SEAGRASS ECOSYSTEM SERVICES REPORT

Hera, Timor-Leste

Blue Ventures

SEAGRASS ECOSYSTEM SERVICES PROJECT

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Executive summary

Summary of key findings from the report

- A rapid assessment and mapping of seagrass in Timor-Leste revealed a rich diversity of seagrass, with 10 species recorded;
- Focused on Hera's 600-hectare bay, the study mapped several large mixed-species meadows covering approximately 247.68 hectares;
- Healthier and more abundant seagrass was noted in coastal zones adjacent to coral reef and mangrove habitats, contrasting with areas heavily impacted by human activities such as deforestation and development;
- Socioeconomic household surveys revealed that fishing is a primary livelihood and an important source of nutrition in Hera, and that were concerns of diminishing marine habitats and fisheries;
- A fisheries assessment highlighted that the top ten fish families identified as important to households in Hera utilise seagrass at some stage of their life cycle, this was corroborated by baited remote underwater video (BRUV) surveys recording 50% of these species within Hera's seagrass meadows;
- No conclusive correlation was found between seagrass cover and fish abundance in Hera. Additional fisheries data is recommended due to the complexity of the area;
- A comparison study on Atauro Island, where seagrass and fisheries may benefit from nearby locally managed marine areas and reduced human activity, showcased significantly increased fish abundance and fish richness;
- An opportunity exists to test local marine management interventions in Hera to improve seagrass and fisheries health, benefiting fisher livelihoods and enhancing resilience to environmental changes;
- The report establishes a baseline for decision-making in Hera and as a replicable case study for Timor-Leste. However, additional community consultations and participatory monitoring are necessary to complete the picture, build management plans and to track changes over time.

Introduction

This report aims to present the results of a seagrass ecosystem services (SES) assessment conducted in Timor-Leste by Blue Ventures (BV), in collaboration with non-governmental organisations (NGOs) Project Seagrass, Seagrass-Watch, Konservasaun Flora No Fauna and the communities of Hera, Beloi and Bikeli. The primary objective of the assessment is to gain a deeper understanding of the ecosystem services provided by tropical seagrass meadows and the value they hold to coastal communities in Timor-Leste. This information aims to serve as a resource to guide community-based marine management decisions and bolster advocacy efforts to ensure representation of seagrass ecosystems within local, regional and national marine policy frameworks.

Principles

The assessment was designed based on two fundamental principles:

1. **Empowerment of local communities**: recognising the pivotal role that local communities play in effective marine management and seagrass conservation, particularly in areas heavily reliant on marine resources.
2. **Addressing policy gaps**: acknowledging the underrepresentation of seagrass at all policy levels, we aimed to develop evidence-based engagement strategies that resonate with policy decision-makers, as well as coastal communities.

By adhering to these principles, we aimed to create an assessment that provides insights into SES and fosters collaboration between communities and policymakers for effective marine management. The findings and recommendations in this report serve as a foundation for enhancing seagrass conservation efforts and promoting the well-being of coastal communities in Timor-Leste.

Figure 1. Blue Ventures Seagrass Coordinator Mima Gomes presenting at the 2023 World Seagrass Day event in Hera, Timor-Leste (Credit: Blue Ventures / Nick Poole)

About seagrass

Seagrass is an underwater plant that grows in shallow marine environments, forming vast meadows on the ocean floor that provide essential services to marine life and coastal communities. Seagrass acts as a nursery, food source and habitat for various marine species, including fish, sea turtles and dugongs. Seagrass helps to stabilise shorelines, prevent erosion and protect coastal communities from storms and tidal surges. Its presence contributes to cleaner water by filtering pollutants and excess nutrients. Seagrass also plays a role in mitigating climate change by absorbing and storing carbon dioxide up to 35 times faster than terrestrial forests (Mcleod et al. 2011).

Figure 2. A small-scale fisher fishing in a healthy seagrass meadow. (Credit: Ocean Image Bank / Ben Jones)

Despite its social and ecological importance, seagrass ecosystems are frequently overlooked in marine management. This is partly due to knowledge gaps, limited awareness and public perception, but also because of funding competition with the more popular coral reef and mangrove ecosystems. By increasing awareness, filling knowledge gaps and dedicating adequate resources to seagrass conservation, we can ensure the sustainability of these marine habitats and the ecosystems they support.

Seagrass in the Indo-Pacific

72 seagrass species have been identified globally and six seagrass bioregions have been defined taking into account species compositions, distribution ranges and influences from both tropical and temperate environments. These characteristics help focus research, monitoring and management decisions in each bioregion.

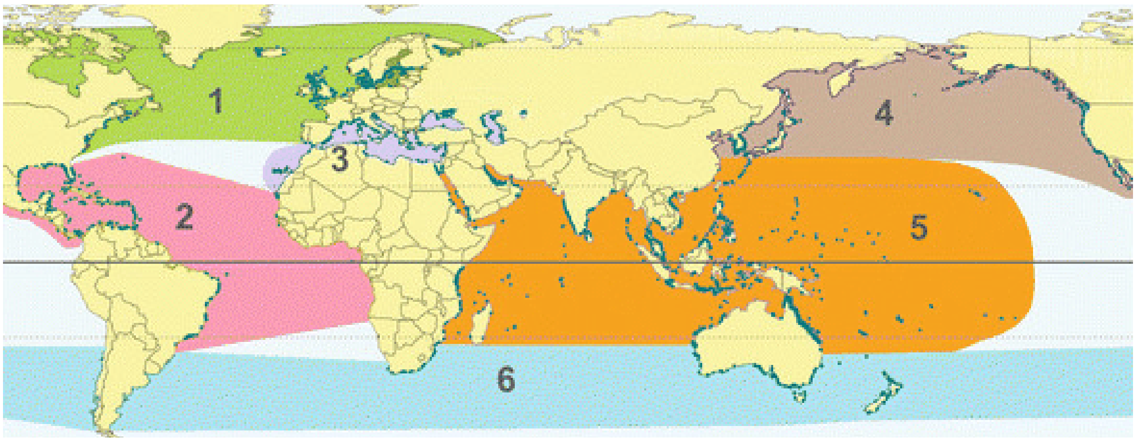


Figure 3. Seagrass bioregions: 1 Temperate North Atlantic, 2 Tropical Atlantic, 3 Mediterranean, 4 Temperate North Pacific, 5 Tropical Indo-Pacific and 6 Temperate Southern Oceans (Short et al. 2007)

The Tropical Indo-Pacific zone has the highest seagrass diversity in the world, with as many as 23 species occurring in mixed-species meadows (Short et al. 2001). These hotspots are largely found on reef flats, providing a reliable nearshore fishing habitat.

Fish assemblages in the Indo-Pacific

The Indo-Pacific also exhibits remarkable fish biodiversity. Seagrass ecosystems play a pivotal role as nurseries and feeding grounds, hosting a diverse array of marine species. The intricate structure of seagrass meadows offers a safe haven for juvenile fish, fostering their growth before they venture into other habitats. Numerous commercially important species depend on seagrass ecosystems for breeding, foraging or residence, thus sustaining fisheries and livelihoods of coastal communities, emphasising the need for their conservation in maintaining biodiversity and supporting coastal livelihoods (Jones et al. 2021).

Marine ecosystem interconnectivity

Seagrass meadows, mangrove forests and coral reefs are often found in close proximity along tropical coastlines and they share several ecological and environmental interactions:

- Seagrass meadows and mangrove forests serve as essential nurseries and habitats. Juvenile reef fish often use these areas as safe havens to grow before venturing into coral reefs;
- Both seagrass and mangroves are effective in trapping and stabilising sediments, reducing sediment runoff from land to coral reef environments. This helps maintain water clarity, which is vital for both seagrass and coral reef health;
- Sediment and particle trapping enables these systems to retain nutrients from the water column, benefiting ecosystem health and growth rates and enhancing the productivity of nearby coral reefs;
- All three ecosystems act as natural buffers, protecting coastlines from erosion and wave energy. Seagrass meadows and mangrove forests are both blue carbon stores. They sequester and store vast amounts of carbon dioxide in their biomass and roots and they lock carbon away within the soil, playing a vital role in mitigating climate change;
- These ecosystems provide interconnected pathways for the movement of marine species. Juveniles and adults of various species move between seagrass, mangrove and coral reef habitats throughout their life cycles, contributing to healthy marine populations.

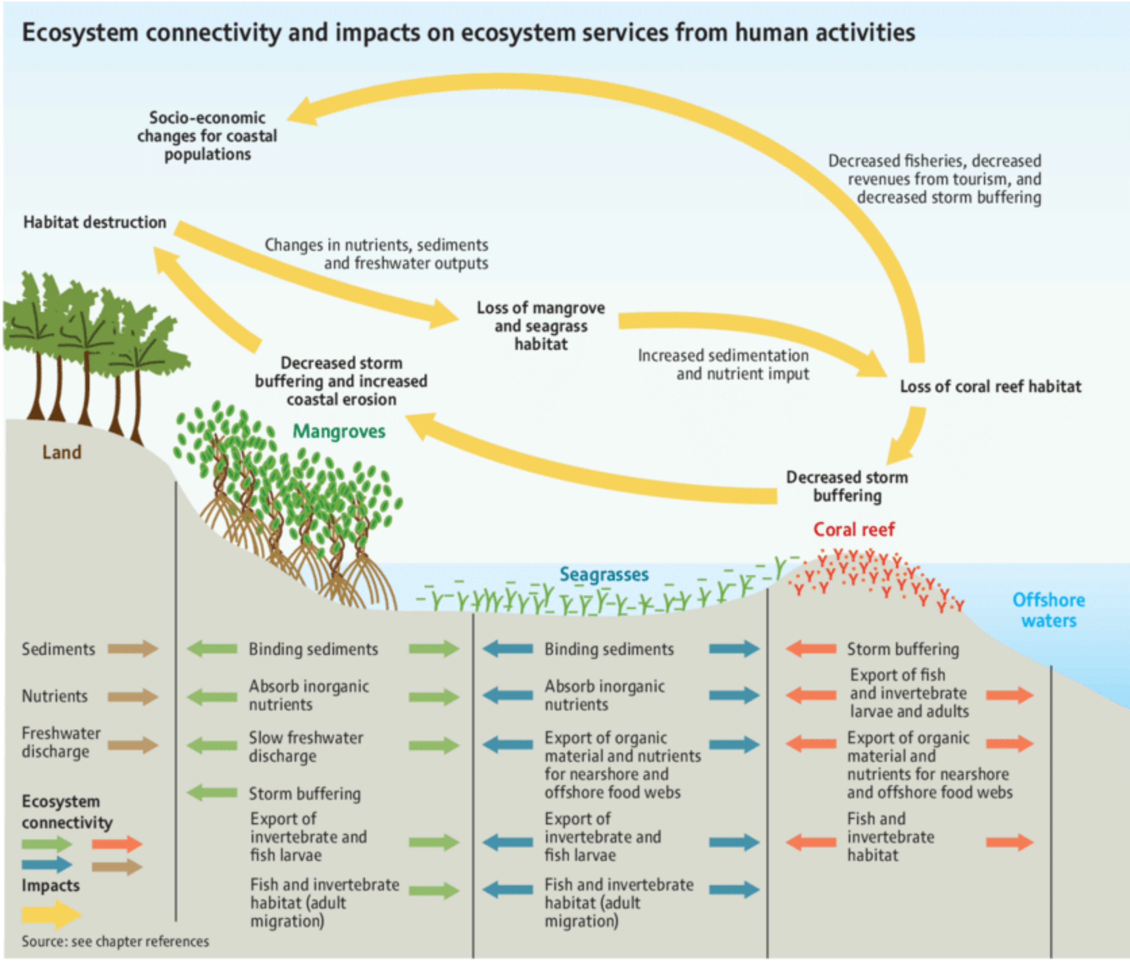


Figure 4. Ecological and physical connectivity between ecosystems (Silvestri et al, 2010)

The interconnectivity between seagrass, mangrove and coral reef ecosystems is essential for maintaining the overall health and resilience of coastal marine environments. Conservation efforts that consider the interconnected nature of these habitats are crucial for safeguarding the biodiversity and ecological functions of marine ecosystems *(Silvestri et al, 2010)*.

Timor-Leste

After experiencing a prolonged period of conflict and unrest, Timor-Leste achieved its independence in 2002. While the country has made notable progress in its recovery, it continues to face challenges, with a significant portion of its population living below the poverty line. Being the youngest country in Asia, there is currently little available data for research. However, the situation is gradually evolving and the purpose of this assessment is to make a meaningful contribution by addressing some of these knowledge gaps - in particular building a case study on the role seagrass ecosystems play in Timor-Leste's small-scale fisheries and their importance to coastal communities.

