fact that both Towner (2016) and Ogden-Fung et al. (2021) collected data on personal income, whereas our survey measured household income.

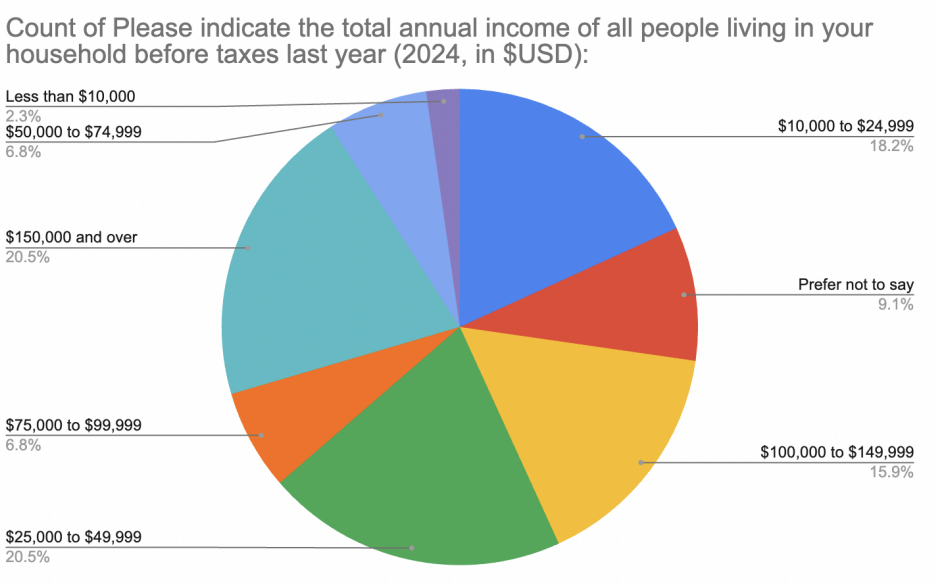


Figure 11.1: Annual income of surfer tourist respondents and all people living in their household before taxes in 2024 (USD).

The overall survey results show a diverse distribution of household incomes among respondents. However, a closer look at the English and Spanish survey versions reveals some notable differences.

In the English survey (left chart in **Figure 12**), the most common income category was $150,000 and over (26.7%), followed by $25,000 to $49,999 (20%) and $100,000 to $149,999 (13.3%). In contrast, in the Spanish survey (right chart in Figure 12), the most common income category was $10,000 to $24,999 (35.7%), followed by $100,000 to $149,999 (21.4%) and $25,000 to $49,999 (21.4%).

Notably, a larger proportion of respondents from the Spanish survey reported household incomes below $25,000 (42.8%), while a higher percentage of English survey respondents (26.7%) reported earning $150,000 or more. Additionally, 7.1% of Spanish respondents reported earning less than $10,000, whereas no respondents in the English survey fell into this category.

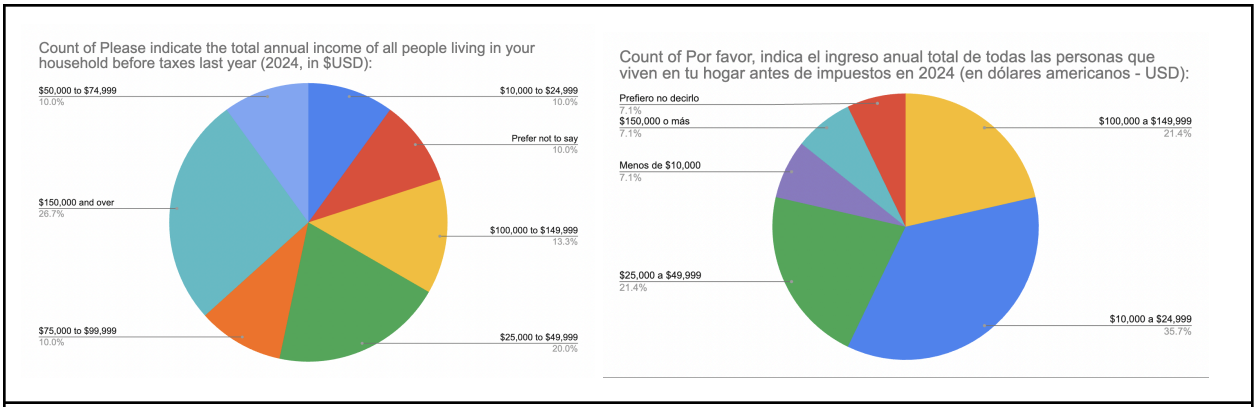


Figure 12: Annual income of surfer tourist respondents and all people living in their household before taxes in 2024 (USD). The figure on the left represents responses from the English version of the survey, while the figure on the right represents responses from the Spanish version.

Surf Trip Preferences and Duration

The majority of respondents (86.4%) indicated that their primary reason for visiting Sumatra was surfing. A smaller percentage (11.4%) reported visiting for general tourism purposes, such as sightseeing and cultural experiences and volunteering or NGO work (2.3%). Notably, in the Spanish-language survey, 100% of respondents selected surfing as their main motivation for visiting Sumatra, reinforcing the prominence of surf tourism in the region.

Surfing experience varied among respondents. The results indicate that the majority of surf tourist respondents are highly experienced surfers. 61.4% reported having surfed for more than 10 years, making this the largest group. This was followed by 15.9% with 4–6 years of experience and 11.4% with 7–10 years. A smaller proportion of respondents are relatively new to surfing, with 6.8% having surfed for 1–3 years and 4.5% for less than a year. These findings suggest that most surveyed surfers have long-term engagement with the sport (**Figure 13**). In terms of self-reported skill level, 59.1% of respondents identified as intermediate surfers, while 36.4% classified themselves as advanced surfers. Only 4.5% of respondents considered themselves beginners, reinforcing the idea that the surveyed group consists mainly of experienced surfers.

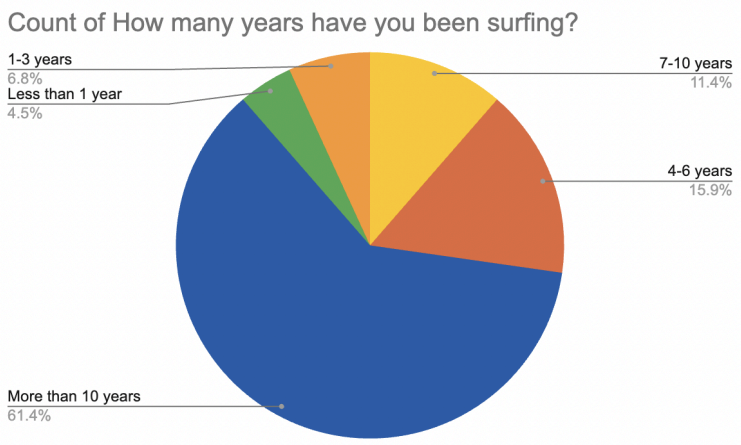


Figure 13: Pie chart showing the distribution of years of surfing experience among surf tourist respondents.

Among the total sample, 29.5% of respondents have surfed in Sumatra. The results indicate that the Mentawais were the most frequently visited surf region, with 8 respondents (16%) having surfed there (**Figure 14**). This was followed by 6 respondents (12%) in North Telos and 5 respondents (9%) in South Telos.

Simeulue had a lower percentage, with 3 respondents (5%), while North Nias was the least visited region, with only 1 respondent (2%). These insights highlight the popularity of the Mentawais and Telos regions among the surveyed surfers.

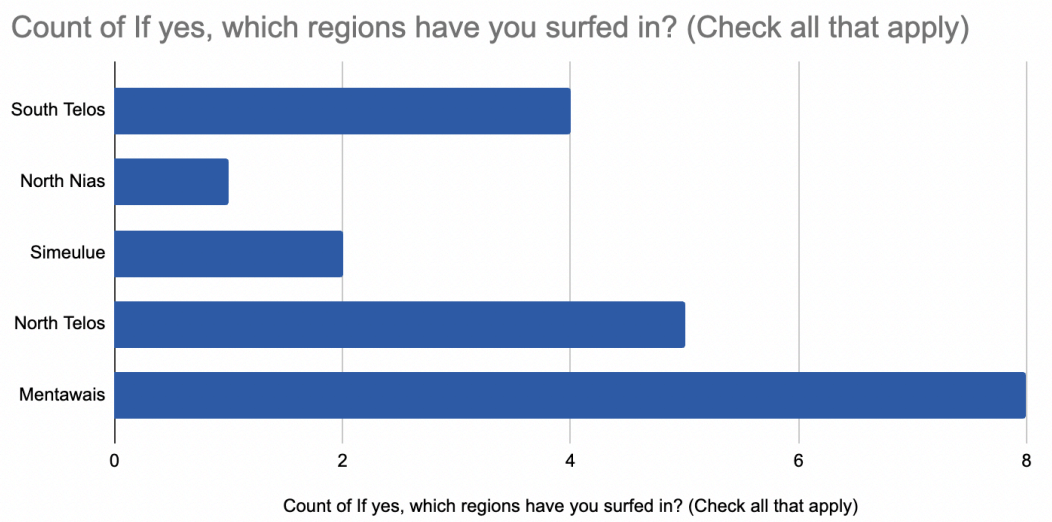


Figure 14: Bar chart showing the aggregated results for regions where surfers who stated they have surfed in Indonesia surfed.

