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Coral reef and seagrass ecosystem health assessment in Tiaro (LMMA), West Guadalcanal, Solomon Islands

Penilaian kesehatan ekosistem terumbu karang dan padang lamun di Tiaro (LMMA), Guadalcanal Barat, Kepulauan Solomon

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Abstract.

Coral reefs, seagrass meadows and associated fish communities are essential coastal ecosystems that provide significant ecological and economic benefits. However, these habitats are increasingly threatened by anthropogenic activities and climate change. This study assessed coral cover, reef fish composition and abundance and seagrass distribution in the Tiaro Locally Managed Marine Area (LMMA), Solomon Islands, to evaluate ecosystem health and conservation effectiveness. Ecological surveys at eleven sites revealed variable coral cover, ranging from 26% to 52%, with bleaching and disease most prevalent at Kotatave (11%) and Kokomu (10%). Herbivorous fish, particularly Pomacentridae and Acanthuridae, dominated the fish assemblages, while predatory species were scarce, suggesting trophic imbalance. Seagrass coverage varied across sites, with *Cymodocea rotundata* being the most dominant species, especially at Leleona (72% coverage). The findings highlight the interdependence of coral, seagrass and fish communities and emphasize the need for integrated, community-based conservation strategies to enhance ecosystem resilience.

Keywords: community-based management, coral reef health, herbivorous fish, seagrass distribution, Tiaro LMMA

Abstrak.

Terumbu karang, padang lamun, dan komunitas ikan yang terkait merupakan ekosistem pesisir yang penting karena memberikan manfaat ekologis dan ekonomi yang signifikan. Namun, ekosistem ini semakin terancam oleh aktivitas antropogenik dan perubahan iklim. Penelitian ini mengevaluasi tutupan karang, komposisi dan kelimpahan ikan karang, serta distribusi lamun di Tiaro Locally Managed Marine Area (LMMA), Kepulauan Solomon, untuk menilai kondisi ekosistem dan efektivitas konservasi. Survei ekologi di sebelas lokasi menunjukkan variasi tutupan karang antara 26% hingga 52%, dengan pemutihan dan penyakit karang paling tinggi terjadi di Kotatave (11%) dan Kokomu (10%). Komunitas ikan didominasi oleh jenis herbivora, khususnya famili Pomacentridae dan Acanthuridae, sementara ikan predator jarang ditemukan, yang mengindikasikan ketidakseimbangan trofik. Tutupan lamun bervariasi antar lokasi, dengan Cymodocea rotundata sebagai spesies yang paling dominan, terutama di Leleona dengan tutupan mencapai 72%. Temuan ini menekankan adanya keterkaitan antara terumbu karang, lamun, dan komunitas ikan, serta pentingnya pendekatan konservasi berbasis masyarakat secara terpadu untuk meningkatkan ketahanan ekosistem.

Kata kunci: distribusi lamun, ikan herbivora, kesehatan karang, pengelolaan berbasis masyarakat, Tiaro LMMA

1. INTRODUCTION

Coral reefs, seagrass meadows and associated fish communities are vital in coastal ecosystems that provide several ecological and economic benefits, including biodiversity, carbon sequestration, coastal protection and fisheries production (Hoegh-Guldberg *et al.* 2009; Unsworth *et al.* 2018; Pendleton *et al.* 2019; Cavada-Blanco *et al.* 2021). Ecologically coral reefs serve as critical habitats for many marine organisms, offering shelter and food, whereas seagrass meadows play roles as

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breeding and nursery grounds for various fish, turtles, mammals and invertebrates, stabilizing sediments and enhancing carbon storage (Duarte *et al.* 2010; Unsworth *et al.* 2012; East *et al.* 2023; Lima *et al.* 2023).

The carbon sequestration potential of seagrass meadows has been widely recognized as an essential ecological function in mitigating global climate change (Serrano *et al.* 2021). Recent studies in Indonesia have shown that seagrass beds store significant amounts of carbon, making them a significant key component of climate resilience strategies in the country (Rahman *et al.* 2023). Despite their ecological importance, these two ecosystems face severe threats from human activities such as overfishing, coastal development and pollution, along with environmental stressors like coral bleaching and seagrass degradation (Waycott *et al.* 2009; Hughes *et al.* 2017). In the Pacific region, including the Solomon Islands, seagrass is experiencing significant degradation due to anthropogenic pressures such as pollution, coastal development and climate change (Brodie and N'Yeurt 2018). The decline of seagrass meadows could have extensive consequences, including the loss of essential fish habitats and the disruption of food webs, further emphasizing the need for immediate conservation measures (Waycott *et al.* 2009; Wawo *et al.* 2014; Unsworth *et al.* 2018).