Figure 5. Map of Timor-Leste

Available coral reef and cetacean research showcases Timor-Leste as one of the world's most biodiverse and important marine environments with 643 reef fish species and 30 cetacean species recorded. Its significance is underscored by small-scale fishing standing as the primary livelihood for the majority of Timor-Leste's coastal communities, providing vital sustenance and income. However, like marine ecosystems worldwide, Timor-Leste's fisheries confront threats such as overfishing, habitat degradation and climate change. To safeguard livelihoods and the region's rich marine biodiversity, marine management measures are needed to ensure the sustainability of its fisheries and to enhance coastal communities' resilience to a rapidly changing environment.

Community-based fisheries management

Recent years have seen the revival of Tara Bandu, a traditional Timorese customary law system, used by communities to manage marine areas and its resources. It is a form of local governance that has been practised for generations by communities in the country. Tara Bandu involves the establishment of rules agreed upon by the community to, among many other uses, manage their resources equitably and sustainably - for instance, by regulating fisheries. These rules are often based on traditional knowledge, customs and beliefs, passed down through generations.

Figure 6. Blue Ventures Conservation Coordinator Dedy Martins facilitates an LMMA Exchange session in Atauro together with the Atauro Tara Bandu Structure. (Credit: Blue Ventures).

The implementation of Tara Bandu can be effective in promoting community involvement in and ownership and stewardship of marine resources. It complements modern marine management approaches and has the potential to be a more inclusive, equitable and impactful means to sustainable marine management. Strengthening and formalising this process will be an important milestone for communities interested in establishing locally managed marine areas (LMMAs) in Timor-Leste.

Summary of key assessment objectives

Building upon the above considerations, the key objectives of this assessment can be summarised as follows:

1. Map and assess the health of an area of seagrass in Timor-Leste where there are links to small-scale fisheries;
2. Conduct an assessment of fish assemblages found in the mapped seagrass area, to elucidate its significance for small-scale fisheries and identify threats and opportunities for improving ecosystem health and productivity;
3. Identify and evaluate the key social and economic factors that influence the value of services provided by seagrass ecosystems to coastal communities;
4. Provide findings, recommendations and potential next steps for seagrass management;
5. Utilise the report as a foundation to support policy recommendations at local, national or regional level.

Methodology

The methods used and described in this section were carefully selected through regular discussions with leading seagrass NGOs Project Seagrass, Seagrass-Watch and the CMS Dugong MoU[1]. Each method was tailored to foster community participation and promote the development of local capacity for community-based seagrass monitoring and management. Additionally, the selection of methods was driven by considerations of location and accessibility, ensuring that all findings are grounded in evidence.

Site selection

Site selection for this assessment was guided by several considerations:

- Presence of seagrass meadows;
- Importance of small-scale fishing;
- Interest in community-based fisheries management;
- Location and connectivity;
- Other points of interest.

Hera

Based on these criteria, the community of Hera was selected for the assessment. The town has a population of approximately 10,175, comprising 2,201 households across six *aldeia* (sub-villages) and features a 600-hectare bay with seagrass meadows, coral reefs and mangrove forests. The area also includes a navy base, power plantation and a large factory.

[1] *Secretariat of the Memorandum of Understanding on the Conservation and Management of Dugongs and their Habitats throughout their Range of the Convention on the Conservation of Migratory Species of Wild Animals (CMS Dugong MoU)*

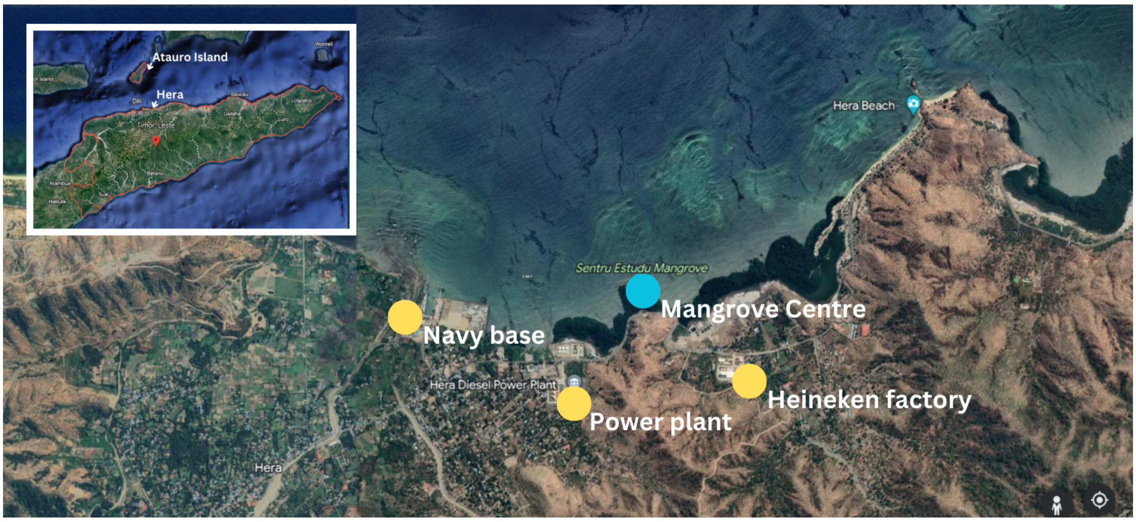


Figure 7. Map of Hera on the north coast of Timor-Leste, including points of interest

Initial consultations with local stakeholders on community-based marine management were positive and local Konservasaun Flora no Fauna (KFF), who manages a mangrove reserve and education centre in the area, expressed interest in collaborating on the assessment.

Comparison sites

To provide valuable insights into SES in different seagrass contexts, we selected two additional sites on Atauro Island, where there is active marine management and less evidence of coastal development and human impact. These sites serve as comparison points for the assessment conducted in Hera, which currently has no existing seagrass management measures.

The first comparison site is a seagrass LMMA zone in Beloi (Uhurala), governed by Tara Bandu regulations that restricts boat moorings and fishing activities. The site is adjacent to a permanent coral reef no-take-zone (Haruina). While conducting observations, we did note some instances of net fishing still occurring in the seagrass area. However, overall, the site appeared largely undisturbed, exhibiting minimal evidence of human impact.

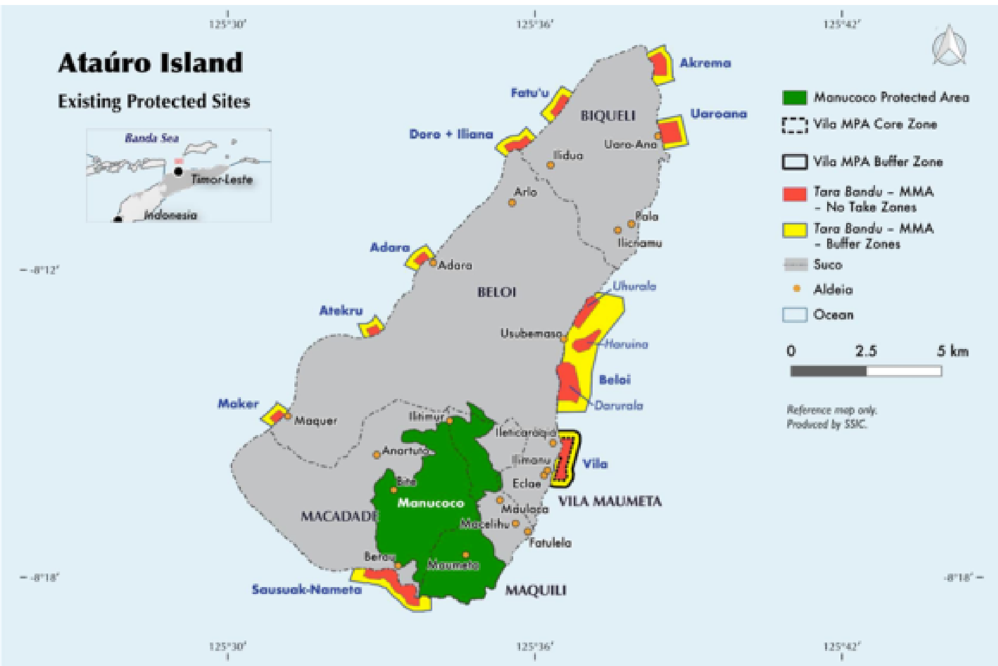


Figure 8. Atauro Island's LMMAs. From the Ataúro Island Sustainable Management Plan (Credit SSIC)

The second site is located in the nearby area of Bikeli (*aldeia* Pala) and shares similar environmental conditions. Although the area is not an active LMMA, the area is situated between two active Tara Bandu LMMAs.

By incorporating these two additional sites alongside Hera, our assessment aims to offer a deeper understanding of how different management strategies and conditions influence seagrass ecosystems and marine biodiversity, in order to identify best practices and inform seagrass management initiatives.

Ecological survey assessments

Information on the distribution and ecological importance of seagrass is essential for effective seagrass resource management. In order to make well informed decisions, coastal managers can benefit from maps that detail the characteristics of seagrass resources, including the specific locations, proportions and number of seagrass species, along with an initial baseline assessment of their health.

Seagrass rapid assessment and mapping

Blue Ventures worked with Seagrass-Watch and Project Seagrass to map the extent and health of the seagrass meadows in Hera. Predetermined waypoints were selected via satellite imagery. GPS was used for navigation and data was collected through one of three methods, dependent on the waypoint conditions:

a. Intertidal (accessible on foot) - A quadrat was placed on the floor in three positions at each waypoint (within a few metres of each other) where seagrass species, abundance and health information was recorded.
b. Subtidal with good visibility - A drop camera with a specialised quadrat attachment was used to collect data from three different positions (as above).
c. Subtidal with poor visibility - A sediment grab sampler was used to retrieve a sample of sediment and seagrass for analysis.

Table 1. Survey steps at each quadrat

Survey Step	Description
Species identification	Each seagrass species was identified and the percentage cover estimated
Health assessment	The health of the seagrass was assessed and documented, including any signs of stress, damage, or disease observed by the surveyors
GPS data collection	Each quadrat position was recorded with a GPS device
Data analysis	Diversity, abundance and health metrics were determined, providing valuable insights into the overall seagrass ecosystem

Due to the size and complexity of the mapping area in Hera, we targeted 275 waypoints spread across the bay. Due to the threat of saltwater crocodiles *(Crocodylus porosus)*, the site was largely mapped using a drop camera, with some ground quadrats used in intertidal conditions that were deemed safe. For more details about the methods and materials for the mapping, visit the Seagrass-Watch website here.

Seagrass Spotter

Seagrass Spotter, a participatory citizen science approach for monitoring and mapping seagrass meadows, was used as a secondary data collection tool. Geotagged photos of seagrass were uploaded through a dedicated mobile application developed by Project Seagrass. Machine learning algorithms then analysed the images to identify and classify seagrass species. This collaborative tool aids global mapping of seagrass and engages the public in environmental monitoring and conservation efforts, promoting awareness and understanding of the critical role that seagrasses play in marine ecosystems.

Baited remote underwater video system

To assess the fish assemblages of Hera's seagrass meadows we collaborated with Project Seagrass. A baited remote underwater video system (BRUVs) was selected as the methodology as they have proven to be a practical and widely accepted tool for non-destructive and accurate underwater sampling and assessments (Cappo, 2004).

We used BRUV systems at each selected site (i.e. Hera, Beloi and Bikeli) to record fish abundance and richness. In total, 70 BRUVs were deployed for one hour, with the first five minutes considered a buffer time to allow fauna to respond to disturbance. Videos were analysed to determine the maximum number of fish recorded at any one time (MaxN) of each fish species and fish species richness. This is a metric commonly used for the quantification of the relative abundance of fish observed in underwater video.

Figure 9. Blue Ventures staff, KFF volunteers and local fishermen deploying a BRUV system in Hera (Credit: Blue Ventures / Ryan Lewis)

The following parameters were assessed as part of the assessment:

- Fish species relative abundance (MaxN)
- Fish species richness
- Environmental factors (E.g. seagrass, proximity to mangroves, corals and rivers)
- Anthropogenic factors (E.g. power plant, navy base, fuel station)

All BRUV surveys were completed between November 2022 and March 2023 during the Timor-Leste wet season. Each survey was scheduled around high tide, ranging from 10am to 4pm, ensuring consistency whilst sampling and greater visibility in turbid areas.

