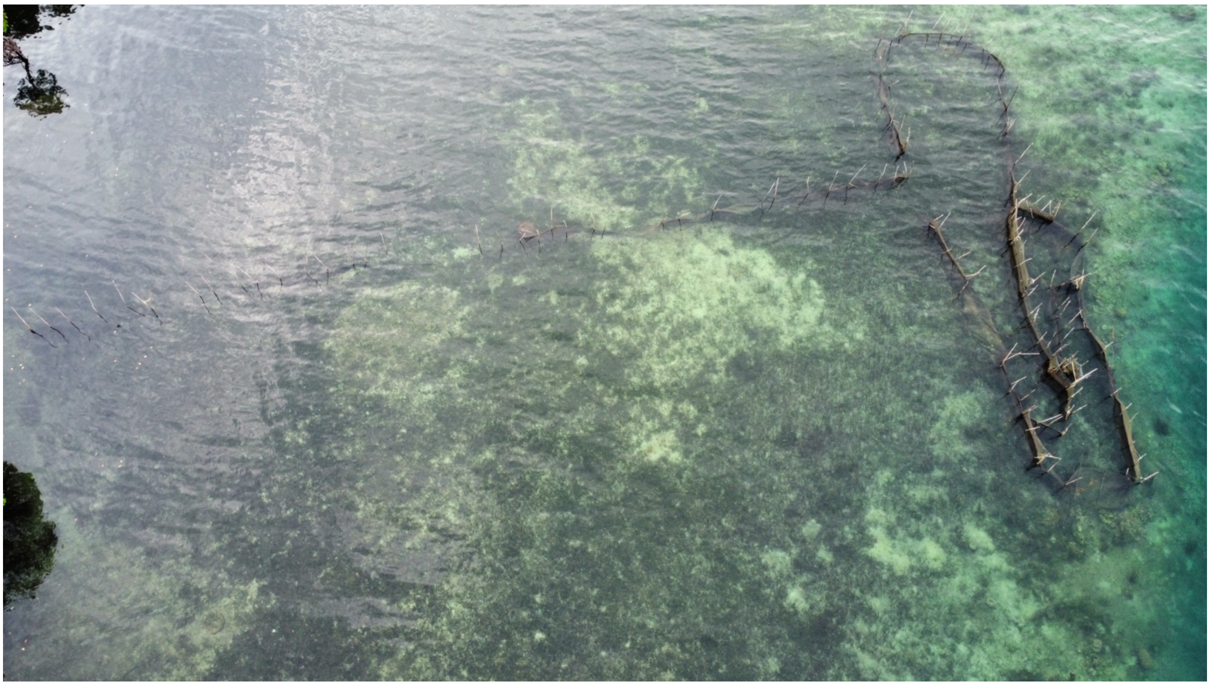
Seagrass meadows support biodiversity and people in North Minahasa, North Sulawesi, Indonesia

TECHNICAL REPORT
For the IKI Seagrass Ecosystem Services Project



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The IKI Project is a partnership between the CMS, Edith Cowan University, Project Seagrass, Seagrass Watch Ltd, Murdoch University, MRS, Blue Ventures, SAN, C3, ZSL, MareCet and Yapeka. The collaboration enhances understanding of seagrass ecosystem services and the capacity to develop and deliver science-based policy solutions in seagrass conservation. It brings together scientists, policy experts, business development experts and conservation NGOs to provide expert and independent advice on seagrass ecosystems services and how these might be relevant to policy and financial solutions to marine conservation issues. This report deals specifically with the assessment of seagrass blue carbon ecosystem services.

Seagrass meadows support biodiversity and people in North Minahasa, North Sulawesi, Indonesia

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Summary

Seagrass meadows are one of the most productive ecosystems in the sea, providing ecosystem services for the planet and its inhabitants. For the coastal communities, seagrass meadows provide a perfect habitat for fish and invertebrates which in turn play pivotal roles for the small-scale fisheries. Therefore, this project aims to provide a clear case study of the environmental, socio-ecological, and economic importance of seagrass ecosystems for coastal communities in North Minahasa, North Sulawesi, Indonesia to guide evidence-based marine protected area (MPA) management. To achieve this, the project set out to demonstrate the links between seagrass meadows, fisheries productivity, and food provision. This was achieved through a program of cooperative research, outreach, and engagement. Based on this case study, seagrass meadows give a clear example of satisfying people's needs for food and a source of income, cultural and medical value for some communities, and a perfect habitat for fish and invertebrate animals. Consequently, protecting seagrass ecosystems should become one of the priorities for coastal conservation to enhance local food security and livelihood and increase local community adaptability in facing climate change.

Introduction

Seagrass ecosystems are one of the important ecosystems in the Indo-Pacific marine environment by providing many services, both directly and indirectly, for people, marine animals, and the earth (Unsworth *et al.*, 2019). In coastal communities, seagrass ecosystems significantly contribute to local food security and livelihood (Fabinyi *et al.,* 2017), while also providing a perfect habitat for many valuable fish species as a source of local income and nutrition (Jones *et al.,* 2021). Therefore, protecting and maintaining the health of the seagrass ecosystems can enhance the local communities' prosperity and resiliency to face climate change (Unsworth *et al.,* 2022).

This project took a case study approach to understand the links between seagrass meadows and food security and was implemented in the coastal areas in North Minahasa, North Sulawesi, Indonesia. The primary study sites were in Bahoi, Bulutui, and Bahoi Villages (Figure 1). Local communities in this region are typically dependent on the marine environment for food and livelihood - including the seagrass ecosystem - as most of them are fishers.

Most of the seagrass ecosystem at the study sites is in good condition but somewhat threatened by several human activities. Common anthropogenic impacts are through gleaning, usually using less destructive methods such as hands, spears (including spear guns), and machetes. Artisanal fisheries use small boats, with or without outboard motors, utilizing hand lines, cast nets, and fixed gillnets to catch their target. Static traps are common, targeting crabs and several types of seagrass-associated fish, such as Siganidae, and Labridae. Boat scars are less evident and are not considered a significant detrimental factor. In some areas, inadequate solid waste management also contributes to the degradation of the seagrass ecosystems.