Given these challenges, regular ecological assessments are essential and priority to track changes in marine ecosystem health and develop sustainable management strategies (Oliver *et al.* 2020; Wang *et al.* 2023). The economic valuation of seagrass ecosystems has also been proposed as a way to emphasize their ecological importance in coastal and marine management policies (Wawo *et al.* 2014; Wahyudin *et al.* 2018). By assigning a monetary value to seagrass ecosystem services, conservation efforts can be prioritized in marine protected areas where ecosystem degradation poses significant threats to the existence of biodiversity and local livelihoods (Wawo *et al.* 2014; Arkema *et al.* 2017).

Like other regions dealing with growing environmental pressures such as Indonesia, where overfishing and climate change threaten coastal ecosystems, the Pacific region faces similar challenges. Rising sea temperatures, ocean acidification and unsustainable fishing practices are putting marine biodiversity and local economies at risk (Bell *et al.* 2018; Bindoff *et al.* 2019). To address these concerns, many communities in the Pacific have adopted Locally Managed Marine Areas (LMMAs) as a way to protect their marine resources. LMMAs are community-led initiatives that give local people like fishers and coastal residents, a direct role in managing the ocean areas they depend on (Govan 2009).

These initiatives typically involve no-take zones, seasonal fishing bans, and habitat restoration to support marine biodiversity and long-term ecosystem resilience (Govan *et al.* 2008; Jupiter *et al.* 2014). One example is the Tiaro Locally Managed Marine Area (LMMA), established in 2012. This project focuses on protecting coral reefs, reef fish and seagrass meadows (Jupiter *et al.* 2014). Like other LMMAs in the Pacific, its success depends on regular ecological monitoring to track changes in the environment and adjust strategies as needed (Govan *et al.* 2008). Ongoing assessments are crucial—not only for collecting data to inform decision-making but also to keep conservation efforts aligned with the changing environment and the needs of local communities (Olsson *et al.* 2004; Tuda *et al.* 2019). By regularly monitoring both ecological and social conditions, LMMAs can adapt to new challenges while ensuring that conservation remains a collaborative and effective process. This community-centered approach highlights how local action can play a key role in preserving marine ecosystems for future generations.

Despite the recognized significance of Tiaro LMMA, recent scientific data on the status of its coral reefs, reef fish populations and seagrass meadows remain limited. Previous studies in Indonesia have shown that community-based management can be effective in maintaining the ecological health of seagrass meadows (Wahyudin *et al.* 2018) and coral reef ecosystems (Govan 2009; Jupiter *et al.* 2014). However, such efforts require a strong foundation of scientific assessments and adaptive conservation strategies (Arkema *et al.* 2017; Pelletier 2020). Given the dynamic nature of marine ecosystems and increasing anthropogenic pressures, an updated assessment is necessary to evaluate the success of conservation measures and guide future management efforts (Oliver *et al.* 2020; Wang *et al.* 2023).

Coral coverage is a key indicator of reef health, as declines in coral cover often signal degradation in coral reef ecosystem (Bellwood *et al.* 2004; De'ath *et al.* 2012). Similarly, reef fish composition and abundance reflect biodiversity and trophic dynamics, despite the fact seagrass coverage provides insights into habitat stability and carbon sequestration potential (Unsworth *et al.* 2015; Robinson *et al.* 2023). In Indonesia, various studies have demonstrated that the presence of seagrass meadows contributes to ecosystem resilience, providing a buffer against coastal erosion and supporting local fisheries productivity (Wawo *et al.* 2014; Syukur *et al.* 2017).

This study aims to assess coral coverage, reef fish abundance and composition, and seagrass distribution at eleven sites within Tiaro LMMA. Site selection was based on ecological significance, accessibility and relevance to ongoing conservation initiatives. Using standardized ecological assessment techniques, including underwater video transects and quadrat-based surveys, this study provides a comprehensive evaluation of ecosystem conditions. The findings offer a scientific basis for enhancing conservation efforts, expanding community engagement in marine protection and improving resource management strategies within Tiaro LMMA.