Four 30cm high BRUV frames were constructed from steel, featuring a 1-metre PVC bait pole extending at a 90-degree angle, equipped with added weights for stabilisation (*refer to the image above*). Atop each frame, a GoPro was affixed, accompanied by a homemade buoy for relocation. A cable tie was used to attach a bait box to the end of the PVC pole. Canned sardines were selected as bait for their oily nature, enabling a more extensive bait plume dispersal compared to non-oily fish.

Each BRUV drop remained submerged for a minimum of one hour and five minutes before retrieval. The initial five minutes of video served as a buffer period, allowing fish and the environment to re-adjust to the camera's placement. Following deployment, the boat moved at least 50 metres away from the camera. Video analysis focused on the one-hour duration from minute five to minute 65, ensuring a more settled environment and that the boat had exited the 50-metre zone projected by the BRUV unit and bait plume. The depth range across all the video samples ranged from one metre to 3.5 metres.

Analysis was undertaken by Blue Ventures staff Cecilia Lay and Mima Gomes, the same staff members who led the deployment process. Due to staggered BRUV system collection throughout the day, some cameras exceeded the one hour and five minutes duration, any surplus video length was disregarded.

MaxN and fish species were recorded via video playback that did not exceed 1x speed. When necessary, species names were confirmed or identified using Fishbase website, textbooks and Google search. If a fish couldn't be identified to the species level, the family name was recorded. Upon completing data entry, an Excel spreadsheet was used for data cleaning and validation. A pivot table was created to calculate the average of MaxN and standard deviation. Graphs and tables, addressing key analysis priorities, were generated using Excel.

Priority areas selected for analysis:

1. Comparing fisheries abundance (MaxN) and fish richness with standard deviation (SD) across the five selected survey sites in Hera;
2. Understanding fish diversity in seagrass and identifying the top 10 most abundant species observed across all seagrass sites;
3. Assessing the species identified as important in the socio-economic household survey against the the data from the BRUV surveys;
4. Comparing the average abundance value of species (MaxN) and fish richness in the non-protected area (Hera) versus comparison sites in Atauro (Beloi and Bikeli).

Socio-economic assessment

Blue Ventures conducted a social and economic household survey encompassing two coastal *aldeia* in Hera. This survey aimed to gain deeper insights into the social and economic conditions of those who heavily rely on coastal resources. By integrating this data, the assessment aimed to establish connections between seagrass ecological findings and their significance and value within the community.

We developed a structured questionnaire to gather information about various aspects of the community's economic and social conditions, including:

- Household demographics, including gender and age;
- Livelihoods, including yearly income, proportion of income from fishing/gleaning and non-fishing/gleaning activities;
- Fishing activities, including number of people (disaggregated by gender) participating in fishing, gleaning, post-processing or selling of fish/shellfish and fishing effort (hours/days fishing);
- Financial resilience, including household expenditure, savings and loans, access to credit and financial decision making (disaggregated by gender);
- Social capital, including trust in decision makers and belief in community capacity to manage fisheries;
- Marine resource management, including perceptions of change in fish catches (number and size) and habitat health, perceived threats, understanding of fisheries management rules, acceptance of fisheries management rules and participation in marine management;
- Food security, including the contribution of fish/shellfish.

The questionnaires were developed as a digital form in KoboToolbox and installed in the Kobo collect app, a digital data collection and management platform.

Survey training was provided to seven enumerators and three BV staff. The training focused on providing an in-depth understanding of the methodology, targets, interview techniques and data integrity. Participants were provided with training materials covering interview scenarios, Kobo questionnaires, strategies for dealing with difficult respondents and adherence to survey protocols.

A stratified random sampling strategy was used to ensure representation of different types of fishing groups. Sampling units were categorised based on geographical location, livelihood, fishing activity and household income level. We calculated a sample size with the total population size of 618 households, level of confidence (90%) and margin of error (5%). A sample size of 190 households was determined to be a statistically significant number to draw reliable conclusions, which was then divided between each sub-village (95 households each). Sampling units were randomly selected within each stratum and household heads or knowledgeable representatives were approached to participate.

The survey was conducted across three days in April 2023 in *aldeia* Ailok Laran and Sukaer Laran. The timing of the surveys were all between 9:00 am and 5:00 pm. The survey locations were selected based on the project site including both coastal and rural areas to ensure sample diversity.

To maintain the data's integrity, the following measures were implemented:

1. In-person evaluations were conducted during breaks to promptly identify and address any problems or errors. Interviewers received follow-up training as necessary to enhance the quality of their interviews;
2. After three days of data collection, both BV and the interviewers performed data validation checks. Each completed questionnaire underwent a thorough review within one day to verify correct and complete data entry;
3. Any identified errors were corrected by the respective interviewer under the direct supervision of the BV team;

4. Throughout the survey, periodic analyses of the collected data were conducted to ensure ongoing quality.

The collected data was cleaned in Excel sheets and then analysed using pivot tables. Descriptive statistics such as means, percentages and frequencies were used to summarise the quantitative data. Inferential statistics, including regression analysis and correlation coefficients, were used to identify relationships and patterns within the data set. Qualitative data was analysed thematically to extract key themes and insights.

Results

Seagrass rapid assessment and mapping

A total of 358 individual points were examined, 275 from drop camera and intertidal quadrats, and 83 from images uploaded to Seagrass Spotter. Seagrass was present at 260 of the mapping points, with percentage cover ranging from 0.7 to 100% and with an average of 36.8%. Ten seagrass species were identified, with the most frequently encountered being *Enhalus acoroides*, *Thalassia hemprichii* and *Halodule uninervis* (39.6%, 23.6% and 10.1% average cover, respectively).

Spatially explicit seagrass maps were created by Seagrass-Watch using PlanetScope Dove (3.7 m × 3.7 m pixel) imagery, field validation point data and a machine-learning model (random forest). A total of 130.92 to 247.68 hectares of seagrass meadows was mapped within the bay.

Figure 10. Data was collected from a total of 358 seagrass mapping points, positioned using remote sensing and random sampling

- *Seagrass present*
- *Seagrass absent*

Figure 11. Machine learning was used to map seagrass extent using the field validation data and remote sensing

- Area classified as seagrass with 100% probability (130.92 hectares)
- Area classified as seagrass with 60% probability (247.68 hectares)

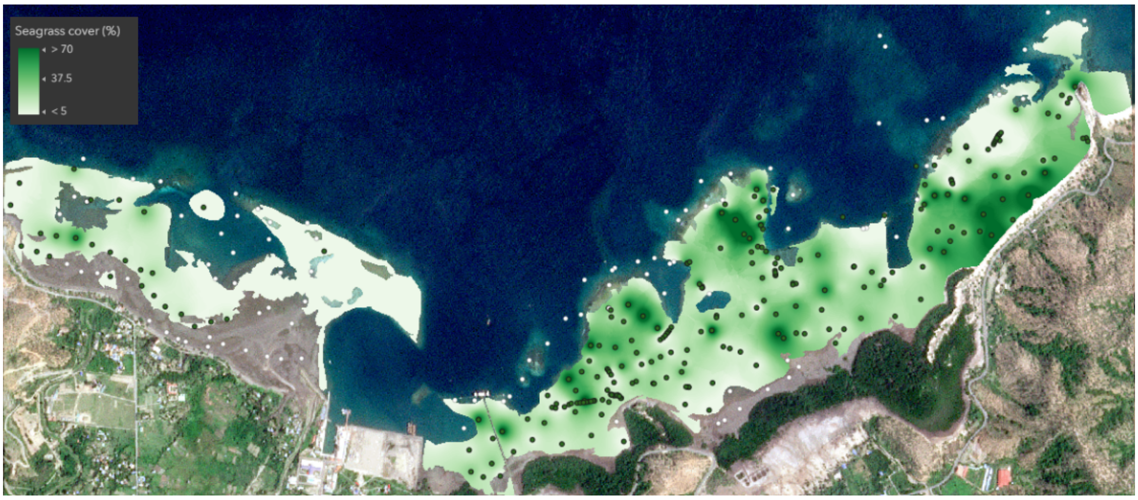


Figure 12. Seagrass cover/density

- > 70% seagrass cover (high seagrass density)
- 37.5% seagrass cover (medium seagrass density)
- < 5% seagrass cover (low seagrass density)

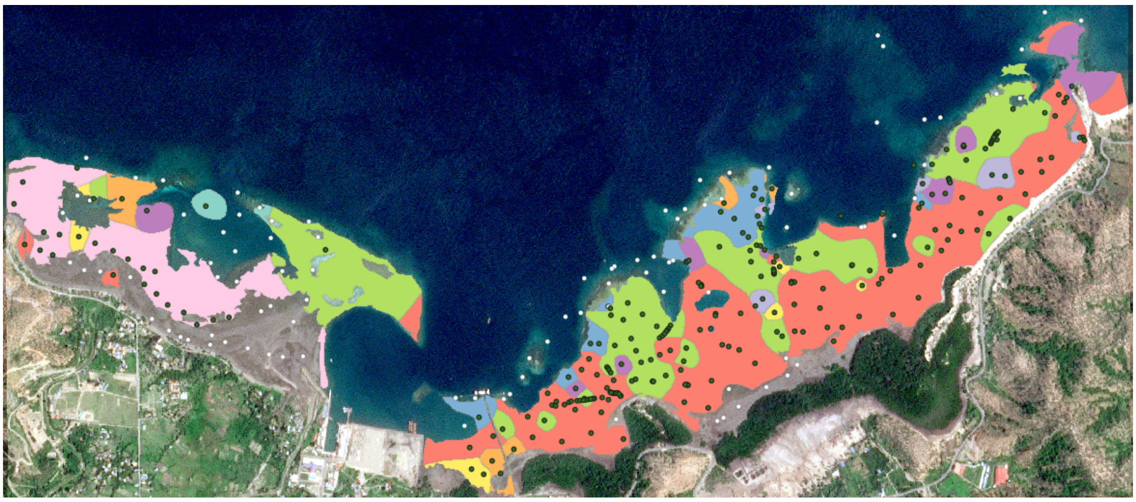


Figure 13. Seagrass species communities

Species code: Enhalus acoroides (EA), Thalassia hemprichii (TH), Syringodium isoetifolium (SI), Halodule uninervis (HU), Thalassodendron ciliatum (TC), Halodule pinifolia (HP), Cymodocea rotundata (CR), Halophila ovalis (HO), Halophila decipiens (HD), Cymodocea serrulata (CS)

EA with TH and SI	*TH with EA and SI*	*HU with TH and EA*
SI with TH and TC	*TC with TH,SI and EA*	*HP with HU, EA and TH*
HO with HP and TC	*HD with HU and TH*	*CR with TH and EA*

The results reveal two distinct seagrass meadows. A meadow to the west covering up to 62 ha and mostly dominated by *Halodule uninervis* or *Thalassia hemprichii*, with smaller sections dominated by *Halophila ovalis* and *Syringodium isoetifolium* and a much larger meadow to the east, covering up to 173 ha and mostly dominated by *Enhalus acoroides* or *Thalassia hemprichii*, with smaller scattered sections dominated by *Thalassodendron ciliatum, Halophila ovalis*, *Halodule pinifolia*, *Cymodocea rotundata* or *Syringodium isoetifolium*.

The maps highlight that seagrass cover is more expansive and abundant on the east side of the bay, situated in shallow subtidal conditions between the reef and mangroves. On the west side of the bay seagrass cover is more sparse, showcasing signs of sedimentation from the river, high algae cover and heat stress from exposed and intertidal conditions.

Seagrass BRUV fisheries assessment

The second phase of the study focused on using BRUV systems to evaluate fish abundance (MaxN) and fish species richness. The deployment strategy involved conducting 70 BRUV surveys across distinct seagrass-centric fishing areas. 54 BRUVS were strategically positioned within five seagrass-based fishing zones. Additionally, eight BRUVS were placed within an LMMA bufferzone in Beloi and another eight were placed north of Beloi in Bikeli, due to high seagrass cover and the proximity of two nearby LMMAs.

Four videos from Hera were not included in the analysis due to technical issues, including the frame settling in the wrong position so that the camera pointed upwards at the surface, or the camera did not record, often linked to SD card issues. Therefore, we present the results from 66 hours of BRUV videos in our data analysis.

Figure 14. 54 BRUV survey sites in Hera, including the four drops that were excluded during analysis.

Figure 15. Map of the eight BRUV survey sites in Beloi, Atauro Island.