When asked about the ideal duration of a surf trip to Sumatra, the majority of respondents (38.6%) preferred staying for 6 to 10 days, closely followed by 34.1% who indicated a stay of more than 15 days. Additionally, 22.7% stated a preference for 11 to 15 days, while only 4.5% opted for a trip of less than 5 days.

Differences were observed between the English and Spanish survey versions. In the English survey, the majority (46.7%) also preferred 6 to 10 days, followed by 30% who chose more than 15 days. In contrast, in the Spanish survey, the most common response was more than 15 days (42.9%), followed by 11 to 15 days (35.7%).

This variation may be attributed to the travel time required to reach Indonesia from respondents' respective countries. 45.5% of respondents were from the United States, where travel times to Indonesia range from 22 to 30 hours. Meanwhile, 31.8% of respondents were from Chile, where travel times range from 28 to 40 hours with multiple layovers. The longer travel time from Chile may explain why Spanish-speaking respondents showed a greater preference for longer stays compared to their English-speaking counterparts.

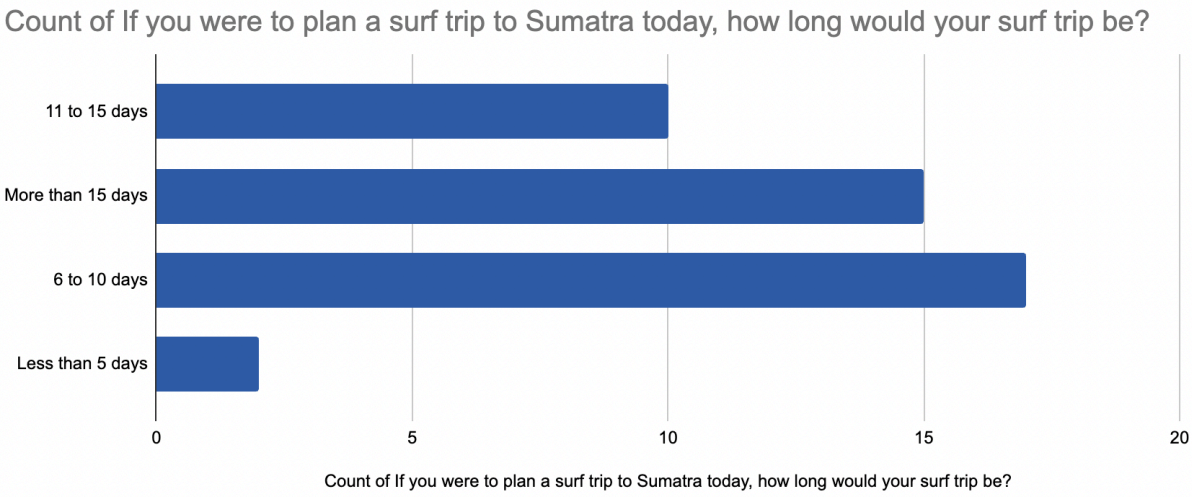


Figure 15: Bar chart showing the aggregated results for the number of days surfers would plan for a surf trip to Sumatra.

Expenditure/Willingness to Pay for Surf Trips to Sumatra

Among the 44 participants, 50% indicated a budget of $2,500 to $5,000 per person for their surf trip to Sumatra (excluding flights). The second most common budget range was $1,000 to $2,500, selected by 34.1% of respondents. A smaller percentage (6.8%) anticipated spending less than $500 or more than $5,000, while only 2.3% expected to budget between $500 and $1,000. These budget preferences are illustrated in **Figure 16**.

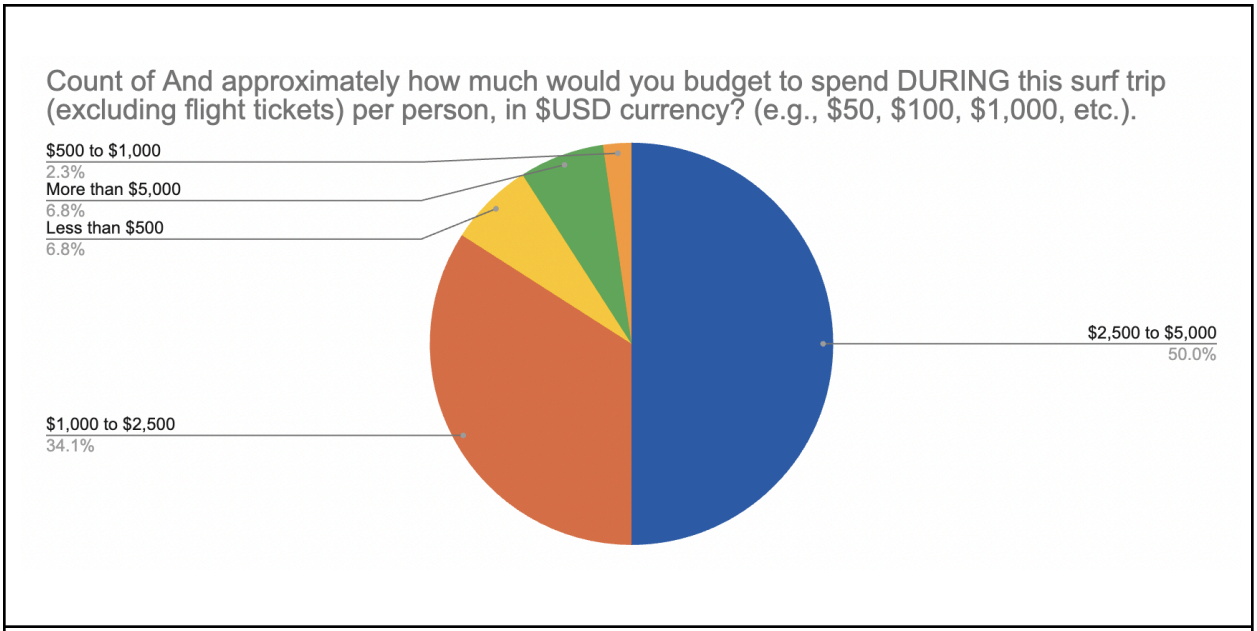


Figure 16: Pie chart showing the aggregated results for the budget (direct expenditure), excluding flight tickets, for the trip duration surfers stated in the previous question.

To assess expenditure patterns, we analyzed the relationship between trip duration and total budget allocation based on the respondents' stated length of stay. Participants provided their intended trip duration and estimated budget (excluding flights). To standardize the data, budget ranges were converted into mid-point values—for example, $1,750 was assigned to the $1,000–$2,500 range. Likewise, trip durations were adjusted to reflect average days within each category, with 6–10 days standardized to 8 days. For broader categories, fixed values were assigned; “More than 15 days” was set to 16 days, and “More than $5,000” was represented as $5,001.

The mean willingness to pay (WTP) or total expenditure per trip among all respondents was $2,931.75 USD. However, mean expenditures varied based on the length of stay:

- More than 15 days: $2,950 per trip
- 11 to 15 days: $3,150 per trip
- 6 to 10 days: $2,809 per trip
- Less than 5 days: $2,750 per trip

To further contextualize these expenditures, we analyzed package trips that included all essential expenses (e.g., transportation—excluding flight tickets—accommodations, all-inclusive food and beverage services, surf boats, recreational equipment, etc.). We found that most package prices ranged from $2,000 to $3,000 USD for an 11-night stay, which aligns with the 11 to 15-day category and falls within respondents' WTP. For example, an all-inclusive surf package at Macaronis Resort for 11 nights costs approximately $2,145 per person, while a surf camp package at Telos Surfing Village is priced at $3,600 USD.

Then, to estimate daily expenditures, we divided each respondent's assigned mid-point WTP by their mid-point trip length. The mean daily WTP (budget per day) for a surf trip was calculated as $284.82 USD per day. However, daily expenditures showed significant variation depending on the length of stay:

- More than 15 days: $184.38 per day
- 11 to 15 days: $242.31 per day
- 6 to 10 days: $351.08 per day
- Less than 5 days: $687.50 per day

These findings suggest that while in most cases, total expenditures increase with longer trips, the average daily budget decreases, indicating potential cost efficiencies for extended stays.