2. METHODOLOGY

2.1. Location and time of study

This study was conducted in Tiaro Bay, Solomon Islands, from September to October 2024 within the Tiaro Locally Managed Marine Area (LMMA). Site selection was based on ecological significance, accessibility and relevance to ongoing conservation efforts, determined through consultations with Tiaro community chiefs, the LMMA committee and the Solomon Islands National Fisheries. Eleven sites were surveyed, comprising eight locations for coral reef and fish assessments and three locations for seagrass evaluations. Data analysis and interpretation were conducted at the Faculty of Fisheries and Marine Science, IPB University, Bogor, Indonesia. **Figure 1** shows the spatial distribution of the research area and sampling site.

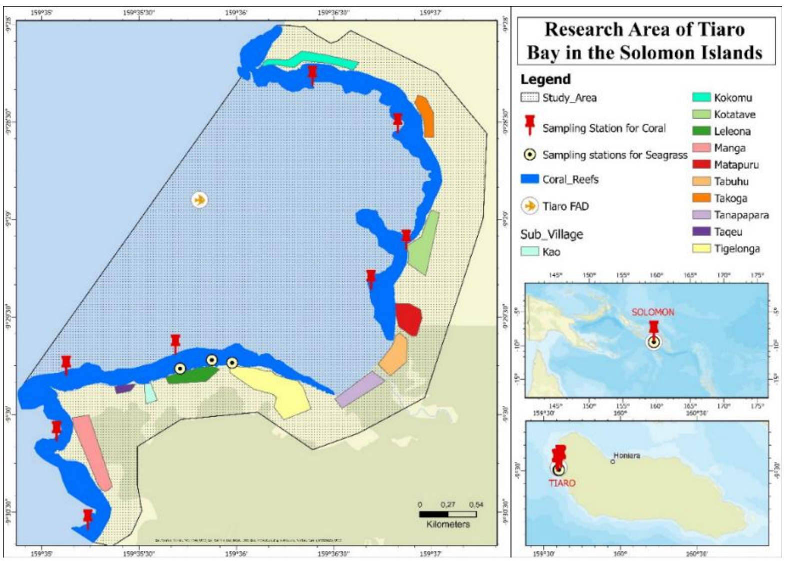

Figure 1. Map of research area and sampling site in Tiaro Locally-Managed Marine Area.

2.2. Data collection and analysis procedures

The research employed a combination of standardized ecological assessment techniques, including the Video Line Transect (VLT) method for coral and fish assessments and the Photo Line Transect (PLT) method in conjunction with quadrat-based surveys for seagrass evaluations. Video Line Transects (VLTs) were chosen to survey large coral reef areas efficiently while reducing diver bias and providing a permanent visual record for future verification (Wartenberg and Booth 2015). The photo Line Transect (PLT) method combined with quadrat sampling was chosen to capture detailed images for accurate species identification and density measurements of seagrass meadows. This approach follows established monitoring protocols to ensure consistent and reliable data collection (McKenzie 2003). Together, these methods support the study's goal of gathering precise and objective ecological data across diverse marine habitats. To conduct the surveys, a set of essential tools was utilized, including snorkel gear, an underwater camera for video documentation, a GPS device for accurate site mapping, a 25-meter measuring tape for transect establishment, waterproof paper for field recordings and $1m^2$ quadrats for seagrass sampling. This combination of methods and equipment allowed for thorough ecological assessments while maintaining consistency and accuracy across all survey sites.

For coral and fish assessments, data collection followed the Video Line Transect (VLT) method, which was adapted from Safuan *et al.* (2015). At each site, a 25-meter transect line was deployed along the substrate, positioned perpendicular to the shoreline to capture variations in benthic cover. A diver equipped with snorkel gear recorded continuous video footage along the transect while maintaining a consistent depth from the substrate. Each site was surveyed using three replicate transects, with a 20-meter separation between them. In total, 24 transects were surveyed across the eight designated coral reef sites.