Figure 16. Map of the eight BRUV survey sites in Bikeli, Atauro Island.

The 50 BRUV surveys in Hera were grouped for analysis based on the five local fishing site names: Bedik, Turismo, Fatuhada, Beraka, Raihenek Mutin (see *figure 17*). There are no current protected areas or active marine management in Hera. We could also group Bedik and Turismo together as areas of significant human development versus Fatuhada, Beraka and Raihenek Mutin as sites with lower levels of human development.

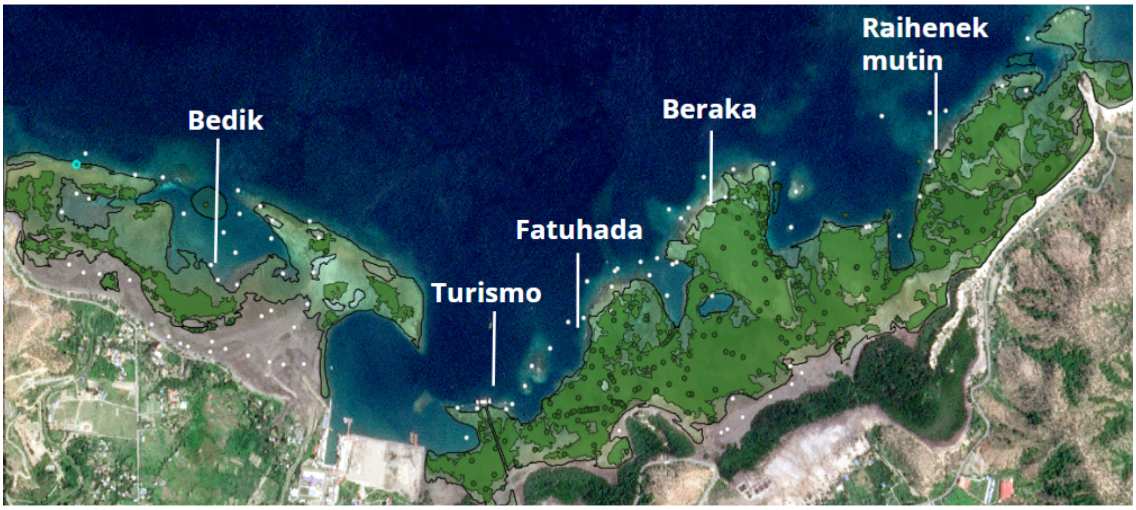


Figure 17. Map displaying small-scale fishing zone in Hera

On Atauro, the two sites (Beloi and Bikeli) could be grouped together as areas with significantly less human impact due to the remoteness of the island and smaller population. They are also located close to several LMMAs, with the Beloi site positioned directly in an LMMA buffer zone.

Average total abundance

Table 2. The total number of MaxN (average of total abundance) with standard deviation of fish abundance and the number of camera drops in each site in Hera.

Sites	Average MaxN	Standard deviation	No. of surveys
Bedik	18.60	10.26	5
Beraka	25.36	19.63	14
Fatuhada	11.75	15.56	4
Raihenek Mutin	5.67	7.45	9
Turismo	4.94	6.30	18

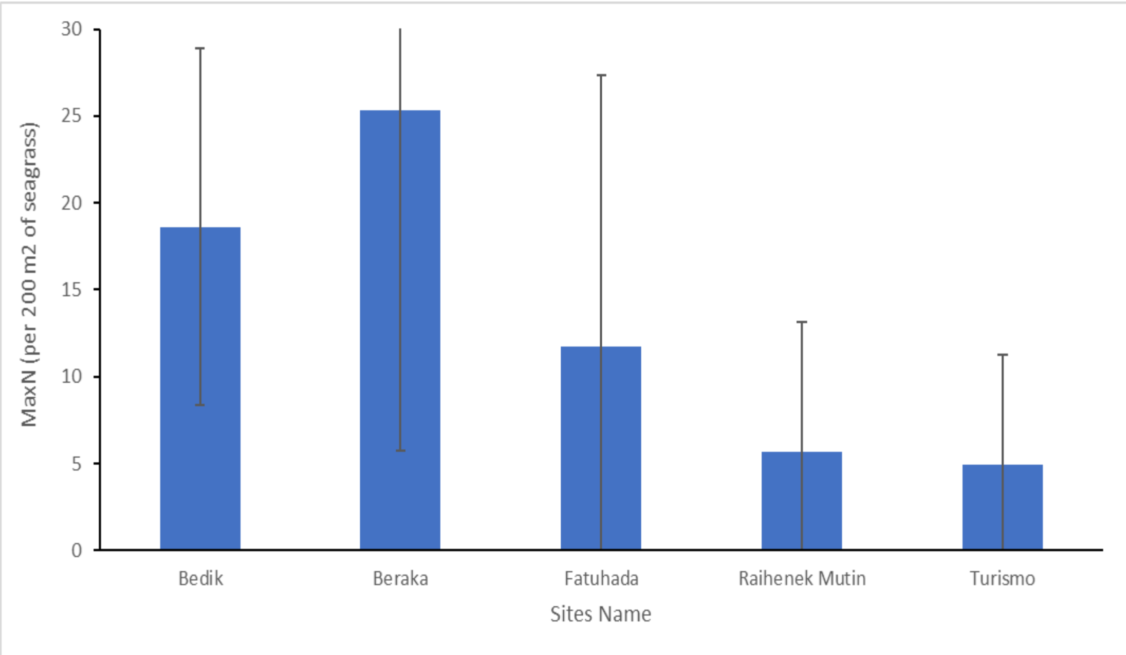


Figure 18. The MaxN (average of total abundance) of fish with sd per 200 m^2 of seagrass in the five fishing sites in Hera

The highest fish abundance in Hera was found in Beraka with an average of 25.36 (± 10.26) MaxN per 200 m^2 of seagrass and the two lowest fish abundance are in Raihenek Mutin with 5.67 (± 7.45) maxN per 200 m^2 of seagrass and Turismo with 4.94 (± 6.30) MaxN per 200 m^2 in Hera (see *figure 18*).

Although Beraka has the highest standard deviation, a focus group of fishers during data validation agreed that they catch more fish in Beraka.

Table 3. The total average of species richness with the standard deviation in Hera.

Sites	Average of species richness	Standard deviation
Bedik	6.80	2.68
Beraka	7.50	4.97
Fatuhada	2.25	0.50
Raihenek Mutin	3.33	2.87
Turismo	2.61	1.97

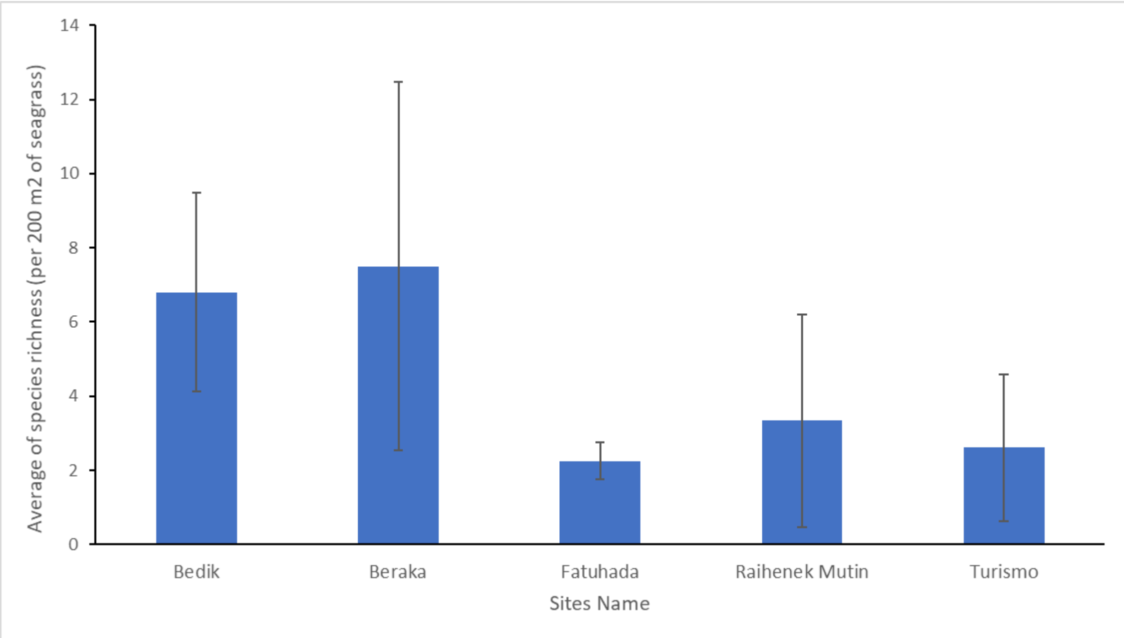


Figure 19. The total average of species richness with sd per 200 m^2 of seagrass in the five fishing sites in Hera

Similarly, the highest species richness is found in Beraka with an average of 7.5 (± 4.97) species per 200 m^2 of seagrass. The second highest is in Bedik with an average of 6.80 (± 2.68) species per 200 m^2 of seagrass. Fatuhada has the lowest average of 2.25 (± 0.50) species per 200 m^2 of seagrass area compared to the other sites in Hera (*see figure 19*).

Table 4. The top 10 most abundant fish species (average) across all seagrass survey sites in Hera

Species Name	Common Name	Average Abundance (sd)
Lethrinus harak	Thumbprint emperor	2.70 ± 0.29
Siganus argenteus	Streamlined spinefoot	1.86 ± 0.28
Siganus canaliculatus	White-spotted spinefoot	1.24 ± 0.31

Chelio inermis	Cigar wrasse	1.12 ± 0.31
Lethrinus variegatus	Slender emperor	0.84 ± 0.35
Sphyraena flavicauda	Yellowtail barracuda	0.58 ± 0.35
Leptoscarus vaigiensis	Marbled parrotfish	0.34 ± 0.35
Lethrinus ornatus	Ornate emperor	0.34 ± 0.35
Caranx melampygus	Bluefin trevally	0.31 ± 0.35
Siganus fuscescens	Mottled spinefoot	0.22 ± 0.35

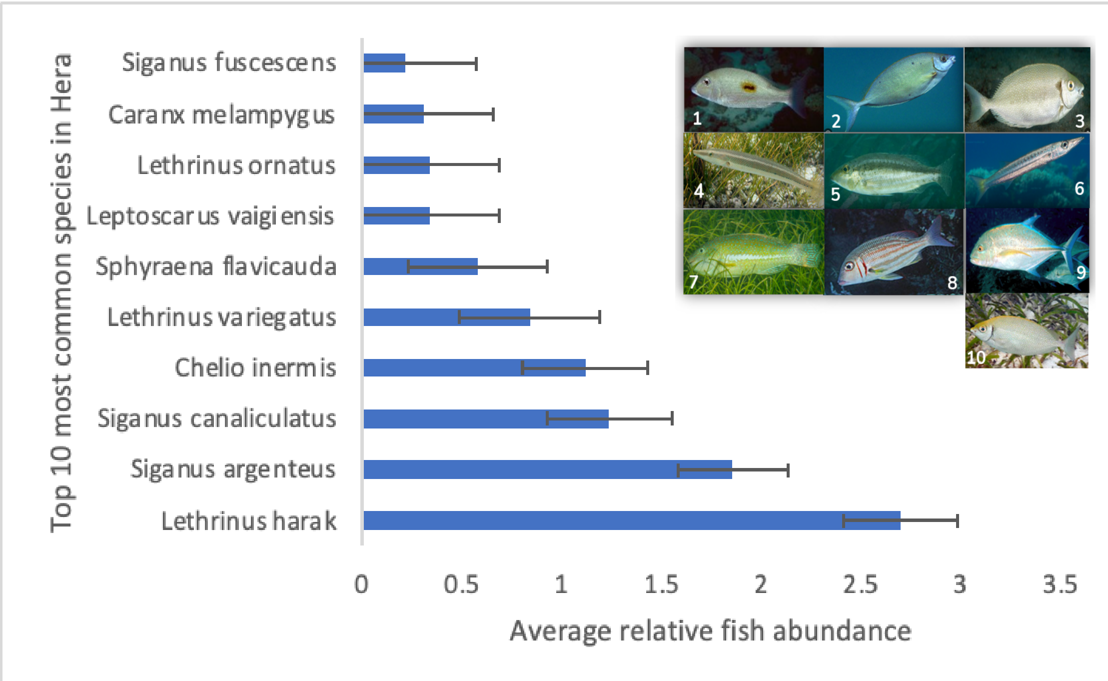


Figure 20. The average relative fish abundance with the standard deviation for the top 10 most frequently seen species in BRUV survey analysis in Hera. Note: this is not including schooling fish such as Megalops cyprinoides and Plotosus lineatus

The most frequently observed species in Hera were *Lethrinus harak* (thumbprint emperor) with a 2.70 (± 0.29) average relative fish abundance and *Siganus argenteus* (streamlined spinefoot rabbitfish) with a 1.86 (± 0.28) average relative fish abundance. Three of the top 10 most abundant fish species were from the family *Siganidae (rabbitfish)*. Shoaling fish, including *Megalops cyprinoides* (oxeye herring / sardine) and *Plotosus lineatus* (striped eel catfish) were excluded from the analysis as they disproportionately skewed the data.