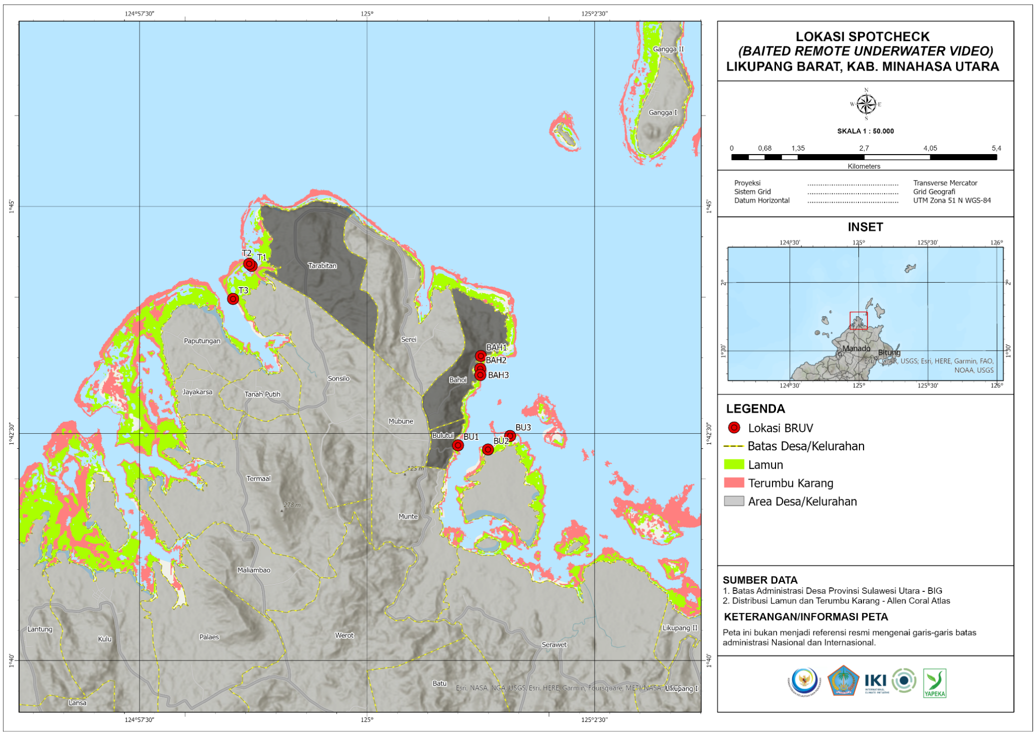

Figure 1. The primary study sites across three sites in North Minahasa, North Sulawesi, Indonesia: Bahoi, Bulutui, and Tarabitan Villages

Objectives and activities completed

1. **Knowledge transfer: stakeholder-engaged research aimed at informing strategic marine management**
    - **a.** The assessment of key seagrass ecosystem service and valuation is already assessed.
    - **b.** Policy recommendations and consultations based on SES assessment will be implemented in the last phase project in 2024.

2. **Establish contribution of seagrass fisheries to the local people and food security,** all activities were completed.
    - a. Household interviews were conducted in three sites: Bahoi, Bulutui, and Tarabitan Villages, a total of 90 respondents were interviewed.
    - b. Database compiled and available for further analysis (and use as required)
    - c. Summary statistics for the value of seagrass created.

3. **Determine species composition and seagrass habitat usage of fish assemblages,** all activities were completed**.**
    - a. Seagrass fish surveys using Baited Remote Underwater Video (BRUV) systems across three sites: Bahoi, Bulutui, Tarabitan Villages.
    - b. Rapid habitat and ecological assessment alongside BRUV surveys.
    - c. Database compiled and available for further analysis (and use as required).
    - d. Summary statistics available for key fishery species (data available for all fishery species).

Methods

To extract data from the seagrass meadow, we used Baited Remote Underwater Video (BRUV) systems at three sites (Tarabitan, Bahoi, Bulutui) to record fish abundance and richness. In total, there are 24 BRUVs per site deployed, each recording for 1 hour and 5 minutes. The extra five minutes are considered as buffer time to allow the local fauna to settle down from the BRUV camera insertion. in 2023and if we're counting the deployment from 2022, there are a total of 72 BRUVs that have been deployed.

We used oily fish (sardines) for the bait and put the bait extended on a PVC pole 1 meter in front of the camera. Between 2022 and 2023, the data collections were divided into two seasons, which are the dry season in July 2022, and the wet season in April 2023. At each sampling site, three BRUVS were placed approximately 50 meters apart.

The BRUV's videos are then analyzed to determine the MaxN of each fish species and the fish species richness; a metric commonly used for quantification of the relative abundance of fish observed in underwater videos. MaxN is equal to the maximum number of fish recorded on screen at any one time. Alongside BRUV samples, 5 quadrats plots (0.25 x 0.25 m) were randomly placed within the area to determine the total percentage cover (0-100%) and floral species composition and canopy height (cm). This was only done in 2022 due to time constraints and blast fishing at Bulutui.

To identify the importance of seagrass to people, 90 household surveys were conducted in three villages, Bahoi, Bulutui, and Tarabitan. The households were chosen randomly and the respondent was the head of the household. During surveys, households were asked multiple questions surrounding marine and coastal resource use. For example, households were asked whether they fish in seagrass and if they prefer seagrass over other habitats and why.

Results & Discussion

Summary of habitat data

Seagrass meadows in the research sites were typically characterized by eight species, including *Enhalus acoroides, Thalassia hempricii, Syringodium isoetifolium, Cymodocea rotundata, Oceana serrulata, Halophila ovalis, Halophila ovalis, Halodule pinifolia.* Seagrass meadows in Bahoi had higher species cover and richness than another site while the canopy height was the lowest. Bulutui has the highest canopy height and epiphyte cover. Meanwhile, in Tarabitan, seagrass meadows had the lowest seagrass cover, species richness, and epiphyte cover but the canopy height was higher than in Bahoi.