This pattern highlights a trend where surfers planning shorter trips tend to allocate a higher daily budget, likely due to more concentrated spending on better quality accommodations, guided experiences, or higher daily travel costs.

We then assessed the relationship between expenditure patterns and respondents' income categories using the following formula:

$$Mean\ Daily\ Expenditure/WTP\ for\ Income\ Brackets\ = \frac{\sum(Daily\ WTP\ of\ individuals\ in\ bracket)}{Number\ of\ respondents\ in\ income\ bracket}$$

The Mean Daily expenditure by Income Bracket (USD) results were:

- $150,000 and over: $467.68 USD/day
- $100,000 to $149,999: $351.65 USD/day
- $75,000 to $99,999: $270.83 USD/day
- $50,000 to $74,999: $249.96 USD/day
- $25,000 to $49,999: $181.74 USD/day
- $10,000 to $24,999: $254.81 USD/day
- Less than $10,000: $62.38 USD/day

The mean daily WTP by income bracket suggests that higher-income respondents tend to be willing to spend more per day on their surf trips. This trend aligns with expectations, as higher-income individuals may have greater disposable income and a higher ability to pay for premium experiences, accommodations, and services. Conversely, lower-income respondents appear to stretch their budgets over longer trips, likely maximizing their experience while keeping daily costs lower.

Participants were asked whether their budget would vary *"based on the quality of experience at any particular surf break"*. In response, 30 participants (68.2%) stated that their budget was dependent, while 14 participants (31.8%) reported it was not.

For those who indicated their willingness to pay was dependent, responses highlighted several key factors influencing their spending decisions:

1. Uncrowded, High-Quality Waves: The crowding of surf breaks emerged as the most significant factor for respondents, followed closely by wave quality. Many participants expressed a greater willingness to pay for access to high-quality, uncrowded surf breaks, emphasizing that overcrowding negatively impacts the overall surf experience. Some respondents stated a preference for paying extra for boat trips to explore less crowded surf spots or for exclusive access to remote surf breaks.

> *"Great waves are getting harder and harder to find, uncrowded great waves even more so. The quality of the wave definitely affects my willingness to spend money to get there, stay there, and surf it."*
> - Surf Tourist

2. Maintenance and Condition of Surf Destinations: Another important consideration mentioned by respondents was the state of maintenance and development at surf destinations. Overdeveloped or poorly maintained surf areas were perceived negatively, reducing the desirability of the location and, in some cases, influencing respondents' willingness to spend money to visit or stay there.

> *“When a surf area feels trashy then I don’t view the place as pristine and I don’t feel like I want to pay as much money to be there. I will always pay more money to go surf at a nicer spot”.*
> - Surf Tourist

3. Conservation-Related Activities: Some respondents indicated that they would be willing to pay more if their trip included conservation-related experiences. These participants valued opportunities to engage in environmental initiatives related to marine protection, coastal conservation, or sustainability efforts.

> *“I would pay additional money to have other experiences included in my trip, related to conservation work.”*
> - Surf Tourist

4. Additional Amenities & Services: Several respondents expressed a willingness to pay extra for experiences that extend beyond surfing, such as surf retreats that include accommodations and amenities. Others highlighted the importance of rental equipment availability, ease of access to surf breaks, and additional recreational activities, noting that these factors influenced how much they were willing to spend on their trip.

5. Flexibility & Planning Considerations: Some participants stated that surf conditions and the need to move between locations played a crucial role in their budgeting decisions. Given that surf trips often require constant travel and adaptability, these respondents emphasized the importance of flexibility when planning their expenses. Others preferred to maximize their overall experience within a reasonable budget, carefully balancing quality, cost, and surf conditions.

WTP for Crowd Management

Survey participants were asked about their WTP for managing overcrowding at surf spots. A total of 30 respondents (68.2%) indicated that they would be willing to pay a one-time fee for crowd management measures. For detailed results on WTP amounts, see **Figure 18**.

WTP for Surf Conservation Efforts

For detailed results on Surf Conservation Efforts WTP amounts, see **Figure 18**.

The survey results indicate that the most significant factors influencing WTP for conservation efforts are ensuring that economic benefits remain within the local community, followed by improving environmental management and supporting locally operated services. A total of 81.8% of respondents agreed that they were more likely to contribute to conservation efforts if they knew the economic benefits would directly support local communities. Additionally, the same percentage expressed a willingness to pay more for a surf experience if it resulted in improved environmental management and local benefits (see **Figure 17**).

The preference for locally owned and operated surf experiences also emerged as a key factor, with 72.7% of participants agreeing that they would prefer a locally operated surf experience due to its contributions to the local economy and conservation efforts (see **Figure 17**).

Furthermore, although agreement levels were generally higher than disagreement, the lowest agreement was observed for the statement regarding the quality of locally owned/operated services and how they influence enjoyment and the likelihood of returning to a surf destination.

These findings suggest that WTP for conservation is driven not only by environmental concerns but also by a desire to support community-based and equitable tourism models.

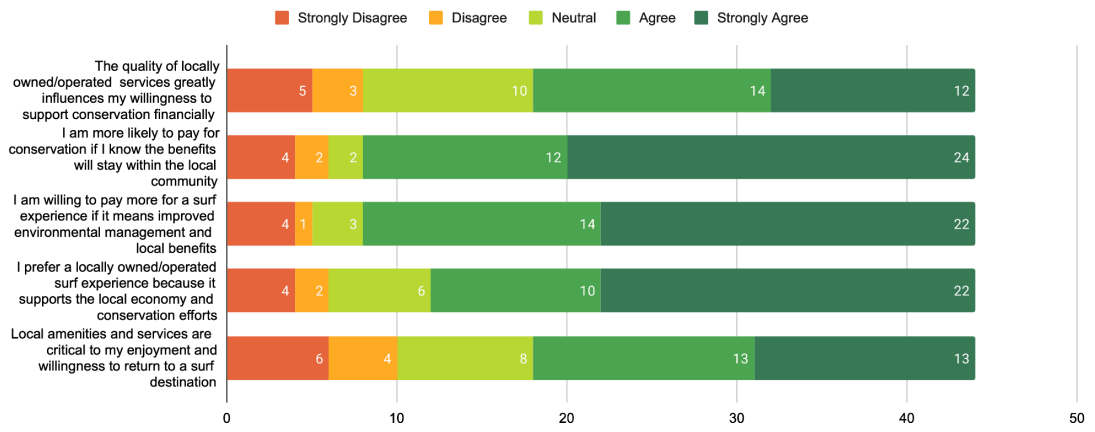


Figure 17: Bar chart showing factors influencing surfers' willingness to pay for conservation efforts and overall surf experience. Responses are categorized by level of agreement with various statements regarding environmental, and local economic benefits, locally owned services, and amenities.

Comparison of WTP Results

Earlier in our analysis of expenditure patterns, we standardized bracketed responses by using midpoints or reasonable fixed values, such as $5,001 for the "More than $5,000" category. This approach ensured consistency in estimating trip budgets while maintaining a conservative estimate for upper-bound responses.

However, when calculating overall mean WTP values for conservation fees, crowd management fees, and general expenditures, we opted to use a $7,500 proxy for the "more than $5,000" bracket. This decision was made because WTP values are particularly sensitive to the influence of high-spending outliers, and using a higher proxy better accounts for respondents who may have spent significantly above $5,000. While this adjustment raises the mean estimate compared to the more conservative $5,001 assumption, it provides a more representative view of potential right-skewed distributions in WTP data. The choice to apply this adjustment should be considered when interpreting the following results.