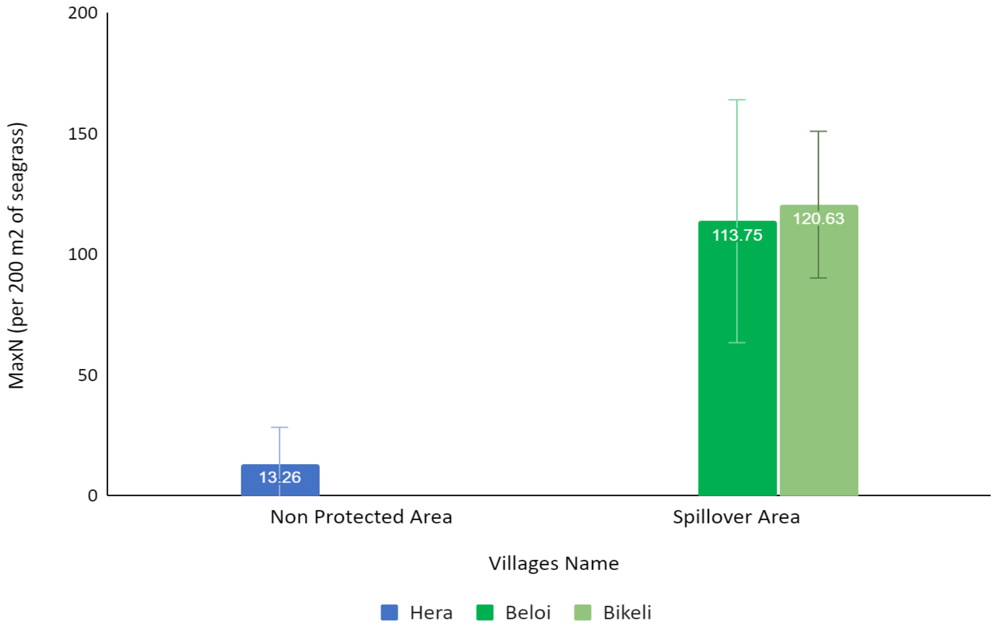


Figure 21. The MaxN (average of total abundance) of fish with sd per 200 m² of seagrass in the non protected area (Hera) versus seagrass meadows near LMMAs in Atauro (Beloi and Bikeli).

Beloi and Bikeli recorded a significantly higher MaxN with 113.75 (± 50.30) and 120.63 (± 30.37) per 200 m² of seagrass, respectively. In comparison, Hera as a non-protected area recorded a much lower fish abundance with 13.26 (± 15.14) MaxN per 200 m² of seagrass.

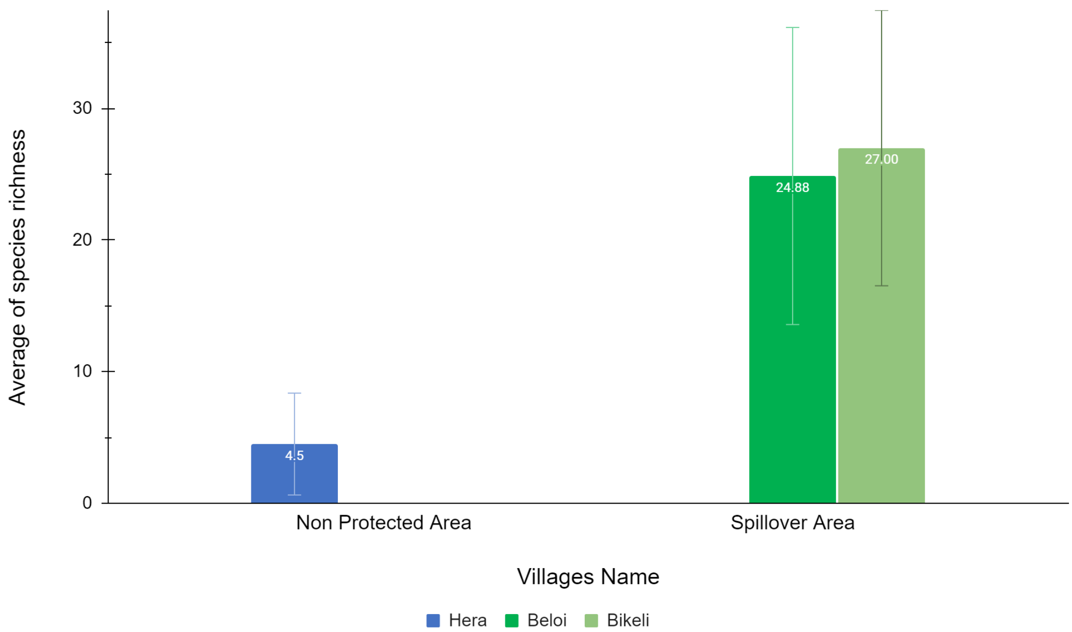


Figure 22. Total average species richness across the three coastal areas: Hera, Beloi and Bikeli

Beloi and Bikeli also recorded a significantly higher average species richness (24.88 ± 11.29 and 27.00 ± 10.47, respectively) compared to the non-protected area in Hera with 4.50 (± 3.87) species richness. In total, 143 different fish species were recorded across the seagrass sites, with 105 different species recorded in Hera and and 139 species recorded across Beloi and Bikeli (*see table A1*).

Socio-economic household survey

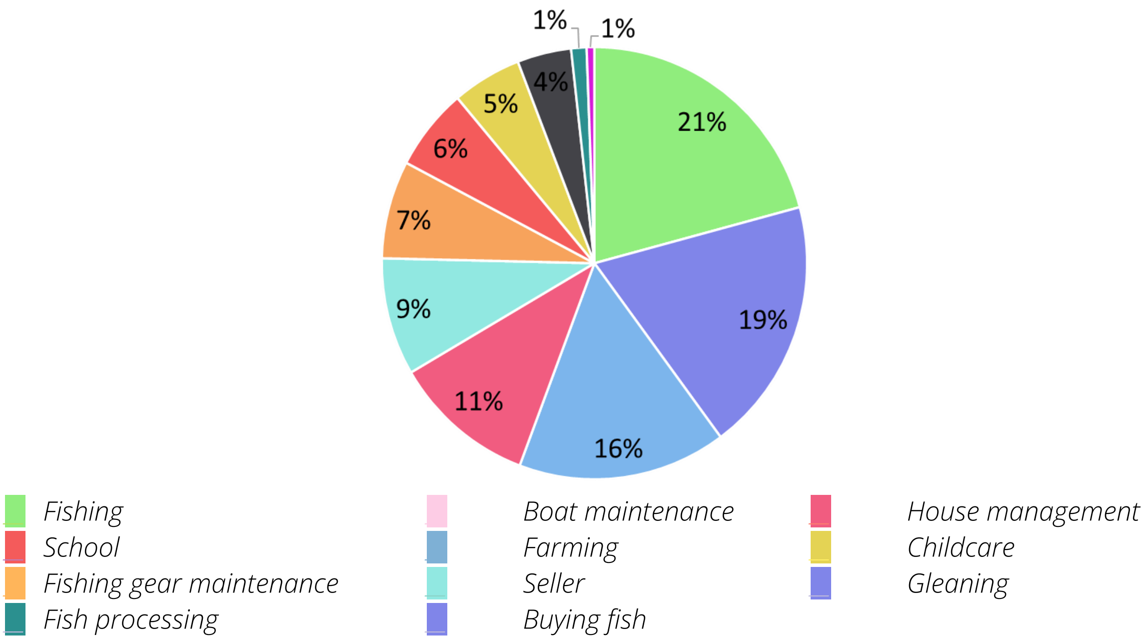
147 households were surveyed from the coastal *aldeia* Ailok Laran and Sukaer Laran in Hera. In total, 61 (41%) men and 86 (59%) women were interviewed.

Table 5. Number of households interviewed in each sub-village, with gender disaggregation

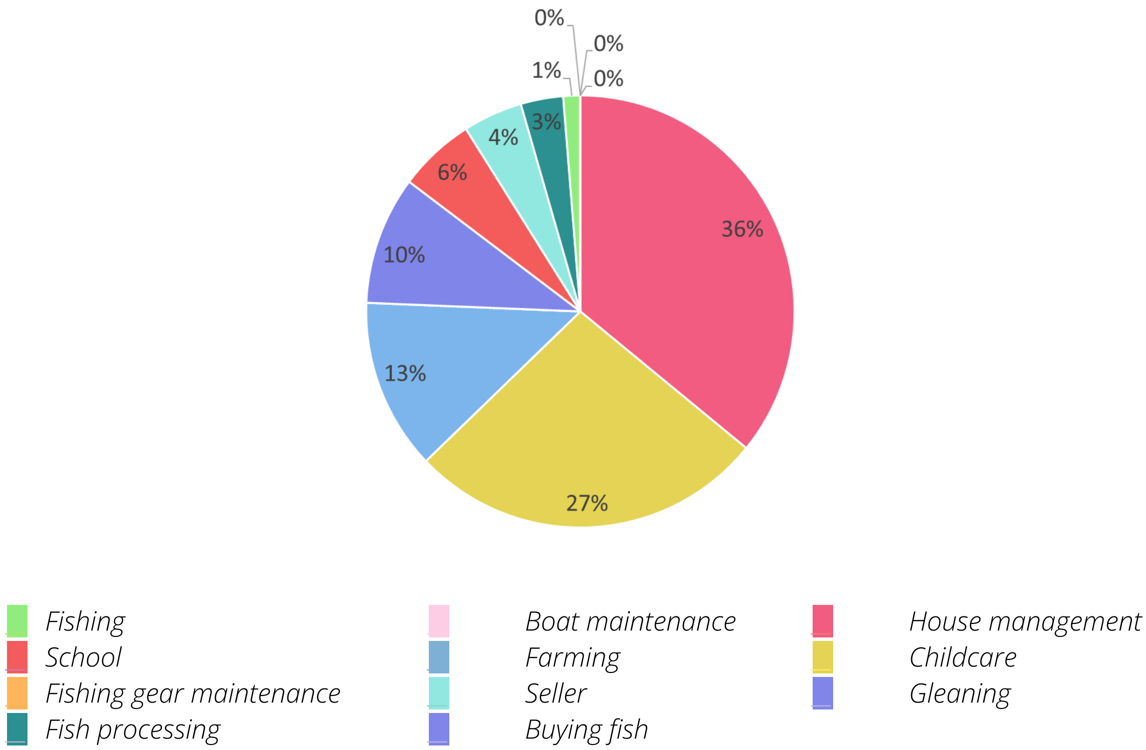
		HERA AILOK LARAN	HERA SUKAER LARAN
1	Total Households	68	79
2	Women Interviewed	39	47
3	Men Interviewed	29	32
4	Mean Number of Men in Household	2	2
5	Mean Number of Non-binary in Household	0	0
6	Mean Number of Women in Household	1	2
7	Mean Number of Youth in Household	2	2