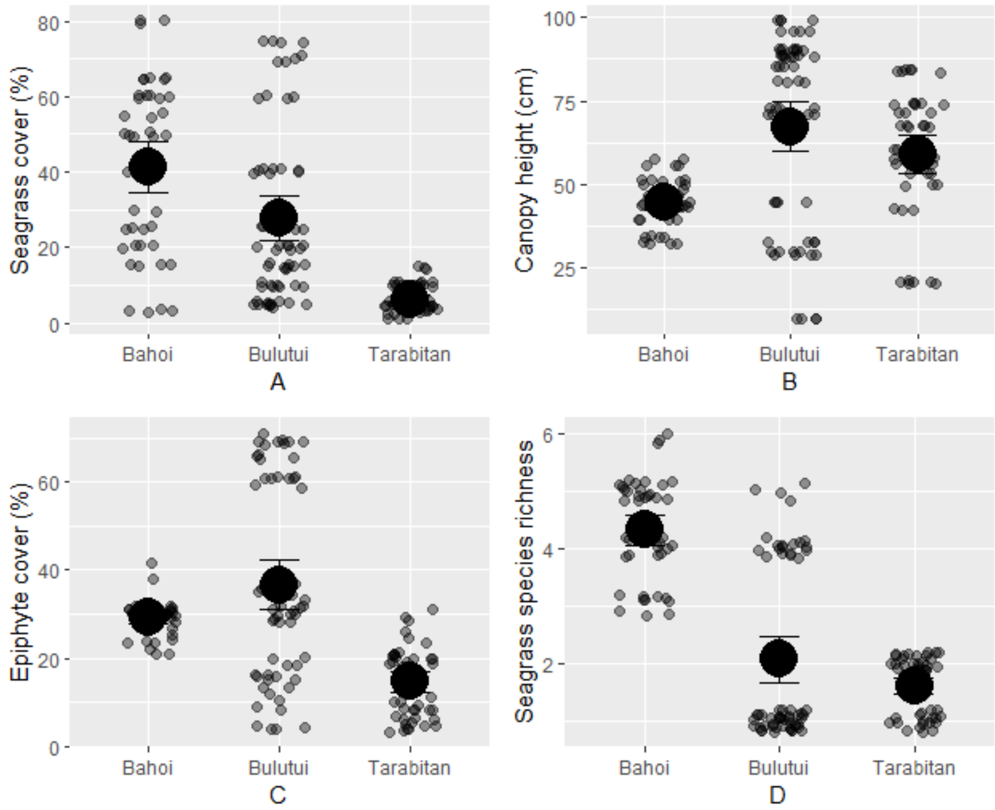

Figure 2. A) Average seagrass cover (%), B) canopy height (cm), C) epiphyte cover, and D) seagrass species richness across sites. Black points represent Mean + SE and grey points represent raw quadrat values.

Summary of seagrass-associated biodiversity

We found an average of 16.1 ± 15 fish in the dry season and 20.3 ± 24.3 fish in the wet season per 200m^2 of seagrass (*typical area covered by a BRUV*) across sites. In Figure 3, the number varied among the sites with Tarabitan having the highest average of fish abundance (32.67 ± 29.37) and species richness (10.08 ± 6.32), especially during the wet season. Overall, Bulutui had the lowest fish abundance (8.42 ± 8.22) and fish richness (4 ± 2.04). Meanwhile, during the wet season, Bahoi and Bulutui represent a greater number than in the dry season, Bulutui was the opposite.

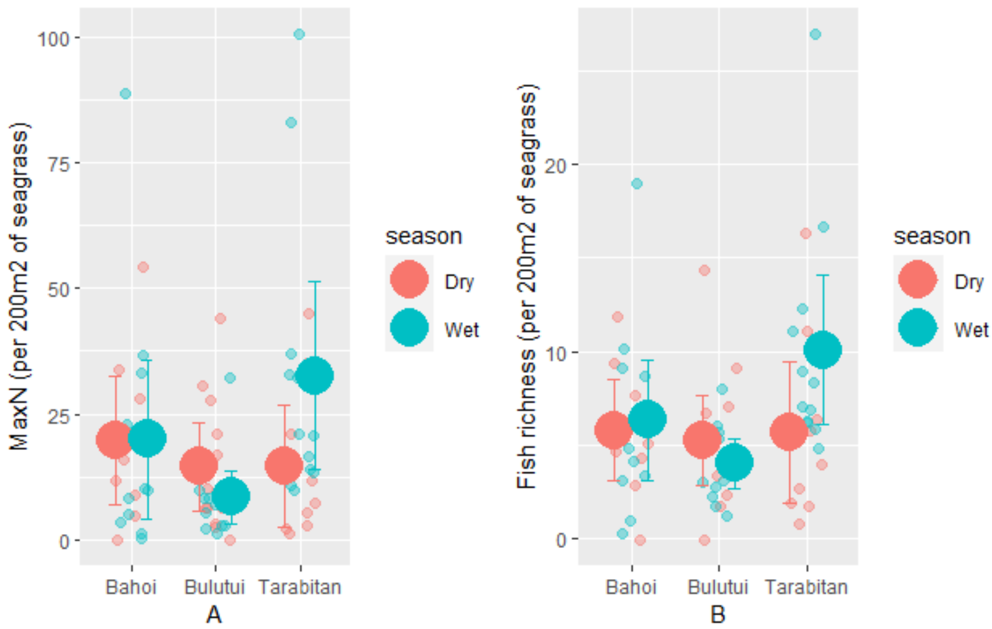

Figure 3. Graph representing A) MaxN and B) fish species richness across sites. The big circle represents the mean and the small circle represents the raw data.

The Siganidae family (Rabbitfish) has the highest fish abundance across the seagrass meadows in North Minahasa (Figure 4). Together with other important species such as Sphyraenidae (Barracuda), Lethrinidae (Emperor), Scaridae (Parrotfish), Labridae (Wrasses), and Acanthuridae (unicornfish), the Rabbitfishes are classified as important fish species for local food based on the household survey. The result confirmed that seagrass ecosystems in these areas are important for coastal communities by safeguarding their food security. Similar to the result in the Zanzibar Islands, the fish families of Siganidae, Lethrinidae, Lutjanidae, Scaridae, and Labridae contributed to 85% of fish abundance across 12 sites (Jones *et al.,* 2021).