Seagrass assessments were conducted using a combination of the Photo Line Transect (PLT) method and quadrat-based sampling, modified from McKenzie and Yoshida (2009). A 25-meter transect line was placed perpendicular to the shoreline in each seagrass meadow site. Along each transect, quadrats measuring $1m^2$ were positioned at 5-meter intervals, alternating along both sides of the transect line. Within each quadrat, high-resolution vertical-angle photographs were taken to ensure comprehensive visual documentation of the seagrass cover. Seagrass species, including *Enhalus acoroides*, *Thalassia hemprichii* and *Cymodocea rotundata*, were identified using the Seagrass-Watch Rapid Assessment & Mapping Manual (McKenzie 2003) and the Solomon Islands Marine Assessment Guide (Green *et al.* 2006). Additional leaf and root samples were collected and preserved for further verification at the Faculty of Fisheries and Marine Science, IPB University.

Following data collection, coral reef and fish analyses were conducted using Coral Point Count with Excel extensions (CPCe) software (Kohler and Gill 2006). The recorded video footage was processed at the Faculty of Fisheries and Marine Science, where still images were systematically extracted at 0.5-meter intervals along each transect, generating a total of 50 frames per transect. Given that each study site consisted of three transects, a total of 150 still frames were analyzed per site, resulting in 1,200 frames across all sites. Coral coverage was classified into distinct substrate categories, including Acropora coral, non-Acropora coral, algae, sand and abiotic elements, following the classification system of English *et al.* (1997). Coral health was further evaluated using established classification frameworks, including those of Gomez and Yap (1988) and Hill and Wilkinson (2004), to assess live coral cover and bleaching incidence. This classification standard is presented in **Table 1**.

Table 1. Standard criteria for assessing coral health following Gomez and Yap (1988).

Condition	Percentage
Poor	0–24.9%
Fair	25–49.9%
Good	50–74.9%
Excellent	75–100%

Fish community structure was analyzed based on species composition and abundance, following the identification guide of Allen (2010) and the classification system of English *et al.* (1997). Fish species were categorized into three functional groups: target fish, which are commonly harvested in fisheries and serve as indicators of fishing pressure (e.g., parrotfish, surgeonfish, coral trout and blacktip sharks); indicator fish, which are sensitive to environmental disturbances and provide insights into reef health (e.g., butterflyfish and angelfish); and major fish, which form the dominant reef-associated fish biomass (e.g., damselfish, wrasse, blennies and triggerfish).

Seagrass cover analysis was conducted using percent cover photo standards, following the methodology outlined by McKenzie (2003). The percentage cover of each seagrass species within each quadrat was estimated based on visual calibration sheets. The total site area occupied by each species was calculated using spatial mapping techniques with GIS-based tools (ArcGIS, Esri 2020) and Coral Atlas (Allen Coral Atlas, n.d.). The seagrass condition at each site was assessed based on Fortes (1990) classification criteria, which categorize seagrass health according to coverage percentage, as shown in **Table 2**.

Table 2. Criteria of the seagrass beds condition in accordance with Fortes (1990).

Condition	Criteria (% Cover)
Excellent	76-100
Good	51-75
Fair	26-50
Poor	0-25

Environmental conditions varied across the study area, with water depth along transects ranging from 1.5 meters to over 5 meters, depending on site characteristics. The analysis framework incorporated three key ecological indicators: coral reef health, measured by live coral coverage and disease prevalence; fish abundance, evaluated through species composition and density per square meter; and seagrass habitat stability, determined by species-specific coverage percentages and overall site-wide mapping.

3. RESULTS AND DISCUSSION

3.1. Coral coverage and condition

The coral coverage across study sites exhibited significant variation, with Suvatara having the highest coral cover at 52%, while Takoqa recorded the lowest at 26%. Sites such as Kokomu, Tatsau and Tavutu displayed moderate coral coverage, ranging from 36% to 37%, with relatively low variability. Conversely, Suvatara and Kotatave had higher standard deviations, indicating considerable spatial variation in coral cover. These findings suggest that while some areas within the Tiaro LMMA maintain moderate to high coral cover, others exhibit substantial degradation (**Figure 2**).