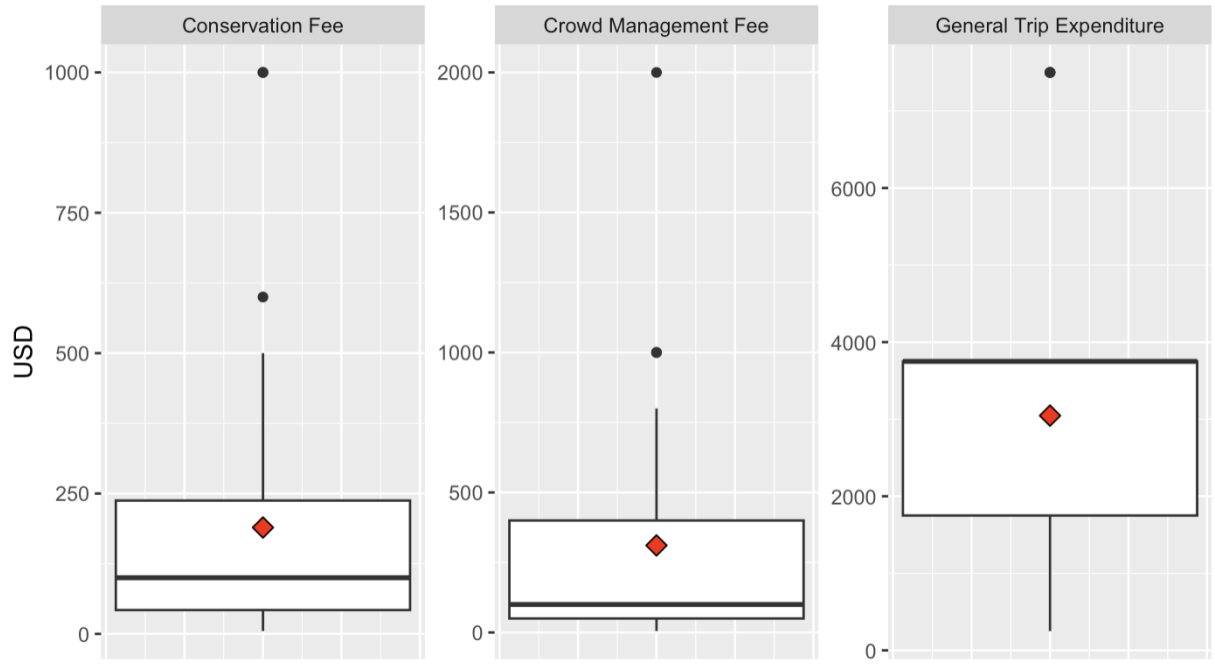


Figure 18. Willingness to Pay (WTP) Box Plot Comparison. This figure presents box plots of WTP values obtained from our survey for three categories: conservation fees, crowd management fees, and general trip expenditures (left to right). The red diamond represents the mean value in each category. Notably, the mean is higher than the median for conservation and crowd management fees, suggesting a right-skewed distribution. While our dataset is sparse, visible outliers may not be considered outliers with a larger sample size. In contrast, for general trip expenditures, the mean is lower than the median, even after applying a $7,500 proxy value for the "More than $5,000" response bracket. This may indicate a different skew direction for general expenditures compared to conservation and crowd management fees.

Table 7. Willingness to Pay (WTP) Summary Statistics. This table displays the mean and median WTP values for conservation fees, crowd management fees, and general trip expenditures, corresponding to the box plots in Figure 18. The values reflect calculations using the $7,500 proxy for the "More than $5,000" expenditure bracket. This choice accounts for the potential influence of high-spending outliers on the mean estimates.

WTP General Expenditure Mean	WTP General Expenditure Median	WTP Crowd Management Mean	WTP Crowd Management Median	WTP Conservation Fee Mean	WTP Conservation Fee Median
3046.053	3750	310.9259	100	189.4737	100

Perceived Benefits of Surf Conservation Outcomes

Respondents rated their perceived level of importance on key surf conservation benefits or outcomes. All percentages refer to respondents who rated each objective as either "important" or "very important" (Shown in **Figure 19**).

The three most important conservation objectives were keeping surf breaks clean and reducing pollution (18.2% rated it as “important” and 77.3% as “very important”), preserving marine biodiversity at surf spots (27.3% “important” 68.2%, “very important”), and protecting coastal and surf ecosystems (29.5% “important” 63.6%, “very important”). These results highlight a strong emphasis on environmental management, particularly pollution control—likely due to its direct impact on surfers' experience—as well as the importance of habitat conservation and marine biodiversity protection.

Beyond environmental concerns, respondents also valued the economic and cultural dimensions of surf conservation. A significant majority emphasized the importance of local community involvement in managing surf ecosystems (31.8% “important”, 61.4% “very important”, while many highlighted the role of sustainable tourism and economic opportunities for local communities (34.1% “important”, 52.3% “very important”). Additionally, 72.7% of respondents considered the enhancement of local identity and traditions an essential aspect of conservation (45.5% “important”, 27.3% “very important”).

On the other hand, the least prioritized outcome was increasing the attractiveness for international surf tourists, with only 36.4% of respondents rating it as “important” or “very important” (27.3% “important”, 9.1% “very important”). These findings suggest that surf conservation strategies should integrate environmental protection, economic sustainability, and cultural preservation to align with surfers' priorities.

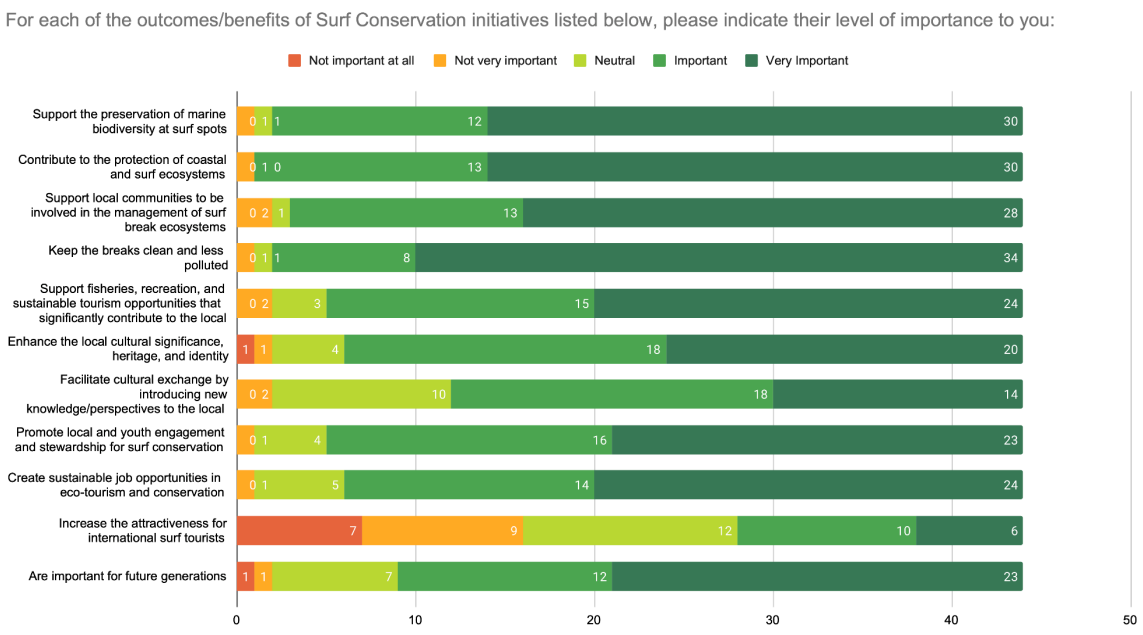


Figure 19: Bar chart showing perceived environmental, social, and economic benefits from surf conservation initiatives. Responses are categorized by level of importance assigned to various conservation outcomes.

Perceived Costs/Concerns About Surf Tourism Development

While respondents acknowledged the benefits of surf tourism, they also expressed significant concerns regarding its potential negative impacts (shown in **Figure 20**). Environmental issues were the most frequently cited concerns, with 75.0% of respondents indicating a high level of concern (“very concerned” or “extremely concerned”) regarding the environmental impacts of increased tourism development. Waste generation was a particularly alarming issue, as 86.4% of participants identified the increase in solid waste due to surf tourism as a major concern. Additionally, 79.5% of respondents expressed concern over the loss of access to natural resources for local communities due to surf tourism expansion.

Economic concerns were also prevalent, with 63.6% of respondents worried about the unequal distribution of income from surf tourism, suggesting that financial benefits may not always reach local populations equitably. Furthermore, 59.1% of respondents expressed concern over increases in the cost of living due to the influx of tourists, and 75.0% reported concerns about increases in prices due to surf taxes or conservation fees.

In addition to environmental and economic concerns, respondents also identified overcrowding as a potential threat to surf quality. 77.3% of participants indicated high concern over the decline in surfing experience due to overcrowding, while 86.4% were concerned about the inability to visit preferred surf spots due to crowding. These findings suggest that improper management of tourism flows could degrade the overall experience for both locals and visitors, emphasizing the need for sustainable crowd management strategies.