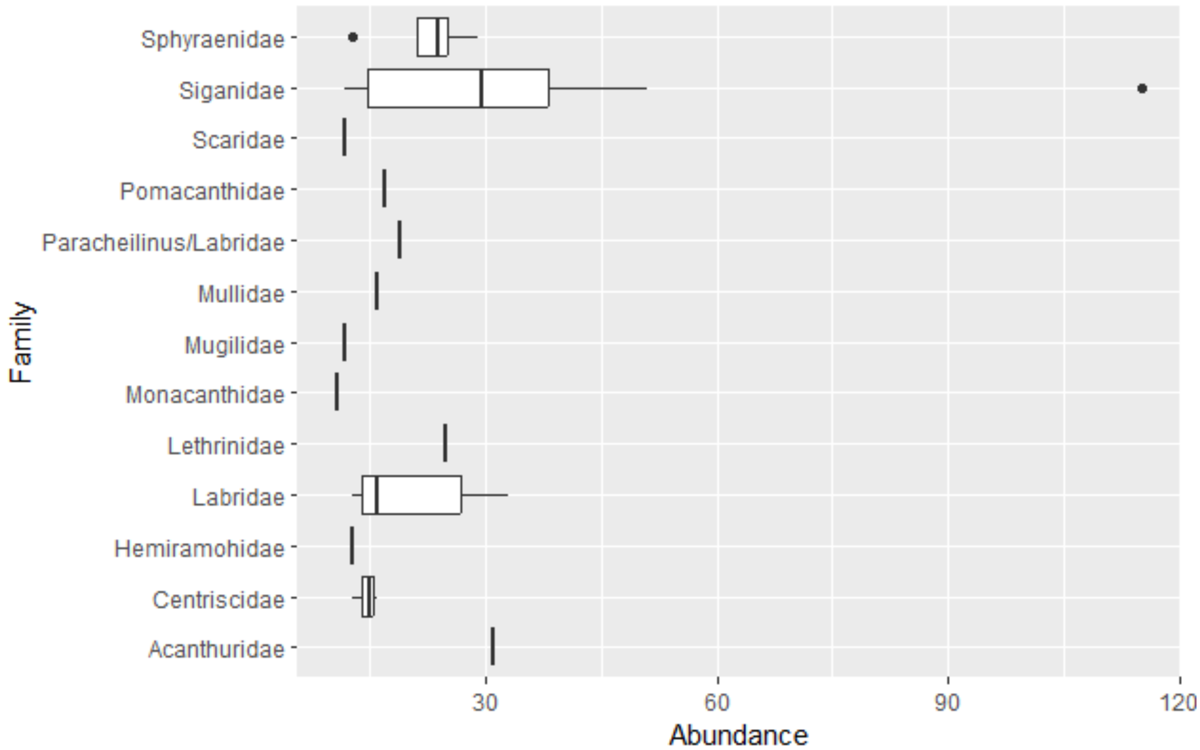

Figure 4. The dominant families were found in seagrass meadows across three sites in North Minahasa

The influence of environmental variables on fish abundance

General Linear Model (GLM) was used to understand the relationship between environmental variables (season, site, depth) to fish abundance across the sites (Table 1). We found that the depth significantly influences the fish abundance (P-value < 0.001) and the site is significantly different in Bulutui (P-value < 0.001) but not in Bahoi and Tarabitan. Therefore, we tried to predict the fish abundance across the sites as shown in Figure 5. The prediction in Figure 5A would represent the fish abundance where the BRUV cameras are placed at the same depth; while Figure 5B predicts the fish abundance when the depth increases.

It is predicted that Tarabitan will still have the highest fish abundance followed by Bahoi and Bulutui; while the fish abundance will be greater in the wet season rather than in the dry season. Furthermore, the predicted fish abundance will increase when the depth is increased which assumes that the deeper seagrass meadow is closer to the coral reef where fish are denser. Similar to research by Gullström *et al.* (2008) in seagrass meadows in Chwaka Bay, Zanzibar Island, the depth significantly influenced the adult and subadult fish densities.

Table 1. The relationship between environmental variable to fish abundance and fish richness using General Linear Model (GLM)

Relationship	Estimate	Std Error	P value
(Intercept)	2.57387	0.09476	< 2e-16 ***
seasonWet	-0.06884	0.08868	0.438
siteTarabitan	0.09778	0.07429	0.188
depth	0.35205	0.08693	5.12e-05 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’
AIC: 1324.4

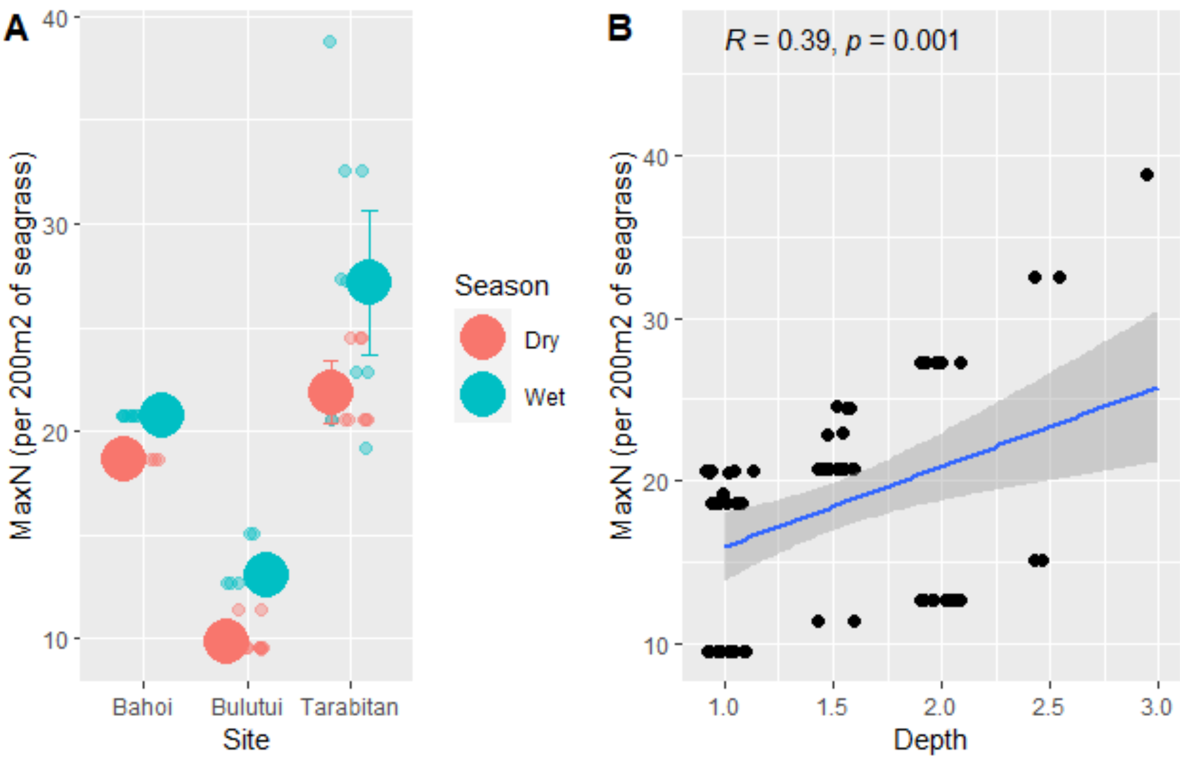

Figure 5. The prediction of fish abundance based on A) Site and B) Depth across the three sites in North Minahasa

The correlation between seagrass fish assemblage and its habitat

The General Linear Model (GLM) is used to determine the relationship between seagrass ecosystems (seagrass cover, canopy height, and epiphyte cover) to the fish abundance across the sites (Table 2). From the table, it is clearly shown that those three variables significantly influenced the fish abundance, especially in Bulutui and Tarabitan Villages. The canopy height is one of the significant predictors of fish abundance in seagrass ecosystems (Gullström *et al.,* 2008). Therefore, we tried to predict the fish abundance based on the seagrass data as shown in Figure 6. As Bahoi Village has the highest seagrass cover and moderate canopy height mean and epiphyte cover, it is predicted to have the highest fish abundance rather than Bulutui and Tarabitan.