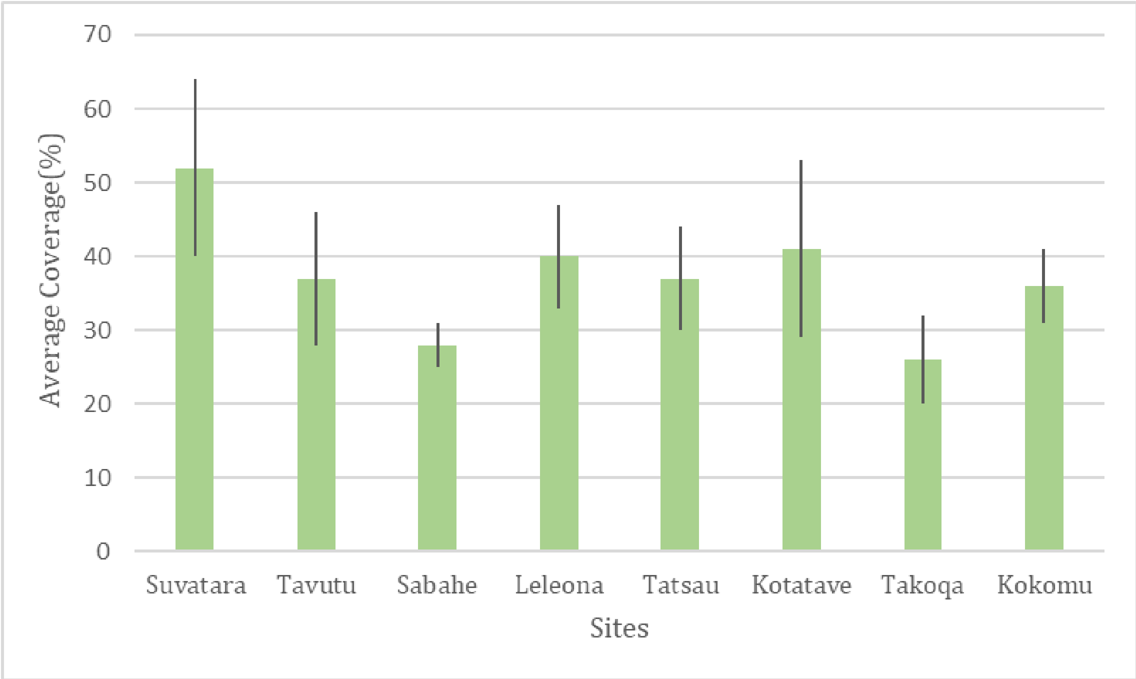

Figure 2. The condition of coral coverage in Tiaro Locally-Managed Marine Area, West Guadalcanal – Solomon Islands.

The highest coral bleaching and disease prevalence were found at Kotatave (11% ± 4) and Kokomu (10% ± 3), as seen in **Figure 3**. The condition indicated environmental stress, probably due to sedimentation, poor water quality and elevated sea surface temperatures (Harvell *et al.* 2007; Baker *et al.* 2008; Hughes *et al.* 2017). Previous studies have demonstrated that coral degradation is strongly linked to pollution, diseases, overexploitation and climate change, as reviewed by Najeeb *et al.* (2025). Similarly, Hughes *et al.* (2003) highlighted that climate-induced coral bleaching, coupled with anthropogenic stressors such as coastal development and sedimentation, significantly reduces reef resilience.

Increased sedimentation from terrestrial runoff could influence coral growth, lower recruitment rates and disturb reef ecosystem dynamics (Rogers 1990; Wenger *et al.* 2020; Tuttle and Donahue 2022). These findings align with broader studies that stress the vulnerability of coral reef ecosystems to human-induced stressors, as found by Burke *et al.* (2002), Hoegh-Guldberg *et al.* (2007) and De'ath *et al.* (2012), strengthening the imperative need for comprehensive conservation strategies in the Tiaro LMMA (Fabricius 2005; Carilli *et al.* 2009; Denley *et al.* 2020).