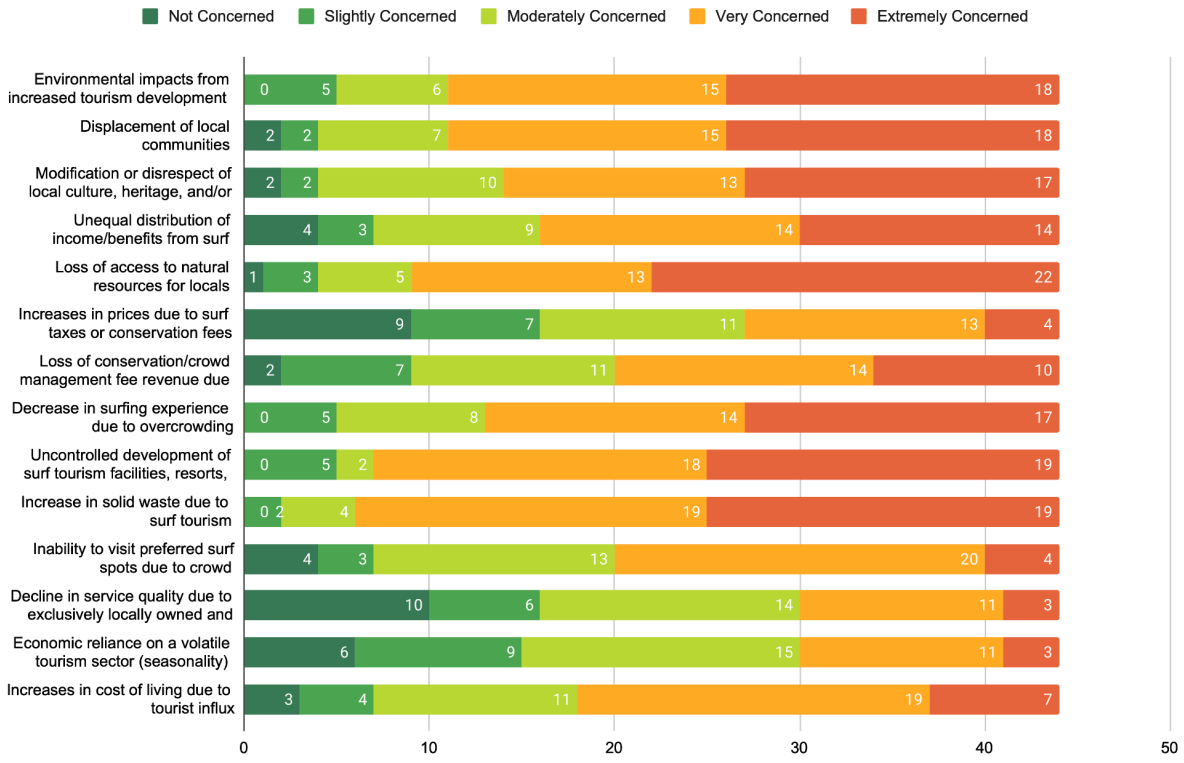


Figure 20: Bar chart showing perceived environmental, social, and economic costs from surf development. Responses are categorized by the level of importance assigned to different potential impacts derived from surf development.

Stakeholder Analysis Results for Objectives 3 and 4

Key priorities for stakeholders

The results from the stakeholder analysis are based on Ogden-Fung et al. (2021) and supplemented with insights from Towner (2016) and Buckley (2002) to compare key perspectives on surf tourism and conservation. Ogden-Fung et al. (2021) used semi-structured interviews and an online survey to gather insights from four stakeholder groups: local community members (5 individuals), government officials (3 individuals), NGO employees (5 individuals), and surf tourists (26 individuals). The analysis revealed four key themes: empowering local community participation, establishing local economic benefits, conserving natural resources, and building a collaborative vision. **Figure 21** shows a stakeholder map of the actors involved in SPAN's initiatives, and **Table 8** presents an example of the key themes and subthemes that emerged from interviews with community members in the study by Ogden-Fung et al.

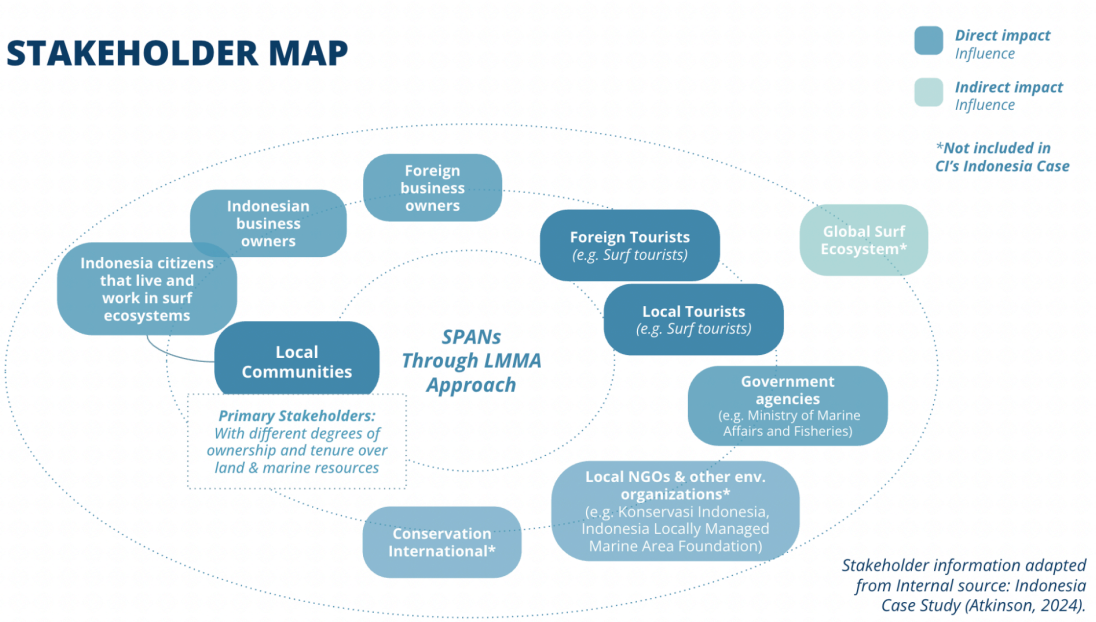


Figure 21: Stakeholder map illustrating key actors involved in surf conservation and tourism management in Indonesia, categorized by direct and indirect influence.

Table 8: Table showing the key themes and subthemes that emerged from interviews with community members in the study by Ogden-Fung et al. (2021)

Table 1. Key themes and subthemes that emerged from participant interviews with Morotai community members. Note: This table lists the number of participants who discussed each theme (n = 5).

Key Themes	Subthemes	Participants
Lack of understanding	New industry	5
	Need educational outreach	5
Lack of participation	More for youth	5
	Need financial incentives	4
	Need more surfing competitions	4
	Language barrier	3
High youth engagement	Improve surfing skills	5
	Learn foreign languages	4
	Befriend surf tourists	4
	Strengthen local pride	3
Establish local economic benefits	Increase surf tourists	5
	Increase income level	5
	Create more homestays	4
	Sell more goods	4
Conserve natural resources	Better beach cleanliness	5
	Benefit future generations	5
Lack of government assistance	Not listening to local voices	5
	Need to implement regulations	3
	Need support for local land ownership	2
	Need better enforcement	2
	Need funding	2
Lack of infrastructure	Need tourist facilities	4
	Need public bathrooms	2
	Need trash bins and recycling equipment	1

Empower Local Community Participation: Stakeholders emphasized the need for increased local participation in surf tourism and conservation efforts. Limited awareness about the economic and environmental potential of surf-related initiatives has resulted in low engagement. Government officials and NGO employees identified educational outreach as a priority to enhance local knowledge and advocacy (Ogden-Fung et al., 2021). This aligns with the community-based tourism (CBT) model, which promotes local involvement, power redistribution, and social capital creation (Okazaki, 2008). However, Towner (2016) found that surf tourists often stay in resorts or charter boats, reducing direct interaction with local communities and limiting economic opportunities.

Establish Local Economic Benefits: Surf tourism presents a potential economic driver for local communities. Stakeholders supported diversifying local businesses, increasing surf tourism in underdeveloped areas, and limiting foreign land ownership to ensure economic benefits remain within communities (Ogden-Fung et al., 2021). Towner (2016) found that surf tourists tend to be high-income earners, with 25% earning between $150,000 and $200,000 per year, suggesting that sustainable surf tourism could attract a high-value market. However, it may be important to promote diversified livelihood opportunities to enhance income resilience within local communities, ensuring that they are not solely reliant on surf tourism as their primary economic driver. Buckley (2002) cautioned against over-reliance on tourism, noting that disruptions such as economic downturns or environmental degradation could threaten local livelihoods. The Mentawai Islands case study (Buckley, 2002) highlighted how a high-value, low-volume model could sustain a profitable surf tourism industry while ensuring long-term local benefits.

Conserve Natural Resources: The need to balance tourism growth with environmental sustainability was widely recognized. Stakeholders supported conservation regulations, surf conservation fees, and a high-cost, low-impact tourism model to limit overdevelopment (Ogden-Fung et al., 2021). Buckley (2002) emphasized that crowd management is critical for both environmental conservation and surf quality, advocating for quota and permit systems to regulate tourist numbers. Towner (2016) found that 39% of surf tourists cited "good quality surf" as their primary travel motivation, reinforcing the importance of recreational capacity management. Additionally, surf tourists significantly contribute to local economies, with annual expenditures in Uluwatu, Bali, for example, estimated at $35.3 million USD (Margules et al., 2014, cited in Ogden-Fung et al., 2021), further demonstrating the economic incentives for conservation. However, it is important to balance this economic development with measures to protect surf breaks and surrounding ecosystems, as unregulated tourism expansion could lead to environmental degradation and the eventual loss of the very resources that attract visitors. While Uluwatu has benefited from significant economic opportunities, it also faces increasing threats from overdevelopment, highlighting the need for sustainable management strategies.