The Principal Component Analysis (PCA) was used to determine the species distribution across the sites (Figure 7). It clearly stated that Bahoi has a high percentage of seagrass cover. *Enhalus acoroides* which are highly correlated to the cannoli height mean, are mostly distributed in Bulutui. Other species such as T*halassia hempricii, Halophila ovalis, Syringodium isoetifolium, Halodule uninervis*, and *Cymodocea rotundata* are mostly distributed in Bahoi as shown in Figure 2.

Table 2. The relationship between seagrass meadows structure to fish abundance and fish richness using General Linear Model (GLM)

Relationship	**Estimate**	**Std Error**	**P value**
Fish abundance ~ site + seagrass cover + canopy height mean + epiphyte cover AIC: 2398			
(Intercept)	3.661066	0.084153	< 2e-16 ***
site.Bulutui	-0.513142	0.056553	< 2e-16 ***
site.Tarabitan	-1.174786	0.088062	< 2e-16 ***
seagrass cover	-0.007285	0.001094	2.75e-11 ***
canopy height mean	0.011164	0.001562	8.92e-13 ***
epiphyte cover	-0.030275	0.002613	< 2e-16 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’

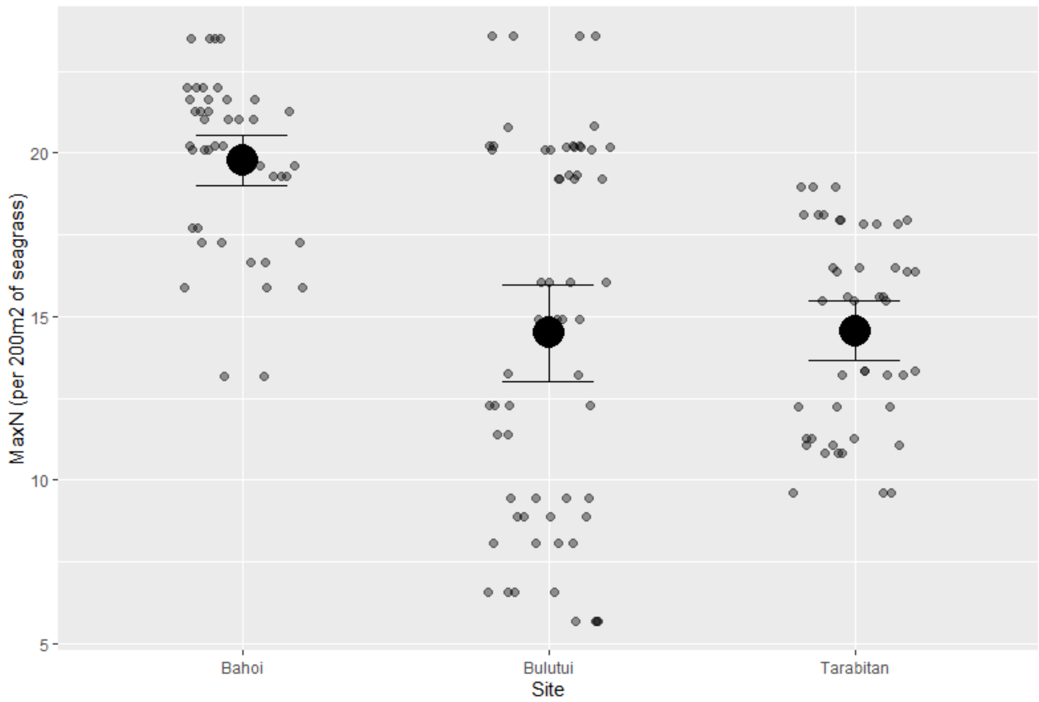

Figure 6. The prediction of fish abundance based on the seagrass ecosystems across the three sites in North Minahasa

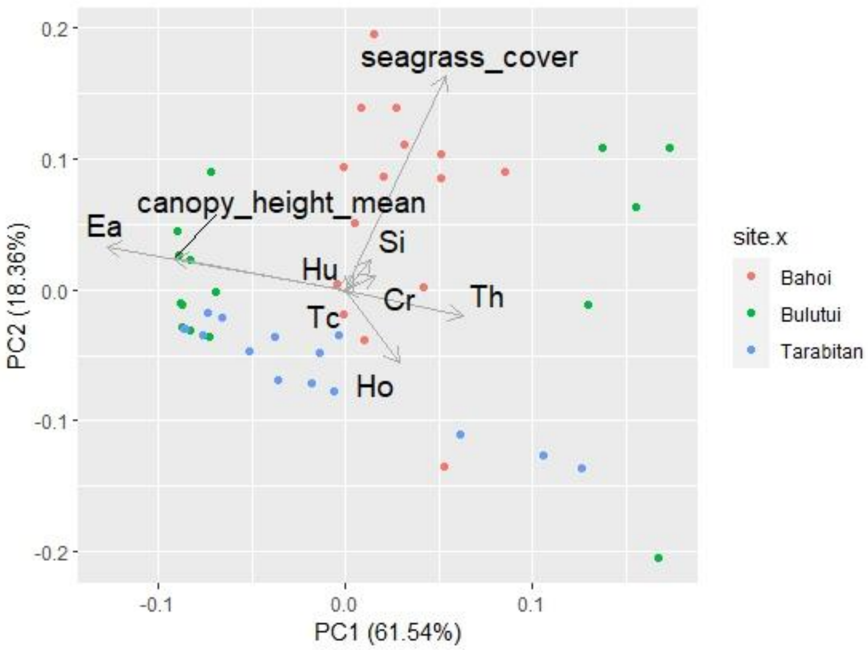

Figure 7. Ordination using Principal Component Analysis of the seagrass ecosystems in Bahoi, Bulutui, and Tarabitan Villages

Summary of social data

Across the 90 numbers of the household survey, the respondents were mostly men responsible for the household income as shown in Figure 8 The respondent's age range was wide with mostly 41-45 years old. Most respondents across the sites were fishers (61%) who took advantage of marine ecosystems (Figure 9A). However, marine and coastal resource use was most common in Bahoi, Bulutui, and Tarabitan Villages, where 64% of households engaged in activities both for food and income (Figure 9B).