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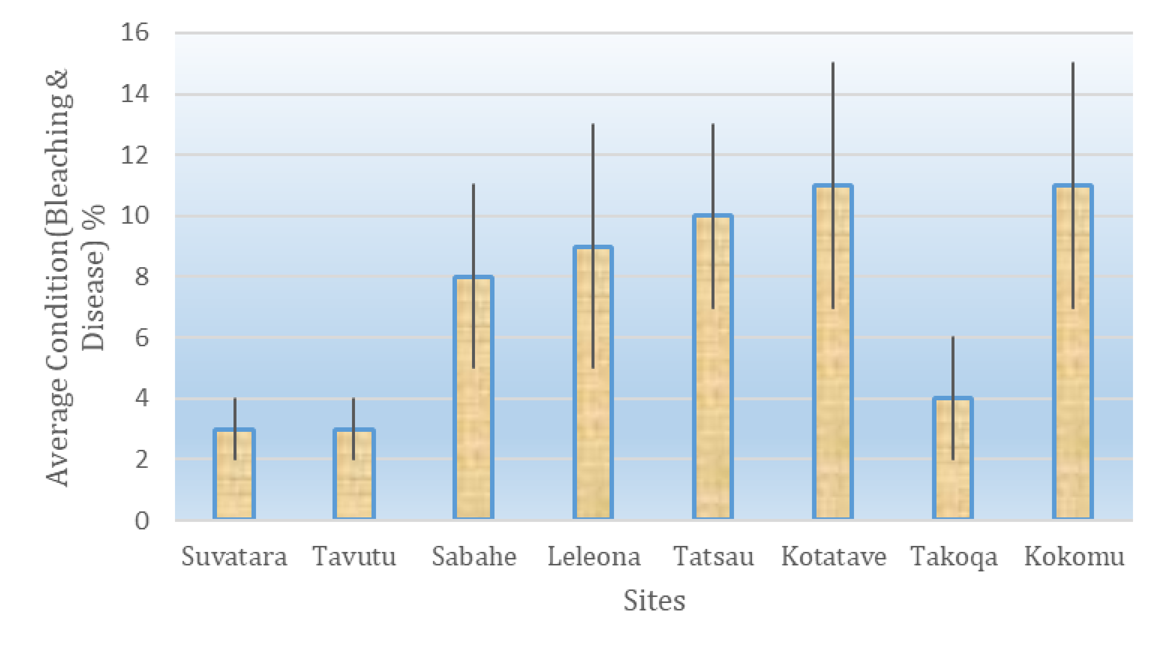

Figure 3. The average condition of coral bleaching and disease prevalence in Tiaro Locally-Managed Marine Area, West Guadalcanal – Solomon Islands.

The decline in coral cover at Takoqa, which is located near human settlements, may be attributed to increased boating activities, sedimentation and/or land-based pollution. Research has shown that human activities increase turbidity levels, limiting photosynthesis in coral ecosystems and affecting the growth of coral (Burke *et al.* 2002; Hughes *et al.* 2003; Fabricius 2005; De'ath *et al.* 2012). Furthermore, the coral reef at Kotatave, situated near a river mouth, may be experiencing higher sedimentation levels, further exacerbating bleaching susceptibility (Rogers 1990; Wenger *et al.* 2020; Tuttle and Donahue 2022). Many research findings proved that increased sedimentation could smother corals, lower larval recruitment and shift competitive dynamics between coral and macroalgae (Baker *et al.* 2008; Carilli *et al.* 2009; Hughes *et al.* 2017). These findings emphasize the need for enhanced conservation measures, particularly in the study areas which are vulnerable to runoff and anthropogenic disturbances (Denley *et al.* 2020; Tuttle and Donahue 2022).

3.2. Fish composition and abundance

The dominant fish families recorded in the study sites were Pomacentridae (Damselfish) with 850 individuals, Acanthuridae (Surgeonfish) with 394 individuals and Scaridae (Parrotfish) with 148 individuals (**Figure 4**). Other reef-associated fish, such as Labridae (Wrasse) and Chaetodontidae (Butterflyfish), were moderately

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represented, while predatory species, including Serranidae (Coral Trout) and Carcharhinidae (Blacktip Shark), were remarkably scarce. The low abundance of predatory species suggests that the reef ecosystem is considered to be experiencing trophic imbalances, probably because of overfishing and/or habitat degradation, as found by Wilson *et al.* (2006), Pratchett *et al.* (2011a), and Goetze *et al.* (2018). Studies showed that loss of reef structural complexity has been linked to decreased fish biomass and shifts in trophic interactions (Graham and Nash 2013; Coker *et al.* 2014; Robinson *et al.* 2023). Additionally, herbivorous fish such as Acanthuridae and Scaridae play an ecology and critical role in maintaining reef resilience by grazing algae and controlling its overgrowth (Bellwood *et al.* 2004; Mumby and Steneck 2008).