Build a Collaborative Vision: Effective stakeholder collaboration is essential for sustainable surf conservation. Stronger communication between local communities, NGOs, and government agencies was identified as key, with NGOs playing a critical role in amplifying community voices in decision-making (Ogden-Fung et al., 2021). Buckley (2002) emphasized the importance of keeping management local, as community buy-in reduces enforcement costs and improves

long-term compliance. Stakeholders also called for government support, policy enforcement, and increased funding to strengthen conservation efforts (Ogden-Fung et al., 2021).

Economic Comparison of Scenarios

To assess the economic implications of implementing sustainability fees in surf tourism, we define key variables:

E: Average expenditure of a surfer in Sumatra
F: Additional fees imposed for conservation, crowd management, or both
n: Number of surfers visiting a surf break annually

Under the business-as-usual (BAU) scenario with no additional fees, the total economic contribution from surfers is given by:

$$V_1 = nE$$

With the introduction of fees, the number of surfers may decline due to crowd management and reduced demand. This reduction is represented by a scaling factor (call it “alpha”), leading to a new total economic contribution:

$$V_2 = \alpha n(E + F)$$

For the implementation of fees to yield a net positive economic outcome, the adjusted economic contribution must exceed the original scenario:

$$V_2 > V_1$$

Substituting the equations:

$$\alpha n(E + F) > nE$$

Dividing both sides by n:

$$\alpha(E + F) > E$$

Rearranging for alpha:

$$\alpha > \frac{E}{E + F}$$

Using our mean values obtained from our survey results (see Table 7), we set our variables per-trip general expenditure **(E)** 3,046 USD, and our per-trip total fee **(F)** to 500 USD (the sum of mean WTP for crowd management and mean WTP for conservation measures).

The critical threshold for alpha is:

$$\alpha > \frac{3,046}{3,046 + 500} = 0.859$$

This indicates that the number of surfers can decline by a maximum of **14.1%** for the fee implementation to remain economically beneficial. This calculation does not account for non-economic benefits such as community development or environmental conservation.

Impact Analysis: Changes in Surfer Numbers

Given that maintaining moderate to low crowding levels likely requires a more significant reduction in visitor numbers, we analyze a scenario where surf tourism declines by 50% (alpha = 0.5). Using:

$$\Delta V = n[(\alpha - 1)E + \alpha F]$$

Substituting values:

$$\Delta V = 1,500[(0.5 - 1)(3,046) + (0.5)(500)]$$

$$\Delta V = 1,500(-1,273) = -1,909,500 \text{ (USD per year)}$$

Using a discount rate of **6.82%** (Bank of Indonesia's interest rate), the present value of these economic losses is:

$$PV = \frac{-1,909,500}{1 - 0.9362} = -29,929,467 \text{ (USD)}$$

Sensitivity Analysis: Impact of Different Surfer Reductions

To evaluate the economic impact under varying levels of annual visitor reduction, the following results were obtained:

Table 9: Economic Differences Sensitivity analysis

Annual Reduction (%)	Per Surfer Annual Difference (USD)	Discounted Value for 1,500 Surfers (USD)
10	145.4	234063.1
20	-209.2	-336767.5
30	-563.8	-907598.2
40	-918.4	-1478428.8
50	-1273.0	-2049259.5
60	-1627.6	-2620090.1
70	-1982.2	-3190920.8
80	-2336.8	-3761751.4
90	-2691.4	-4332582.1

Economic Differences Conclusion

The results indicate that the economic viability of implementing sustainability fees in surf tourism depends on the magnitude of visitor reduction. While a modest decline (≤14.1%) can still yield positive economic outcomes, more substantial reductions lead to significant economic losses. Future analyses should incorporate non-economic benefits, such as environmental preservation and local community welfare, to provide a more comprehensive evaluation of sustainable surf tourism initiatives.

Discussion and Conclusions

Findings from Objective 1 revealed that target surf breaks in western Sumatra identified for SPA implementation ranked lower in terms of total SCI scores compared to surrounding surf spots

with more infrastructure and development. To better understand which of the impact categories were impacting the overall value, we analyzed how each break ranked relative to each other for each individual category. In doing so, we found that while the target sites experienced lower human pressure from development, they also had less area formally dedicated to conservation–potentially due to their remote locations and limited access, which can hinder ecological assessments that lead to conservation interventions.

This discrepancy underscores limitations of the SCI: while it works as a valuable, landscape-scale prioritization tool, it should not be used as the sole determinant for selecting conservation sites. Instead, it can be used as a guiding framework to determine where conservation efforts may be more beneficial, but analysis at a more focused level is necessary to determine the best places for implementation. Priority setting can change based on which pressure-state-response variable is deemed more important to achieving the intended conservation goals. For example, if carbon storage is determined to be a higher priority than presence of established protected areas, site designation may shift accordingly. Site selection can also be affected by external factors outside of the established framework, such as ease of implementation and new conservation policies in the local area.

Survey findings from Objective 2 reinforce the idea that surf tourism presents both opportunities and risks. Respondents highlighted the economic potential of surf tourism while indicating concern for associated environmental threats. Addressing these risks will require effective policy interventions and management strategies. Addressing environmental concerns through effective waste management and conservation strategies, ensuring equitable economic distribution, and implementing community-driven tourism policies could help mitigate the most pressing concerns associated with surf tourism development. Importantly, surf conservation strategies must integrate environmental protections with economic sustainability and cultural preservation, prioritizing local community needs and local stakeholder concerns. Strengthening the connection between high-quality local services, economic benefits, and environmental sustainability is a key strategy for improving buy-in and increasing financial support for SPA implementation.

Results from the CBA analysis in Objective 3 suggest that conserving and protecting coral reef ecosystems through interventions such as MPAs or SPAs offers significant, long-term ecological and economic benefits over a BAU scenario that does not provide marine protections. The higher NPV resulting from conservation supports the case for ecological preservation resulting in enhanced economic returns through sustained ecosystem services, Services which benefit local livelihoods and tourism. These findings emphasize the importance of prioritizing coral reef protections in tourism and development policies in Indonesia. Over the long term, SPAs can serve as a cost-effective strategy to sustain ecosystem services and community benefits, including livelihoods

To conduct a more comprehensive SPA-based CBA, several steps and data limitations must be addressed. First, obtaining coral loss data specific to the western Sumatra region is essential for refining impact estimates. Future studies should also be undertaken to understand benefits that

exist beyond just coral reef protection, such as those associated with mangroves and SPAs. Additionally, incorporating surf-specific data, such as tourists' WTP, revenues, and expenditures, into the model to determine TEV would strengthen the justification for SPAs in surf-rich areas. This study adopted a lower-bound case and did not include revenue derived specifically from surf tourism to avoid double counting. Furthermore, assessing distributional effects and welfare weights will help identify who bears the costs and benefits of SPAs, which is particularly relevant in areas where international businesses and hotels dominate the surf tourism economy, potentially limiting local economic retention. Understanding these dynamics will allow for more equitable policy recommendations and appropriate discounting of costs and benefits.

The stakeholder analysis carried out for Objectives 3 and 4 highlights the interconnectedness of economic, environmental, and social factors in surf tourism and conservation. While support for sustainable management strategies– such as local business development, crowd control, and conservation policies–is strong, ensuring equitable stakeholder participation remains a key challenge. Effective SPA implementation will require strategies that align community needs with conservation priorities, while also addressing the social inequities embedded within surf tourism. Existing supportive policy frameworks for implementation are also necessary,

This study contributes to the growing body of work linking surfing with marine conservation, offering an original synthesis of ecological, economic, and stakeholder insights to support the implementation of SPAs. Through an integrated approach—utilizing biodiversity indices, cost estimation, economic valuation, and stakeholder engagement—we demonstrate that SPAs, when grounded in a community-based framework, present a promising model for balancing ecosystem protection with sustainable development in western Sumatra and beyond.

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Appendices

Appendix A: SCI Data

Link to data used to calculate SCI values under the pressure-state-response framework: https://docs.google.com/spreadsheets/d/1A024fTLodrhu_i8imnCq04bBeGRntg2EGjFP_iuL02Y/edit?usp=sharing

Appendix B: Full LMMA Costing Scenario Table

[The full costing scenario table is too large to be included in the appendix, when we archive our data, a link to the costing table will be included here]

Appendix C: Milestones from Likupang Study

Crawford et al. (2006) uses the following milestones to measure the progress of LMMAs in the Likupang region.