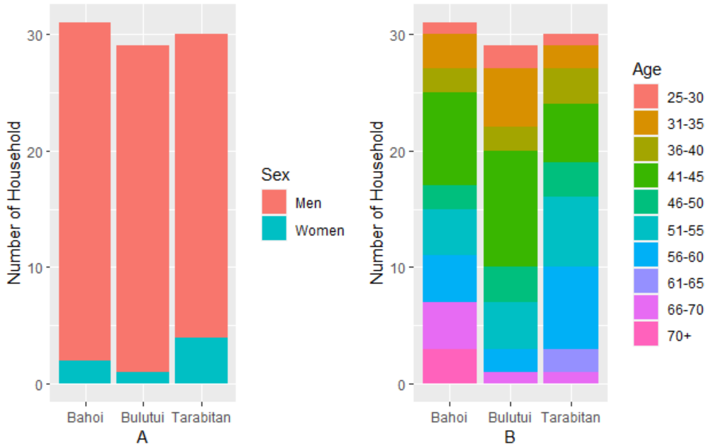

Figure 8. Bar graphs representing the A) Sex and B) Age of the household respondents (n=90)

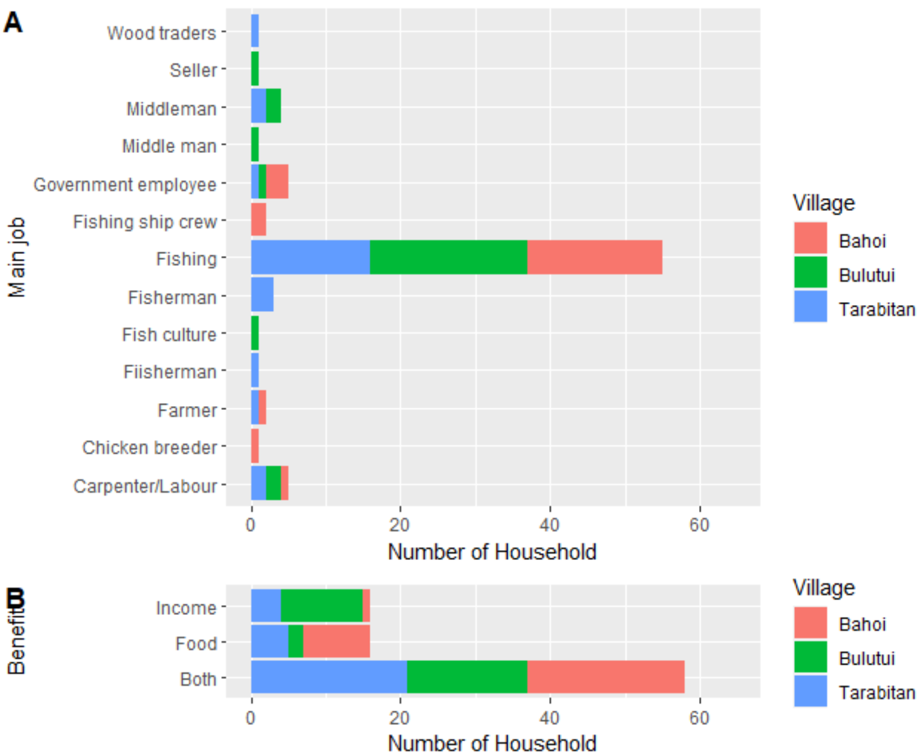

Figure 9. Bar graphs representing A) the main job and B) the benefit they took from marine ecosystems of the respondents across the site (n=90)

In each site, a mere number of household respondents preferred fishing in only seagrass habitat; however, almost half of them fishing in both seagrass and other habitat such as coral reefs, and mangroves (Figure 10). Moreover, fishing in coral reefs was more popular across the site with 36%, 53%, and 26% preferred to fishing only in coral reefs in Bahoi, Bulutui, and Tarabitan respectively. Furthermore, only a few fishers (under 5 respondents at each site) consume their catch, 9 of 30 respondents in Bulutui tended to sell their catch, and most of them both sell and consume their catch (53% in Bulutui, 37% in Bahoi, and 83% in Tarabitan).

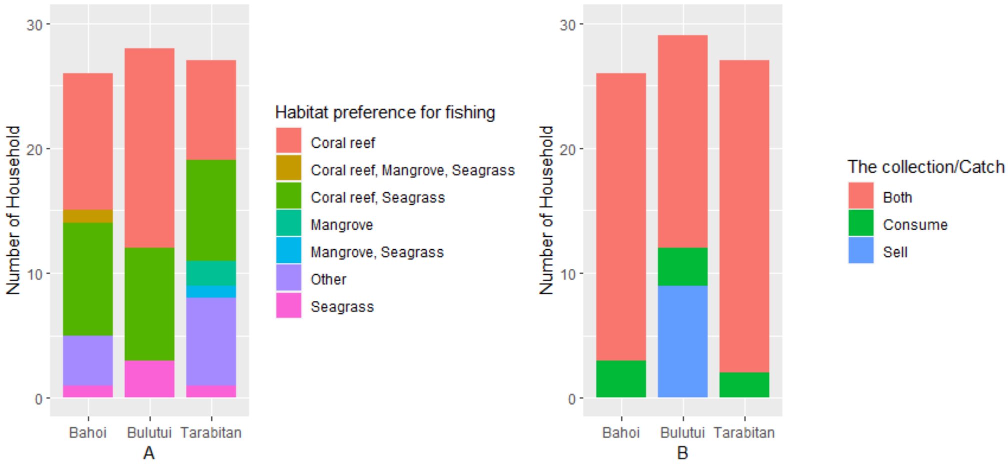

Figure 10. Bar graphs representing the number of households (n=90) that A) Habitat preference for fishing and B) What they do with their collection/catch

Figure 11 revealed that fish is the most important source of protein in Bahoi, Bulututi, and Tarabitan Village with almost 100% of the household eating fish every day or every meal. Another source of protein eaten by households across the sites was egg and meat, with egg was more frequent than meat.