Household activities were recorded for each household, split by gender and youth:

a) Men



b) Women



c) Youth

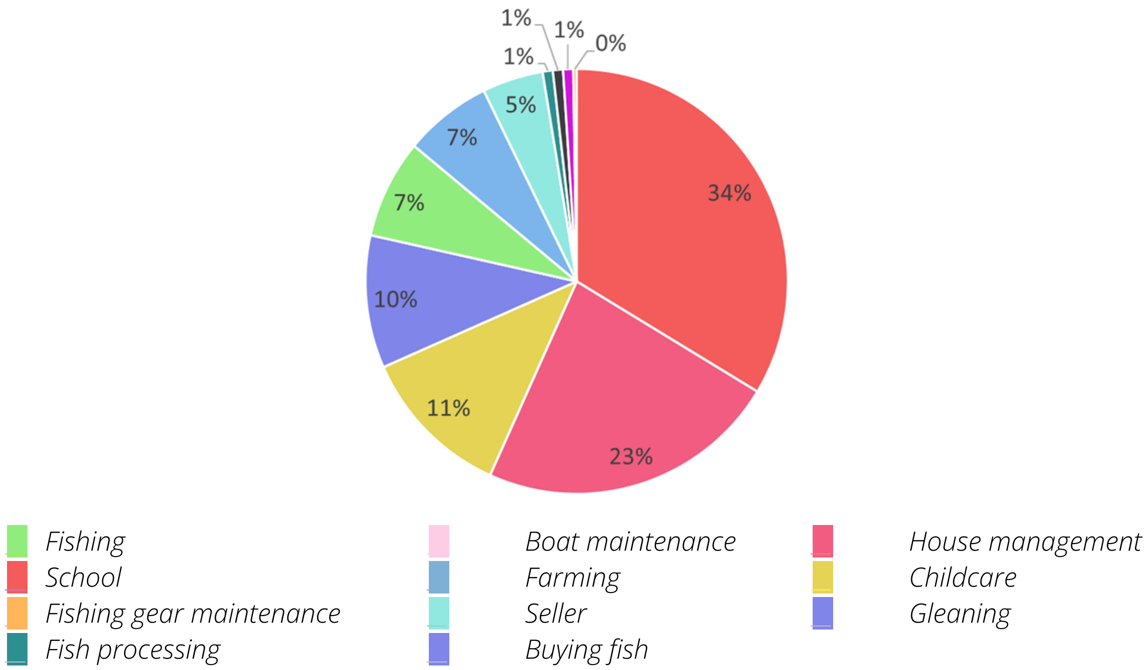


Figure 23. Top household daily activities, disaggregated by gender and youth

In Chart a), the primary household activities for men are delineated with fishing (21%) and gleaning (19%) emerging as predominant, followed by farming (16%) and selling fish (11%). Conversely, Chart b) underscores women's engagement in house management (36%) and childcare (21%) as primary activities, followed by farming (13%) and gleaning (10%). Finally, Chart c) visually represents the prominent household activities for youth, with school attendance (34%) and household chores (23%) taking precedence, accompanied by childcare (11%) and gleaning (10%).

Percentage of men and women engaging in fishing and gleaning activities in Hera:

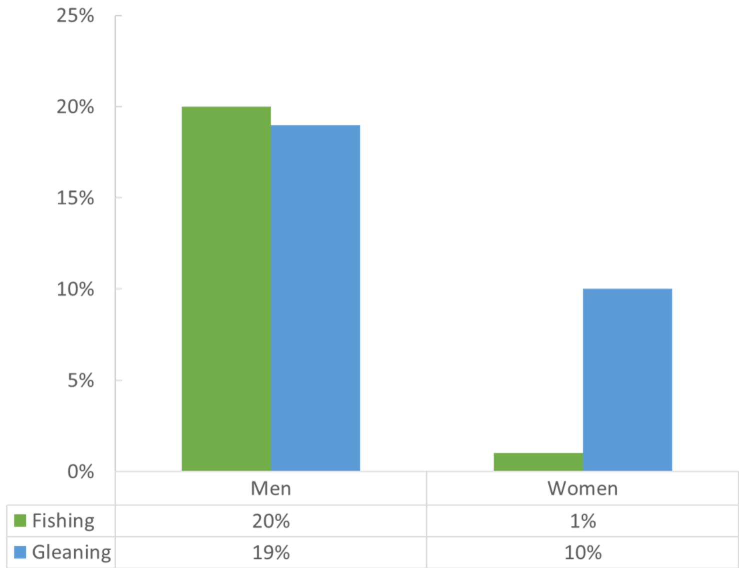


Figure 24. Household members fishing and gleaning in Hera

The findings (*figure 24*) highlight a notable disparity in the level of involvement between men and women in direct fishing activities. Specifically, men exhibit a significantly higher participation rate at 20%, contrasting with a lower engagement of women at 1%. Women demonstrate a greater involvement in gleaning activities, accounting for 10%, while men also contribute actively with a rate of 19%.

Priority fishing habitats for fishers in Hera:

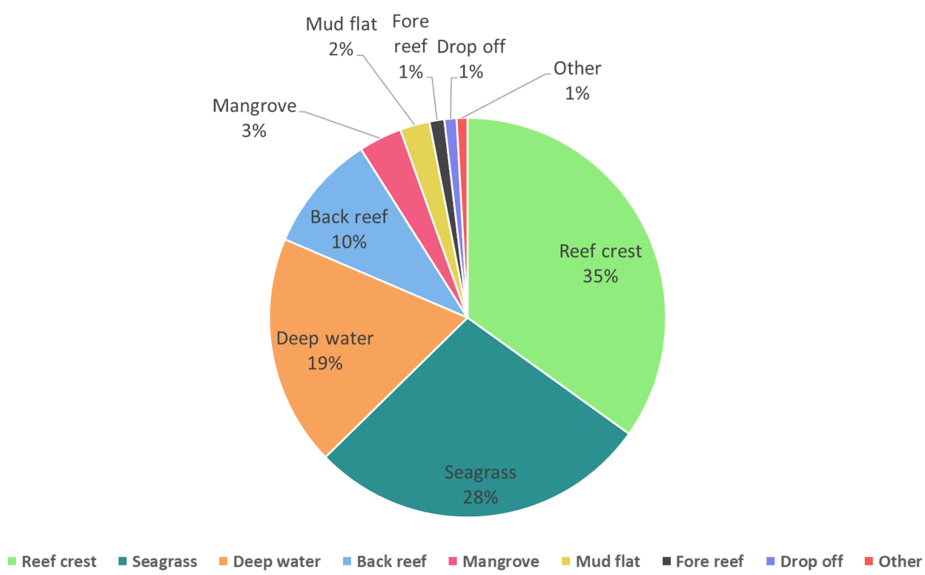


Figure 25. The most common fishing habitats identified by households in Hera

According to the survey, reef crest (35%) and seagrass (28%) are the primary habitats for fishing and gleaning, whilst deep water (19%), back reef (10%) and mangrove (3%) play notable roles.

Habitat quality compared to five years before:

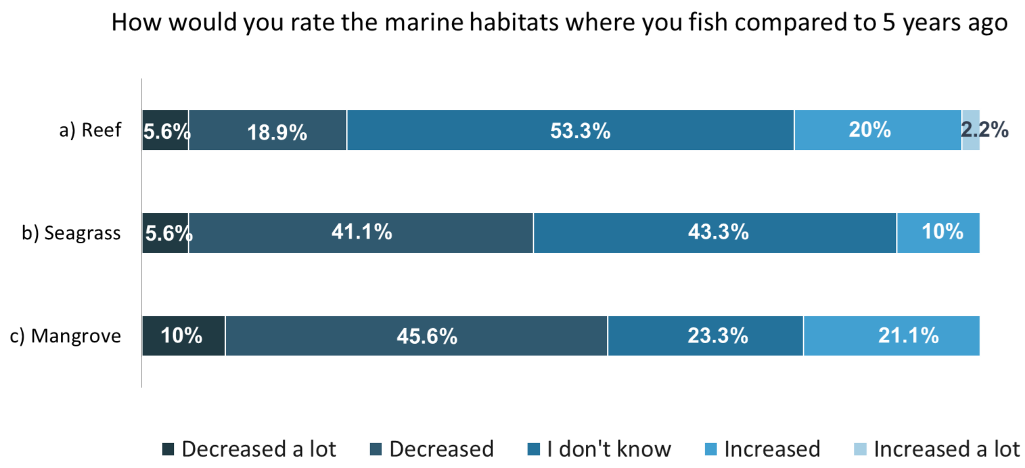


Figure 26. Number, size and value of catch compared to five years ago

The data indicates a perception of overall decline in the health of three distinctive habitats in Hera over the past five years. The most substantial concern was reported on mangrove habitats where 55.6% of fishers reported a decline in health or quality, followed by seagrass habitats with 46.7% and reef habitats with 24.5%.

Fish and invertebrate catch compared to five years before:

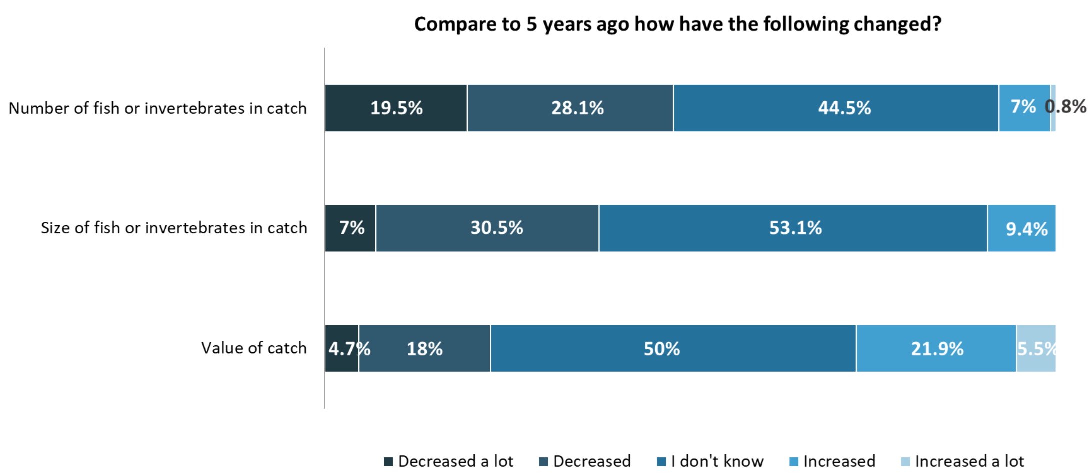


Figure 27. Number, size and value of catch compared to five years ago

The data reveals that 47.6% of respondents reported a decline (28.1%) or a significant decline (19.5%) in catch compared to five years ago. In contrast, 7.08% noted an increase and 44.5% were uncertain. Additionally, 37.5% indicated a decrease in catch sizes, while 9.4% reported an increase. Regarding catch value, 27.4% perceived an increase and 22.7% believed it had decreased. Notably, a majority of respondents expressed uncertainty about changes, possibly due to misinterpreting the question or responding on behalf of another household member.

Top 10 highly valued fish families to households in Hera:

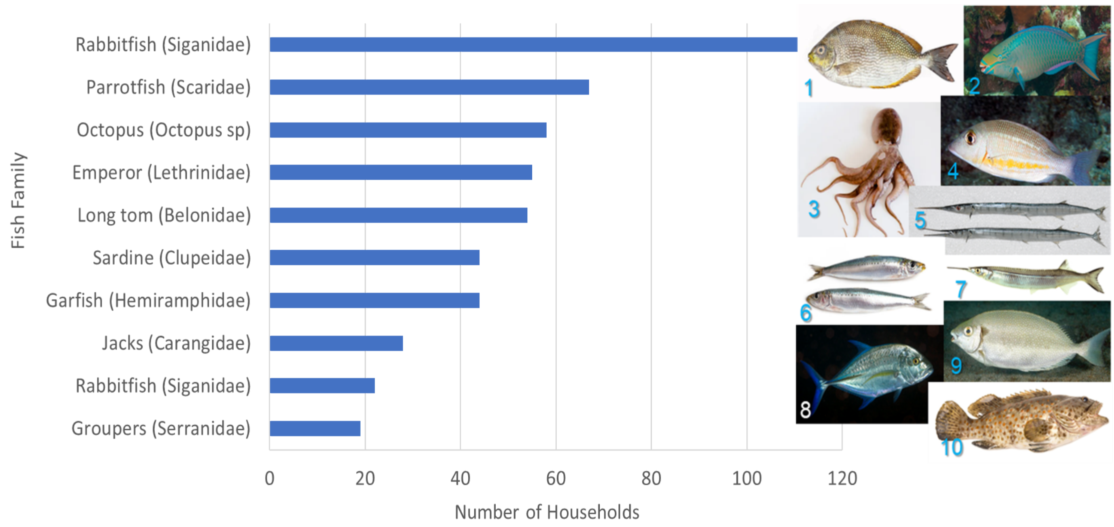


Figure 28. Fish families identified as priorities to fishing households in Hera

The results from the survey question "which fish species are most important to your household" reveal the importance of certain fish in Hera for sustenance or income. Respondents were often unable to identify species level, so fish families were used to maintain accuracy. *Siganidae* (rabbitfish) was identified as the most common top priority fish, followed by *Scaridae* (parrotfish), *Octopus* sp. (octopus) and *Lethrinidae* (emperor), *Belonidae* (long tom), *Clupeidae* (sardine), *Hemiramphidae* (garfish), *Carangidae* (jack) and *Serranidae* (grouper) were also notable inclusions.