- Development of a coastal profile;
- Selection of a marine sanctuary site and/or;
- Selection of mangrove sanctuary site;
- Formation of a management group;
- Development of a village ordinance;
- Development of a management plan;
- Submission of a grant proposal for installation of marker buoys and signboards, and;
- Installation of sanctuary boundary marker buoys and signboards.

Regarding the computation of the final milestone score, Crawford et al. writes, “each site was given a score for each indicator. A score of zero was assigned if the milestone had not been achieved, 0.5 if the milestone had been partially achieved, and 1 if the milestone was fully achieved. Scores were summed for a total possible Milestone/Progress score ranging from zero to eight. The senior project extension agent responsible for supervision of activities in Likupang scored each site for each milestone indicator.”

Appendix D: Online Surf Tourist Survey - English Version

**Also available in Spanish version*

SURF TOURIST SURVEY

CONTEXT/CONSENT

Welcome to our survey on Surf Protected Areas (SPAs) in West Sumatra, Indonesia! We are a team of master's students from the Bren School of Environmental Science & Management at UCSB, working with Conservation International. This survey aims to understand your perception of surf conservation and gauge your willingness to pay for strategies that could enhance your surfing experience while protecting valuable surf breaks and marine environments.

Your feedback will help us inform strategies for managing surf tourism in a way that balances environmental protection with surfers' needs. Whether you are considering visiting in the future or are a seasoned surfer familiar with Sumatra's breaks, your insights are invaluable.

Participation and Consent:

This survey will take approximately 10-20 minutes to complete. If you choose to participate, you will have the option at the end of the survey to enter a drawing for a **chance to win one of four (4) gift cards, each valued at $100 USD**, as compensation for your time. Possible prizes include gift cards from Patagonia, Rip Curl, or Amazon. Winners will be contacted via email by April to select from the available prize options. **Please submit your responses by February 28.**

Please note that this survey is entirely anonymous; no personal identifiers will be collected, and your responses will remain confidential. Participation is voluntary, and you are free to withdraw at any time. **By proceeding with this survey, you confirm that you are at least 18 years old, have read and understood this consent form, have not previously taken this survey, and agree to participate.**

If you agree to these terms, please proceed with the survey.

Please read the questions carefully and respond as honestly as possible. If you have any questions, feel free to contact Manuela Díaz at manueladiaz@ucsb.edu or Ryan Anderson at rka@ucsb.edu. More detailed information can be found in **Conservation International Website.**

Let's get started!

UCSB Approved Protocol # 11-25-0055

SECTION 1 | Surfing Experience in Sumatra

1. Have you ever surfed in Sumatra?
    a. Yes
    b. No

2. If yes, which regions have you surfed in? (Check all that apply)
    a. North Telos
    b. South Telos
    c. Mentawais
    d. Mainland
    e. North Nias
    f. South Nias
    g. Other Regions(Please specify):

3. If you were to plan a surf trip to Sumatra today, how long would your surf trip be?
    a. Less than 5 days
    b. 6 to 10 days
    c. 11 to 15 days
    d. More than 15 days

4. And approximately how much would you budget to spend **DURING this surf trip** (excluding flight tickets) **per person, in $USD currency**? (e.g., $50, $100, $1,000, etc.). *(For example, this includes costs associated with accommodations, surf packages, food, and in-country transportation, among others.)*
    a. Less than $500
    b. $500 to $1,000
    c. $1,000 to $2,500
    d. $2,500 to $5,000
    e. More than $5,000
    f. Other Specify in $USD currency: [Text Box]

5. Does the amount you're willing to pay/budget for this trip vary based on the quality of experience at any particular surf break?
    a. Yes
    b. No

6. If yes, why?
    a. [Short Answer]

SECTION 2 | Willingness to Pay for Crowd Management Efforts

Context: Overcrowding at popular surf breaks can diminish the surfing experience and impact the local environment. Effective crowd management can help preserve the quality of surf breaks and ensure a better experience for all surfers. Your responses will help us understand your perspective on contributing financially towards these efforts.

1. Based on your previously stated length of stay for your trip in Sumatra, would you be willing to pay an extra **one-time crowd management fee per person for your entire surf trip** to ensure that the surf breaks maintain a low to moderate number of surfers?
    a. Yes
    b. No

2. If yes, on average, how much would you be willing to pay for a one-time crowd management fee per person, per surf trip (covering your full stay in this location, based on your previously stated length of stay) to ensure that the surf breaks maintain a low to moderate number of surfers? (in $USD)
    a. [Short Answer]

3. Is your willingness to pay dependent on having crowd management at any specific surf breaks?
    a. Yes
    b. No

4. If yes, why?
    a. [Short Answer]

SECTION 3 | Willingness to Pay for Conservation Efforts

Context: Conservation initiatives in West Sumatra's surf areas focus on promoting sustainable surfing experiences, keeping the ocean healthy and clean, and preserving marine life, benefiting both surfers and local residents. Financial contributions from surfers like you could support ongoing and future surf conservation efforts. Your financial support can make a significant difference. Contributions could help with beach clean-ups, mangrove protection to absorb CO2, shoreline erosion control, safeguarding surf breaks, and bolstering the surrounding marine and coastal ecosystems.

In this context please answer the following questions:

1. Based on your previously stated length of stay for your trip in Sumatra, would you be willing to pay an extra **one-time conservation fee per person for your entire surf trip to support conservation efforts** in these areas?
    b. Yes
    c. No

2. If yes, on average, how much extra would you be willing to pay for this one-time conservation fee per person, per surf trip to support conservation efforts in these areas? (in $USD)
    a. [Short Answer]

3. Is your willingness to pay dependent on having conservation measures in/near any specific surf breaks?
    a. Yes
    b. No

4. If yes, why?
    a. [Short Answer]

5. **Please indicate the degree to which you agree or disagree with the following statements** to help us understand what factors influence your willingness to pay for surf conservation efforts and shape your overall surf experience:

	Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a	The quality of locally owned/operated services greatly influences my willingness to support conservation financially	1	2	3	4	5
c	I am more likely to pay for conservation if I know the benefits will stay within the local community	1	2	3	4	5
d	I am willing to pay more for a surf experience if it means improved environmental management and local benefits	1	2	3	4	5
e	I prefer a locally owned/operated surf experience because it supports the local economy and conservation efforts	1	2	3	4	5
f	Local amenities and services are critical to my enjoyment and willingness to return to a surf destination	1	2	3	4	5

SECTION 4 | Perceived Environmental, Social, and Economic Benefits of Surf Conservation

1. **For each of the outcomes/benefits of Surf Conservation initiatives listed below, please indicate their level of importance to you:**

	Statement	Not important at all	Not very important	Neutral	Important	Very Important

a	Support the preservation of marine biodiversity at surf spots	1	2	3	4	5
c	Contribute to the protection of coastal and surf ecosystems	1	2	3	4	5
d	Support local communities to be involved in the management of surf break ecosystems	1	2	3	4	5
e	Keep the breaks clean and less polluted	1	2	3	4	5
f	Support fisheries, recreation, and sustainable tourism opportunities that significantly contribute to the local economy	1	2	3	4	5
g	Enhance the local cultural significance, heritage, and identity	1	2	3	4	5
j	Facilitate cultural exchange by introducing new knowledge/perspectives to the local community	1	2	3	4	5
k	Promote local and youth engagement and stewardship for surf conservation	1	2	3	4	5
l	Create sustainable job opportunities in eco-tourism and conservation	1	2	3	4	5
m	Increase the attractiveness for international surf tourists	1	2	3	4	5
n	Are important for future generations	1	2	3	4	5

2. **Any other benefits/positive impacts associated with surf conservation initiatives that are important to you:**
    - **a.** [Short Answer]

SECTION 5 | Perceived Environmental, Social, and Economic Costs of Surf Tourism Development

1. **Please indicate the degree to which you are concerned about potential costs/negative impacts associated with surf tourism development:**

	Statement	Not Concerned	Slightly Concerned	Moderately Concerned	Very Concerned	Extremely Concerned
a	Environmental impacts from increased tourism development	1	2	3	4	5
b	Displacement of local communities	1	2	3	4	5
c	Modification or disrespect of local culture, heritage, and/or identity	1	2	3	4	5
d	Unequal distribution of income/benefits from surf tourism	1	2	3	4	5
f	Loss of access to natural resources for locals	1	2	3	4	5
g	Increases in prices due to surf taxes or conservation fees	1	2	3	4	5
h	Loss of conservation/crowd management fee revenue due to mismanagement or corruption	1	2	3	4	5
i	Decrease in surfing experience due to overcrowding	1	2	3	4	5
j	Uncontrolled development of surf tourism facilities, resorts, homestays	1	2	3	4	5
k	Increase in solid waste due to surf tourism	1	2	3	4	5
l	Inability to visit preferred surf spots due to crowd management measures	1	2	3	4	5
m	Decline in service quality due to exclusively locally owned and operated experiences	1	2	3	4	5
n	Economic reliance on a volatile tourism sector (seasonality)	1	2	3	4	5
o	Increases in cost of living due to tourist influx	1	2	3	4	5

2. Any other **costs/negative impacts** associated with **surf tourism development** that concern you:
    a. [Short Answer]

SECTION 6 | Demographics
First, we will ask you some demographic questions that are important for understanding your responses to the rest of the survey.