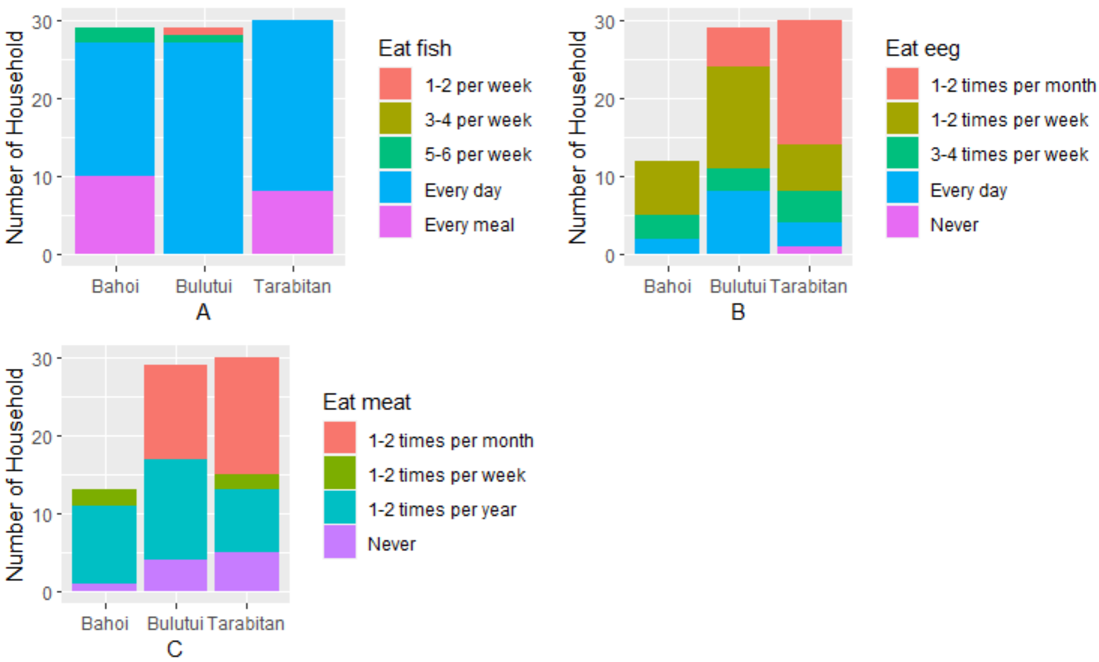

Figure 11. Bar graphs representing the number of households (n=90) who A) eat fish, B) eat egg, C) eat meat in their daily diet

Seagrass ecosystems not just provide food and a source of income for coastal communities in North Minahasa, North Sulawesi but have been used by people in Bulutui Village for medicine and cultural value (Digdo *et al.,* 2023). Based on the household surveys, we found that people in Bulutui use the *Enhalus*'s seed to medicate the body if they have a cold. Others also used the dried *Enhalus*'s leaves, boiled them, and used the steam to warm their body. The species *Enhalus acoroides* also is pivotal for Muslims in Bulutui Villages to indicate the Ramadhan seasonal opening. When the *Enhalus*'s flowers blossom, local people know that the holy Ramadhan month has started.

Using the Local Ecological Knowledge (LEK), we can find that seagrass is very important for coastal communities across the sites (Figure 12). As it provides fish for them, there is a decreasing number of fish compared to five years ago with almost 80 respondents agreeing with this statement. More than half of the respondents understand that overfishing could be the reason for the loss of fish communities. Furthermore, some existing activities on seagrass ecosystems such as gleaning have less impact on the seagrass and its animals' assemblages. Even though, almost all the respondents (98%) realize that damaging the marine environment will bring difficulties for their lives in the future.

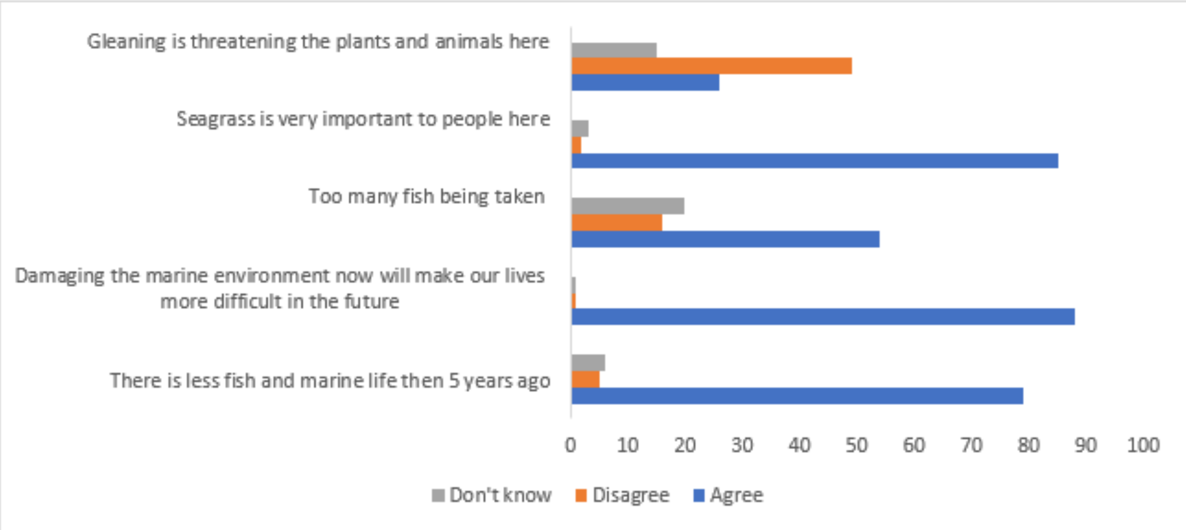

Figure 12. Local community's perception of seagrass ecosystems across the three sites (n=90).

Combining evidence from both ecological and social surveys we can provide evidence that seagrass meadows in North Sulawesi are important for biodiversity and people. These findings correlate well with others across the globe based on the study by Cullen-Unsworth et al. (2014) which showed that understanding the coupled socio-ecological systems could be crucial to increasing the coastal community's resilience towards environmental change.

Conclusions, remaining evidence and management gaps

Seagrass ecosystems give a clear example of how socioeconomic and ecological systems are correlated. Local communities are the marginal people who are threatened by climate change and a healthy seagrass ecosystem might enhance their resiliency in facing climate change. Therefore, coastal conservation should include seagrass meadows as one of the key habitats alongside the coral reefs and mangroves to enhance the protection of biodiversity and strengthen food security and livelihood. Community seagrass conservation action plans are required to force the stakeholders, governments, and policymakers to put the seagrass ecosystems in their management framework which is supported by national policy and legislation.

Reference

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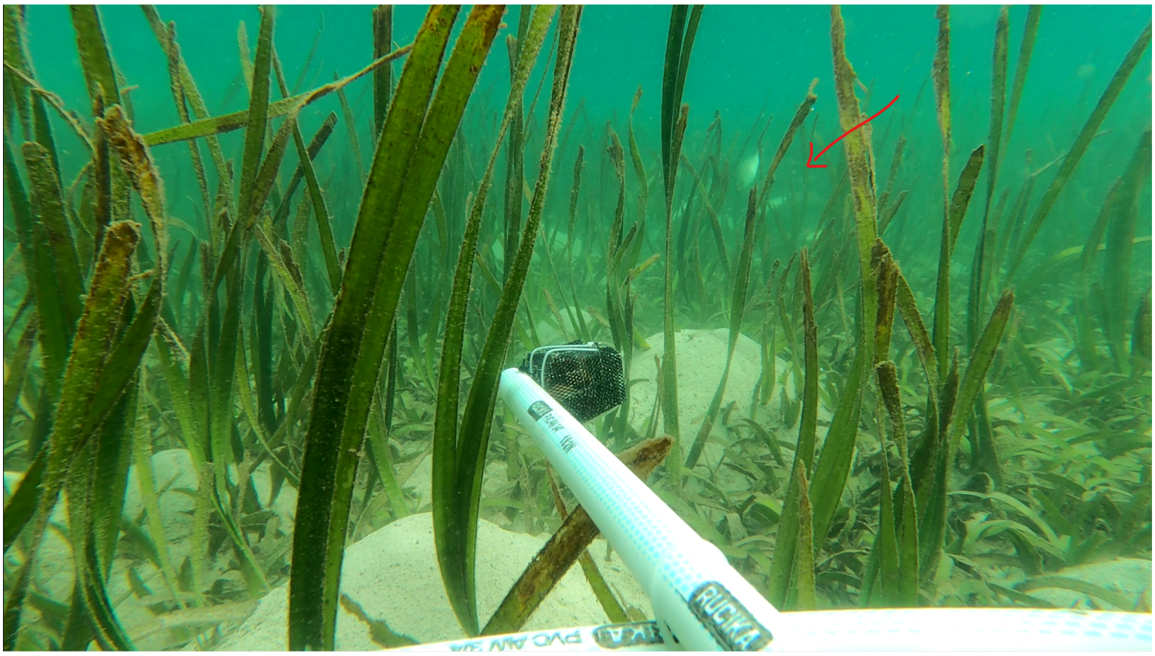
Appendices