Table 6. Top 10 important fish species and their presence in the BRUV analysis in Hera

Fish (described by households at family level)	**Abundance in BRUV analysis - MaxN**	**Role of seagrass (high/moderate/ low/ none)**
1. *Siganidae* (rabbitfish) *Includes multiple species of Siganidae all known locally as Kitan*	3.47 ± 3.11 Composed of: *Siganus argenteus* *Siganus fuscescens* *Siganus spinus* *Siganus vulpinus*	High *(feeding, shelter, nursery, reproduction, browsing, foraging)*
2. *Scaridae* (parrot fish)	0.48 ± 1.73	Moderate *(feeding, nursery, shelter)*
3. *Octopodidae* (octopus)	*One Hapalochlaena lunulata was recorded, but not included here as this venomous species is not consumed or sold*	Low (egg deposition, shelter)

4. *Lethrinidae* (emperor)	4.28 ± 6.90	High *(feeding, shelter, nursery, spawning, foraging)*
5. *Belonidae* (needlefish)	0	Moderate (feeding, nursery, *shelter*)
6. *Clupeidae* (sardines & herrings)	0	Low *(nursery, shelter)*
7. *Hemiramphidae* (garfish)	0	Low *(spawning ground, shelter)*
8. *Carangaidae* (jack)	0.28 ± 0.69	Moderate *(feeding, nursery)*
9. *Siganus guttatus* (orange spotted spinefoot) and *siganus canaliculatus* [2]	2.68 ± 7.28 From *Siganus canaliculatus*; no *Siganus guttatus* identified	High *(feeding, shelter, nursery, reproduction, browsing, foraging)*
10. *Serranidae* (grouper)	0	Low *(foraging, spawning ground, nursery)*

While all 10 fish families are recognized for utilising seagrass during at least part of their life cycle, only five of them were observed during the BRUV surveys in Hera: *Siganidae* (referred to locally as kitan and paripa), *Scaridae, Lethrinidae and Carangidae*. The absence of the remaining five fish families may suggest low population numbers or methodological limitations, such as the challenge in capturing more elusive species (e.g. *Octopodidae*) and those active during the night.

Table 7. Top 10 fish species and their presence in the BRUV analysis in Atauro

Fish (described by households at Family level)	**Fish Abundance MaxN - Atauro (Beloi & Bikeli)**
1. *Siganidae* (rabbitfish)	8.33 ± 4.54
2. *Scaridae* (parrot fish)	17.6 ± 0.47
3. *Octopodidae* (octopus)	0 ± 0.00
4. *Lethrinidae* (emperor)	8.8 ± 1.46

[2] *These two species are known locally as Paripa. Paripa was identified by households separately of the Siganadae mixed-species known as Kitan, listed above*

5. *Belonidae* (needlefish)	2.27 ± 8.78
6. *Clupeidae* (sardines and herrings)	0 ± 0.00
7. *Hemiramphidae* (garfish)	0 ± 0.00
8. *Carangaidae* (jack)	0.4 ± 0.51
9. *Siganus guttatus* (orange spotted spinefoot) and *siganus canaliculatus*	7.27 ± 11.31 For *Siganus canaliculatus*, no *Siganus guttatus*
10. *Serranidae* (grouper)	0.13 ± 0.26

For comparison we analysed the same fish species against the BRUV data collected in Atauro. Seven out of the 10 fish families were recorded, with significantly higher fish abundance recorded for key fish families *Siganidae* (rabbitfish), *Scaridae* (parrotfish) and *Lethrinidae* (emperor) compared to Hera, indicating that management measures may be having a positive impact on fish abundance and richness.

Discussion

Importance of seagrass and key fisheries in Hera

Our objective was to enhance our understanding of the connection between seagrass ecosystems and the livelihoods of fishing communities. By integrating socio-economic findings with seagrass mapping and BRUV results, we aimed to assess the role seagrass plays in sustaining fisheries considered of the highest value to the community in Hera.

The social survey confirmed that fishing and gleaning constitute the primary income-generating activities in households across the two *aldeia* surveyed. While fishing is predominantly carried out by men, gleaning is an important activity for men (19%), women (10%) and youth (10%) in the community. The results identified that the top ten most important fish to households in Hera are all associated with seagrass habitats (*see figure 28 and table 6*). This finding was corroborated by the BRUV surveys where 50% were observed in Hera's seagrass meadows, rising to 70% at comparison sites in Atauro. In total, 143 different fish species were recorded in the seagrass assessment, showcasing the range of fish using seagrass across different ontogenetic stages of their lifecycle (*see table A1*).

Although reef crest was identified as the most common fishing habitat in Hera (35%), seagrass ranked a close second (28%), underlining its value as both a fishing ground and a nursery supporting nearby coral reefs. Households in Hera also expressed a shared perception that their marine habitats are in declining health (*see figure 25*), aligning with a perceived decrease in fish and invertebrate catch over the same time period (*see figure 27*).

Figure 29. A degraded seagrass meadow, showing signs of eutrophication in Hera (Credit: Blue Ventures)

While not definitive, this reasonably strong suggestion of declining habitat and fish catch aligns with the low fish abundance (MaxN) observed in Hera, as well as anecdotal evidence of unsustainable fishing practices. Overall, this provides a positive indication of the importance of and the role seagrass plays in supporting fisheries valuable to the community. It implies that management interventions considering improved habitat health could lead to improved fisheries abundance and species richness in Hera.

Comparison sites

The notably elevated fish abundance (MaxN) and species richness observed at seagrass sites in Beloi and Bikeli suggest that Hera's averages might be considerably lower than what is anticipated for a thriving ecosystem (*Table 9*). As shown in the results, Hera had a significantly lower fish abundance (13.26 $\pm$ 15.14) and fish richness (4.50 $\pm$ 3.87), compared to the Atauro which had over 750% higher abundance and over 500% higher species richness: Beloi abundance (113.75 $\pm$ 50.30), richness (24.88 $\pm$ 11.29) and Bikeli abundance (120.63 $\pm$ 30.37), richness (27.00 $\pm$ 10.47).

Figure 30. A thumbprint emperor (Lethrinus harak) in an dense seagrass meadow in Beloi, Atauro Island (Credit: Blue Ventures)

While the scope of the study did not include investigating potential causes for differences, it seems highly likely that community-based marine management is a contributing factor to the higher abundance and species richness in Atauro. However, it should be noted that Atauro's smaller population and island isolation may contribute to its elevated fish abundance, whereas Hera's marine ecosystems face more significant challenges from human development. More information on the socio-economic and fisheries context of Atauro would be needed for a comprehensive analysis.

Nevertheless, this emphasises the potential for abundant and diverse fish populations in well-maintained seagrass meadows, as exemplified by the protected areas around Atauro Island. With the absence of marine management measures in Hera, there is an opportunity to test targeted interventions to enhance the health of Hera's seagrass meadows and to monitor its impact on priority fisheries.

Unclear correlation between seagrass cover and fish abundance and richness in Hera

The mapping results enabled a comparative analysis of seagrass cover against fish abundance and richness across the five fishing sites in Hera. Beraka, the site with the highest fish abundance and richness, also recorded high seagrass cover and prevalence of larger seagrass species like *Enhalus acoroides* and *Thalassodendron ciliatum*. Conversely, Turismo, exhibiting low seagrass cover, recorded the lowest fish abundance—a trend consistent with findings in the Indo-Pacific, suggesting that higher seagrass cover and structural complexity positively influence fish abundance (Jones et al. 2021).

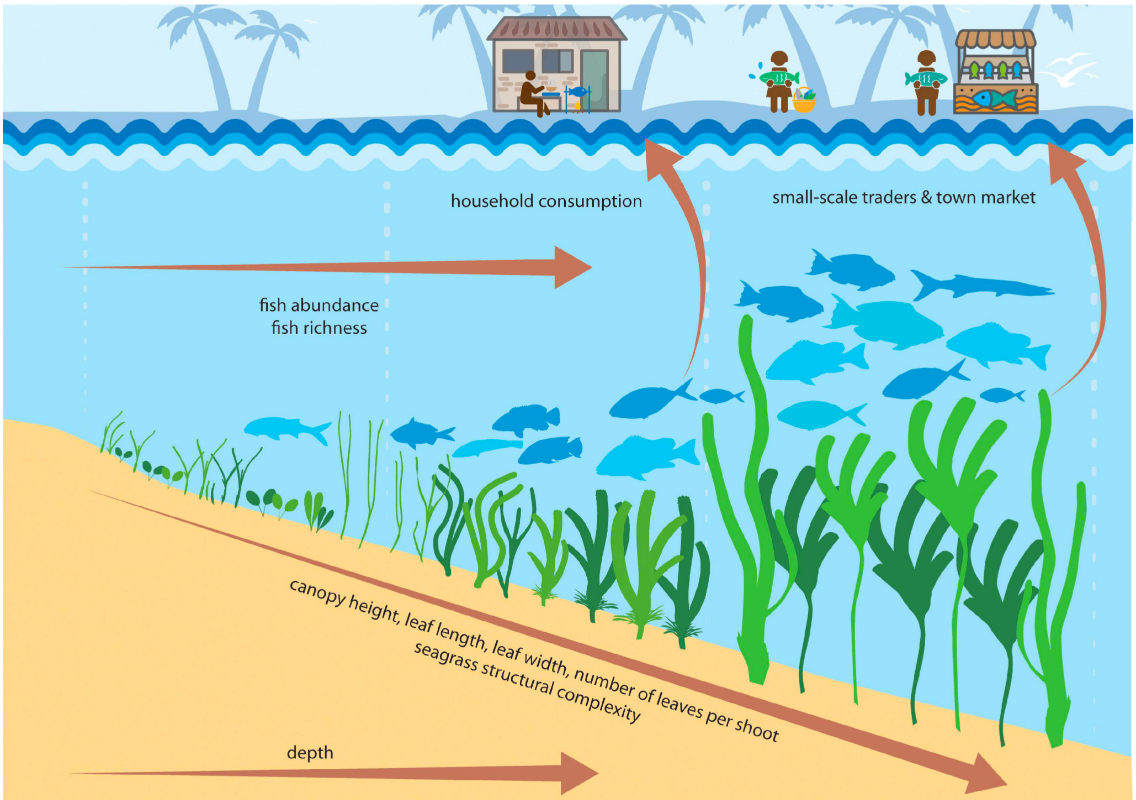
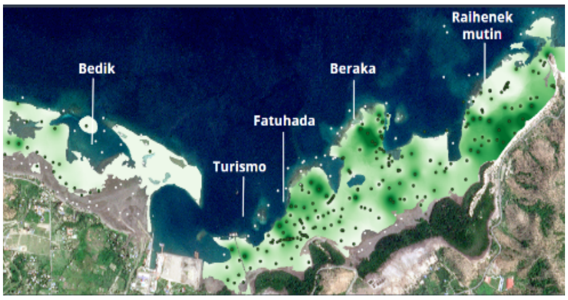
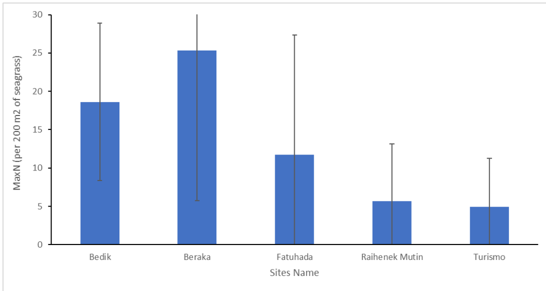


Figure 31. Illustration of how seagrass structure influences fish dynamics (Jones et al. 2021)

This trend was challenged by Bedik, which, despite having the lowest seagrass cover and being dominated by smaller seagrass species like *Halodule uninervis* or *Thalassia hemprichii*, recorded the second-highest fish abundance and species richness in Hera. Additionally, Raihenek Mutin, the most dense area of seagrass predominantly featuring *Enhalus acoroides*, recorded comparatively low fish abundance and richness, introducing complexity to the relationship between seagrass characteristics and fish abundance in Hera.





However, the scope of the study limits the ability to draw overall conclusions about correlation between fish abundance in seagrass cover. BRUV surveys were limited in the western part of the bay due to the presence of a Navy base and oil line. As a result there is limited fish abundance data from low-density seagrass areas, making it difficult to assess any correlation and there is no comparative fish abundance data for areas that are only sand or mud. This is a potential option for future research to investigate.