1. **How did you hear about this survey?**
    a. Conservation International Australian Advisory Group
    b. Conservation International Event Guest Follow-Up
    c. Social Media
    d. Other _____

2. **Age**: What is your age?
    a. 18-24 years
    b. 25-34 years
    c. 35-44 years
    d. 45-54 years
    e. 55-64 years
    f. 65 and over

3. **Gender**: What is your gender?
    a. Male
    b. Female
    c. Non-binary
    d. Prefer not to say
    e. Other (please specify)

4. **Country of Residence**: Which country do you currently reside in?
    a. Australia
    b. USA
    c. European Union
    d. Indonesia
    e. Chile
    f. Other (please specify)

5. **Frequency of Visits to West Sumatra:** How often do you visit **surf spots** in West Sumatra?
    a. I've never been
    b. I've been once
    c. I'm planning my first visit
    d. Once a year

e. 2-3 times a year
f. More than 3 times a year
g. I've been several times
h. I live in the area and surf there year-round

6. What is/would be your **primary reason for visiting Sumatra**?
    a. Surf
    b. General tourism (sightseeing, cultural experiences)
    c. Business
    d. Visiting friends or family
    e. Research or educational purposes
    f. Volunteering or NGO work
    g. Other (please specify)

7. **Years of Surfing Experience**: How many years have you been surfing?
    a. Less than 1 year
    b. 1-3 years
    c. 4-6 years
    d. 7-10 years
    e. More than 10 years

8. **Surfing Skill Level:** Please rate your surfing skill level:
    a. Beginner
    b. Intermediate
    c. Advanced
    d. Professional

9. **Occupation**: What is your occupation?
    a. Student
    b. Employed (full-time)
    c. Employed (part-time)
    d. Self-employed
    e. Unemployed
    f. Retired
    g. Other (please specify)

10. **Education Level**: What is the highest level of education you have completed?
    a. Some high school
    b. High school graduate
    c. Some college
    d. College degree
    e. Graduate degree
    f. Other (please specify)

11. **Annual Household Income (USD):** Please indicate the total annual income of all people living in your household before taxes last year (2024, in $USD):
    a. Less than $10,000
    b. $10,000 to $24,999
    c. $25,000 to $49,999
    d. $50,000 to $74,999
    e. $75,000 to $99,999
    f. $100,000 to $149,999
    g. $150,000 and over
    h. Prefer not to say

12. **Open-ended question:** Is there anything else you would like to tell us about yourself, your experience with surfing and coasts in West Sumatra, and/or your thoughts on Surf Conservation/Development?
    a. [Paragraph Answer]

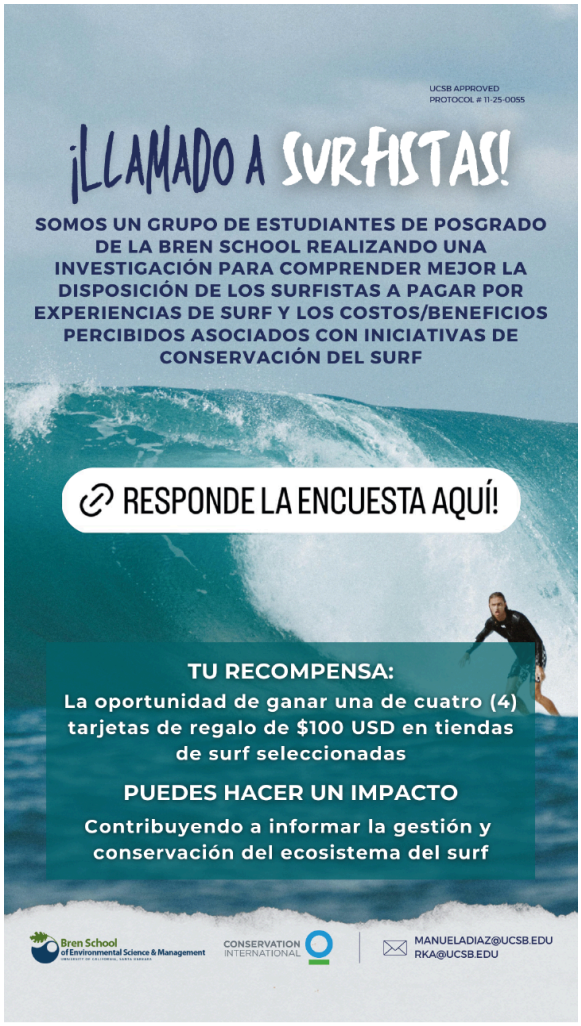
13. Please click the button below **if you would like to enter a drawing for a chance to win one of four (4) $100 USD gift cards** (or the equivalent in local currency) as compensation for your time.

SEPARATE FORM:

Please enter your email address below if you would like to participate in a drawing for a chance to win a $100 USD (or equivalent in local currency) gift card as compensation for your time. Potential prizes include gift cards from Patagonia, Rip Curl, Billabong, or Amazon. Depending on the location of the winner, you will be asked to select your preferred prize.

a. [Paragraph Answer]

Appendix E: Online Surf Tourist Survey Recruitment Flyers



Appendix F: Workshop Supplies Material Costing Spreadsheet

Category	Item	Quantity	Unit Cost (USD)	Total Cost	Notes & Assumptions
Materials Costs	**Workshop Supplies**				5 workshops over 6 months, 100 atendees. We assume there will be repeat attendees so new notebooks and tshirts are not needed for every workshop. Markers, pens and left over supplies are collected at the end of each workshop and brought to the next one. So the first workshop would have the highest cost.
	Paper	2 pack 100 shets each	$10		
	Flip Charts	6 pads	$96.60		
	Easel	6 at $12	$72		
	Markers	1 pack of 100 Crayola	$17		
	Pens	1 pack of 120	$16		
	Pencils	1 box of 150	$13.50		
	Index Cards	1 pack of 160	$8		
	Post-it Notes	15 pads	$11		
	Tape	1 box, 6 rolls	$10		
	Notebooks	100 pack lined noteb	$50		
	T-shirts	9 packs of 12	$352		
Total:			$656		

Appendix G: Specific Role Salary Data Used

Scientist with GIS Skills

Job Title	Average Salary (IDR)	Average Salary (USD)
Environmental Scientist	395669818	25718.54
GIS Developer	334585090	21748.03
Cartographer	328450025	21349.25
GIS Analyst	285505866	18557.88
GIS Specialist	285119374	18532.76
GIS Coordinator	259334150	16856.72
Geospatial Specialist	255693319	16620.07
Geospatial Engineer	251201686	16328.11
Environmental Chemist	249510092	16218.16
GIS Technician	210717523	13696.64
Conservation Scientist	166863002	10846.10

Community Outreach and Facilitators

Job Title	Average Salary (IDR)	Average Salary (USD)
Public Relations Specialist	283504232	18427.775
Community Relations Manager	265429534	17252.920
Community Engagement Specialist	248363973	16143.658
Outreach Worker	247478875	16086.127
Community Organizer	218458698	14199.815
Community Outreach Worker	201980767	13128.750
Community Liaison	136798533	8891.905
Outreach Coordinator	135151933	8784.876

General Conservation Roles

Job Title	Average Salary (IDR)	Average Salary (USD)
Wildlife Manager	398857034	25925.707
Environmental Scientist	395669818	25718.538
Environmental Project Manager	370951676	24111.859
Marine Biologist	325479361	21156.158
Natural Resource Manager	310234376	20165.234
Conservation Technician	229482777	14916.381
Ecologist	195410339	12701.672
Wildlife Biologist	184413220	11986.859
Natural Resource Specialist	166225678	10804.669
Conservation Officer	166000402	10790.026
Wildlife Technician	150510590	9783.188

Youth Engagement and Education

Job Title	Average Salary (IDR)	Average Salary (USD)
Education Director	467976630	30418.481
Education Administrator	462077765	30035.055
Education Manager	338101393	21976.591
Educational Assistant	325130929	21133.510
Youth Advocate	306507886	19923.013
Education Consultant	299642087	19476.736
Education Curator	284187766	18472.205
Youth Worker	240997013	15664.806
Youth Pastor	222914826	14489.464
Youth Coordinator	209629800	13625.937
Education Coordinator	203837058	13249.409
Education Facilitator	147894561	9613.146