Appendix 1. School of *Siganus argenteus* (Forktail Rabbitfish) in Tarabitan's seagrass meadows


Appendix 2. a *Pseudocaranx dentex* (White trevally) in Tarabitan's seagrass meadows

Appendix 3. Ten highest fish species were found both in dry and wet seasons across three sites.

Tarabitan Dry Season

Family	Species	Common name	MaxN per Sp
Pomacanthidae	*Dischistodus chrysopoecilus*	White-spot damsel	17
Centriscidae	*Aeoliscus strigatus*	Razorfish	13
Scaridae	*Calotomus spinidens*	Spinytooth parrotfish	12
Monacanthidae	*Acreichthys tomentosus*	Bristle-tail file-fish	11
Siganidae	*Sphyraena obtusata*	Yellowtail Barracuda	9
Labridae	*Cheilio inermis*	Cigar Wrasse	8
Mullidae	*Upeneus tragula*	Freckled goatfish	8
Ptereleoidae	*Siganus canaliculatus*	White-spotted spinefoot	7
Apogonidae	*Apogon endekataenia*	Candystripe cardinalfish	5
Apogonidae	*Ostorhinchus angustatus*	Broadstriped cardinalfish	4

Tarabitan Wet Season

Family	Species	Common name	MaxN per Sp
Siganidae	*Siganus argenteus*	Forktail Rabbitfish	115
Siganidae	*Siganus fuscescens*	Mottled spinefoot	34
Acanthuridae	*Naso thynnoides*	Oneknife unicornfish	31
Sphyraenidae	*Sphyraena obtusata*	Yellowtail Barracuda	29
Mullidae	*Parupeneus barberinus*	Dash-and-dot goatfish	16
Centriscidae	*Aeoliscus strigatus*	Razorfish	15
Siganidae	*Siganus spinus*	Little spinefoot	15
Labridae	*Cheilio inermis*	Cigar Wrasse	13
Monacanthidae	*Paramonacanthus japonicus*	Hairfinned leatherjacket	11
Aulostomidae	*Aulostomus chinensis*	Chinese trumpetfish	10

Bahoi Dry Season

Family	Species	Common name	MaxN per Sp
Siganidae	*Siganus margaritiferus*	Pearly-spotted rabbitfish	51
Sphyraenidae	*Sphyraena flavicauda*	Yellow-tail Barracuda	24
Labridae	*Cheilio inermis*	Cigar Wrasse	14
Hemiramohidae	*Zenarchopterus rasori*	short garfish	13
Siganidae	*Siganus argenteus*	Forktail Rabbitfish	12
Monachantidae	*Acreichthys tomentosus*	Bristle tailed filefisf	8
Carangidae	*Carangoides orthogrammus*	Yellow-spotted trevally	6
Mungilidae	*Liza vaigiensis*	diamond-scale mullet	6
Hybrids	*Halichoeres melinochir*	orange-fin wrasse	5
Pinguipedidae	*Parapercis cylindrica*	Sharpnose sandperch	5

Bahoi Wet Season

Family	Species	Common name	MaxN per Sp
Labridae	*Cheilio inermis*	Cigar Wrasse	33
Siganidae	*Siganus argenteus*	Forktail Rabbitfish	29
Labridae	*Pseudodax mollucanus*	Chiseltooth Wrasse	27
Centriscidae	*Aeoliscus striganus*	Razorfish	16
Labridae	*Halichoeres cloropterus*	Pastel-Green wrasse	16
Sphyraenidae	*Sphyraena obtusata*	Yellowtail Barracuda	13
Lethrinidae	*Lethrinus harak*	Thumbprint emperor	7
Labridae	*Novaculichtys taeniourus*	Rockmover Wrasse	6
Labridae	*Anampses melanurus*	White-spotted wrasse	6
Labridae	*Halichoeres pallidus*	Pale Wrasse	6

Bulutui Dry Season

Family	SpeciesLatin	SpeciesCommon	MaxN per Sp
Siganidae	Siganus argenteus	Forktail rabbitfish	30
Sphyraenidae	Sphyraena flavicauda	Yellotail Barracuda	24
Siganidae	Siganus margaritiferus	Pearly-spotted rabbitfish	14
Mugilidae	Crenimugil crenilabis	Fringelip Mullet	12
Mugilidae	Neomyxus leuciscus	Acute-jawed mullet	7
Labridae	Cheilio inermis	Cigar Wrasse	7
Gerreidae	Gerres argyreus	Black-tip silverbelly	5
Mugilidae	Liza vaigiensis	Diamond-scale mullet	5
Scaridae	Scarus psittacus	Palenose parrotfish	5
Lethrinidae	Lethrinus harak	Black-blotch Emperor	4

Bulutui Wet Season

Family	SpeciesLatin	SpeciesCommon	MaxN per Sp
Lethrinidae	*Lethrinus harak*	Black-blotch Emperor	25
Labridae	*Cheilio inermis*	Cigar Wrasse	19
Monacanthidae	*Acreichthys tomentosus*	Bristle-tail filefish	10
Labridae	*Thalassoma hardwicke*	Six-barred wrasse	6
Pomacentridae	*Amblyglyphidodon ternatensis*	Ternate Damsel	5
Pomacentridae	*Pomacentrus smithi*	Smith's damsel	4
Chaetodontidae	*Chaetodon lunulatus*	Redfin Butterflyfish	3
Mullidae	*Parupeneus barberinus*	Dash-dot Goatfish	3
Labridae	*Halichoeres melanochir*	Orange-fin Wrasse	2
Pomacentridae	*Amblyglyphidodon sp 1*	Yellow-lip Sergeant	2