A deeper dive into local fishing dynamics may provide more clarity on anomalies within the results. Incorporating fisheries profiling and regular catch landing monitoring would further contribute to a comprehensive understanding of the influence of fishing activity in each area. This additional context would support decision-making related to sustainable fisheries management, ensuring improving coastal livelihoods are a priority focus for any marine management interventions introduced.

Implications for marine management in Hera

The rapid assessment and mapping revealed seagrass cover is more degraded on the west side of the bay (Bedik) where there is no protection from mangroves and evidence of sedimentation from the nearby river estuary. Gleaners highlighted Bedik has suffered from several damaging floods, consistent with historically-high extreme weather events in Timor-Leste in recent years. As this is predicted to continue or increase in the future, there is an increasing threat to seagrass in Bedik, posing challenges for seagrass conservation and restoration in this area.

The central area (Turismo) has variable seagrass cover with many microalgae and algae blooms observed during the assessment. Algae blooms in seagrass meadows are primarily caused by an excess of nutrients, particularly nitrogen and phosphorus, in the water. This is potentially due to the proximity of a nearby power plant, but further investigation would be needed. Algae blooms are harmful to seagrass and fish, blocking light, depleting oxygen and altering habitat structure, collectively contributing to declines in seagrass health, biodiversity and ecosystem functionality (Burkholder et al. 2007).

The health and extent of seagrass meadows on the eastern side of the bay are more positive where several large meadows are abundant and in relatively good health

(Fatuhada, Beraka and Raihenek Mutin). This is likely due to the protection offered by adjacent mangrove forests and coral reefs and reduced human activity. Additionally, the mixed-species meadows found here (predominantly made up of *Enhalus, Thalassia* and *Thalassodendron)* typically display more ecosystem services as larger more resilient seagrass species (Mtwana Nordlund et al. 2016), compared to the smaller species (*Syringodium*, *Halodule* and *Halophila)* found to the west of the bay.

The results suggest that initiating future area-based fisheries management and seagrass conservation efforts on the eastern sites of Hera, where seagrass meadows are healthier and face fewer ongoing environmental and anthropogenic threats, is more likely to achieve positive impact in the short to medium term. The suitability of the eastern side is enhanced by the presence of mangrove and coral reef ecosystems. If proven effective, this approach could serve as a catalyst for expanding management to more complex areas that may pose greater challenges for recovery.

Conclusion

In summary, the assessment highlights the important role of seagrass meadows in Hera as essential habitats and nurseries for fish species crucial to small-scale fishers. The identification of 143 species associated with seagrass highlights the significant value of these ecosystems, especially considering that the top 10 fish important to Hera households all rely on seagrass at some point in their lifecycle.

The documented lower fish abundance and species richness in Hera, combined with the community's perception of declining habitat health, emphasises the necessity for targeted management interventions. Taking inspiration from the success of Tara Bandu and area-based management measures in Atauro, we propose similar strategies in Hera to maximise the benefits of seagrass as both a fishing ground and nursery. Our findings indicate that concentrating efforts on the healthier eastern seagrass meadows in Hera, characterised by larger and more resilient seagrass species and facing fewer environmental and anthropogenic threats, holds promise for positive impacts. Given the significance of fisheries as a primary income source in Hera, community involvement in decision-making and management is pivotal for the success of proposed interventions and for building livelihood resilience to changing environmental conditions.

Despite study limitations, such as limited fisheries data in certain areas, we advocate for ongoing participatory monitoring, adaptive management and future research to bridge these gaps. Sharing the results within the community and beyond contributes to the collective knowledge base and offers a potential model for replicable seagrass and sustainable fisheries management initiatives in Timor-Leste.

Additional recommendations

Policy

Using Tara Bandu customary law as a governance system has helped enable a more holistic and community-centric approach to managing resources on Atauro Island. There is an opportunity to replicate and formalise this process in Hera to enhance the national government’s recognition of the rights of Suco Councils (regional authorities) and communities to democratically manage their near-shore coastal areas. Close liaison between local stakeholders, the Suco Council and the national government via the Ministry of Agriculture, Livestock, Fisheries and Forestry, will be essential towards strengthening a process that has the potential for the replication across Timor-Leste.

Additional comments and reflections

It was outside the scope of the study to assess how including seagrass management within or nearby LMMAs may impact wider ecosystem and fisheries health, versus including only reef areas. 15-30% of fish use multiple habitats, of which 20% are commercially valuable, by targeting multiple interconnected ecosystems there is a higher chance of improving fish abundance and species richness (Honda et al. 2013). This is a strongly recommended area for future research, including potential participatory action research conducted alongside the community in Hera or other locations, trialling marine management that covers a combination area of seagrass and reef. This could be used for future comparison against reef-specific management within TImor-Leste and in other countries.

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Annex

Table A1. List of the 143 individual species recorded during the BRUV analysis in Timor-Leste

Scientific Name	Common Name
Acanthurus bahianus	Barber surgeonfish
Acanthurus nigricaudus	Blackstreak surgeonfish
Acanthurus thompsoni	Thompson's surgeonfish
Acanthurus triostegus	Convict surgeonfish
Aeoliscus strigatus	Razorfish
Aluterus scriptus	Scrawled filefish
Amphiprion clarkii	Clark's anemonefish
Amphiprion polymnus	Saddleback anemonefish
Amanses scopas	Broom filefish
Acreichthys tomentosus	Bristle-tail file-fish
Arothron immaculatus	Immaculate puffer
Arothron hispidus	White-spotted puffer
Balistapus undulatus	Orange-lined triggerfish
Calotomus viridescens	Viridescent parrotfish
Calotomus carolinus	Stareye parrotfish
Cantherhines dumerilii	Barred Filefish/Whitespotted filefish
Cantherhines pardalis	Wirenet filefish/ honeycomb filefish
Caranx melampygus	Bluefin trevally
Centropyge bicolor	Bicolor angelfish
Centropyge vrolikii	Pearlscale angelfish
Chaetodon kleinii	Sunburst butterflyfish
Chaetodon trifascialis	Chevron butterflyfish
Chaetodon lunula	Raccoon butterflyfish
Chaetodon auriga	Threadfin butterflyfish
Chaetodon vagabundus	Vagabond butterflyfish
Cheilio inermis	Cigar wrasse
Cheilinus trilobatus	Tripletail wrasse

Cheilinus chlorourus	Floral wrasse
Chrysiptera tricincta	Threeband demoiselle
Chrysiptera cymatilis	Blue Devil damselfish
Chromis viridis	Blue green damselfish
Chromis notata	Pearlspot chromis
Ctenochaetus striatus	Striated surgeonfish
Ctenochaetus flavicauda	Pale-tailed bristletooth
Dascyllus aruanus	Humbug dascyllus
Dascyllus reticulatus	Reticulate dascyllus
Dascyllus trimaculatus	Threespot dascyllus
Epinephelus bleekeri	Duskytail grouper
Epinephelus merra	Honeycomb grouper
Fistularia commersonii	Bluespotted cornetfish
Gerres oyena	Common silver-biddy
Gymnocranius elongatus	Forktail large-eye bream
Gymnocranius euanus	Japanese large-eye bream
Gymnosarda unicolor	Dogtooth tuna
Halichoeres chloropterus	Pastel green wrasse
Halichoeres melanurus	Tail-spot wrasse
Halichoeres marginatus	Dusky Wrasse
Halichoeres trimaculatus	Threespot wrasse
Hipposcarus longiceps	Pacific longnose parrotfish
Hemigymnus melapterus	Blackeye thicklip (juvenile)
Labroides bicolor	Bicolor cleaner wrasse
Labroides dimidiatus	Bluestreak cleaner wrasse
Lethrinus harak	Thumbprint emperor
Lethrinus variegatus	Slender emperor
Lethrinus ornatus	Ornate emperor
Lethrinus rubrioperculatus	Spotcheek emperor
Lethrinus atkinsoni	Pacific yellowtail emperor
Lethrinus obsoletus	Orange-striped emperor
Lutjanus fulvus	Blacktail snapper

Lutjanus gibbus	Humpback red snapper
Lutjanus fulviflamma	Longspot snapper
Lutjanus bohar	Two-spot red snapper
Megalops cyprinoides	Oxeye herring (sardine)
Monotaxis heterodon	Redfin emperor/bream
Mulloidichthys vanicolensis	Yellowfin goatfish
Mulloidichthys flavolineatus	Yellowstripe goatfish
Naso unicornis	Bluespine unicornfish
Neoglyphidodon melas	Bowtie damselfish
Novaculichthys taeniourus	Rockmover wrasse
Novaculoides macrolepidotus	Emerald wrasse/Seagrass wrasse
Parapercis tetracantha	Reticulated sandperch
Parapercis lineopunctata	Nosestripe sandperch
Parapercis xanthozona	Java sandperch
Parapercis barberinoides	Bicolor goatfish
Parupeneus barberinus	Dash-and-dot goatfish
Parupeneus indicus	Indian goatfish/Yellowspot goatfish
Parupeneus multifasciatus	Manybar goatfish
Parupeneus macronemus	Long-barbel goatfish
Parupeneus crassilabris	Doublebar goatfish
Parupeneus barberinus	Dash-and-dot goatfish
Petroscirtes mitratus	Floral blenny/Highfin fangblenny
Plectroglyphidodon leucozonus	Singlebar devil
Pseudochromis flammicauda	Firetail dottyback
Pseudodax moluccanus	Chiseltooth wrasse
Pteragogus trispilus	Flagfin wrasse
Pterocaesio tile	Bluestreak fusilier
Pentapodus bifasciatus	White-shouldered whiptail
Pentapodus trivittatus	Three-striped whiptail
Pervagor janthinosoma	Blackbar filefish
Plotosus lineatus	Striped eel catfish
Pomacentrus melanochir	Burrough's/Indonesian damsel

Pomacentrus wardi	Ward's damsel
Pycnochromis caudalis	Blue-axil chromis
Pycnochromis margaritifer	Bicolor chromis
Rhinecanthus verrucosus	Blackbelly triggerfish
Rhinecanthus aculeatus	Picasso triggerfish
Scolopsis monogramma	Monogrammed monocle bream
Scolopsis bilineata	Two-lined monocle bream
Scolopsis trilineata	Three-lined monocle bream
Scarus rubroviolaceus	Redlip parrotfish IP/Ember parrotfish
Scarus perrico	Bumphead parrotfish
Scarus psittacus	Common parrotfish/Palenose parrotfish
Scarus hypselopterus	Yellow-tail parrotfish (juvenile)
Scarus tricolor	Tricolor parrotfish - IP
Scarus globiceps	Violet-lined parrotfish
Siganus vulpinus	Foxface
Siganus canaliculatus	White-spotted spinefoot
Siganus fuscescens	Mottled spinefoot
Siganus argenteus	Streamlined spinefoot (rabbitfish)
Siganus spinus	Little spinefoot
Sufflamen chrysopterus	Flagtail triggerfish/Halfmoon triggerfish
Stethojulis bandanensis	Red shoulder wrasse
Stethojulis elongatus	Razor wrasse
Stethojulis interrupta	Cutribbon wrasse - IP
Stethojulis strigiventer	Silver-streaked/three-line wrasse
Stethojulis trilineata	Three-lined rainbowfish/Fourline rasse
Sphyraena flavicauda	Yellowtail barracuda
Sphyraena barracuda	Great barracuda
Sphyraena flavicauda	Yellowtail barracuda
Pterocaesio tile	Bluestreak fusilier
Scarus russelii	Eclipse parrotfish
Scarus schlegeli	Parrot yellowbar/Yellowband parrotfish

Scarus rubroviolaceus	Redlip parrotfish IP/Ember parrotfish
Scarus perrico	Bumphead parrotfish
Scarus psittacus	Common parrotfish/Palenose parrotfish
Scarus hypselopterus	Yellow-tail parrotfish (juvenile)
Scarus tricolor	Tricolor parrotfish - IP
Scarus globiceps	Violet-lined parrotfish
Stethojulis interrupta	Cutribbon wrasse - IP
Thalassoma hardwicke	Sixbar wrasse
Thalassoma lunare	Moon/crescent wrasse
Thalassoma jansenii	White-barred wrasse/Jansen's wrasse
Upeneus tragula	Freckled goatfish
Zebrasoma scopas	Brushtail tang/Twotone tang (surgeon)
Zanclus cornutus	Moorish idol