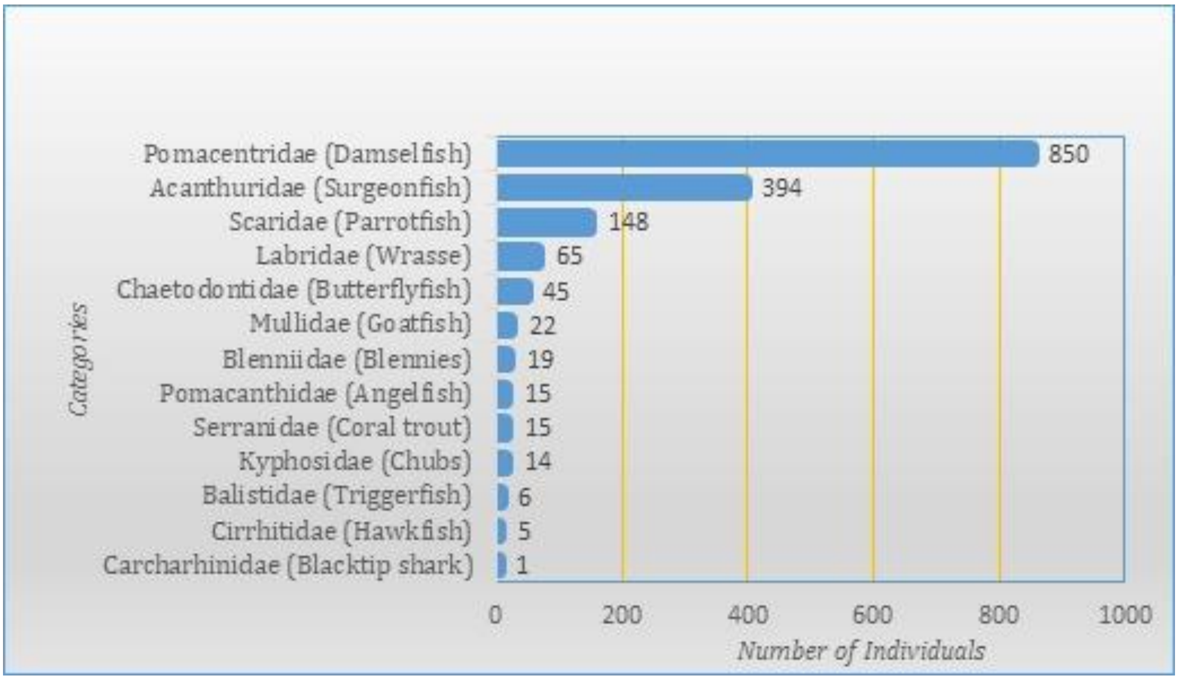

Figure 4. Composition of fish in the coral ecosystem of Tiaro Locally-Managed Marine Area, West Guadalcanal – Solomon Islands.

The highest fish abundances were recorded at Kotatave (1.2 fish/m^2) and Kokomu (1.1 fish/m^2), while Suvatara, Tavutu, Sabahe and Takoqa exhibited the lowest abundances at 0.8 fish/m^2 (**Figure 5**). The increased fish abundance in degraded coral sites suggests a proliferation of herbivorous species, such as parrotfish and surgeonfish, which often thrive in algae-dominated environments following coral mortality (Wilson *et al.* 2006; Graham *et al.* 2011; Adam *et al.* 2015). Several studies have shown that herbivorous fish play a significant role in reef resilience and health by grazing macroalgal to control its growth, thereby influencing coral recovery dynamics

(Bellwood *et al.* 2004; Mumby and Steneck 2008). However, a continued decline in coral cover may cause a fish diversity reduction, because more complex structure of reefs supports a greater variety of species (Alvarez-Filip *et al.* 2011; Pratchett *et al.* 2011a; Coker *et al.* 2014). In their study Hughes *et al.* (2010) and Graham and Nash (2013) elucidated that loss of reef structural complexity has been linked to decreased fish biomass, altered trophic interactions and the collapse of specialized reef fish populations.

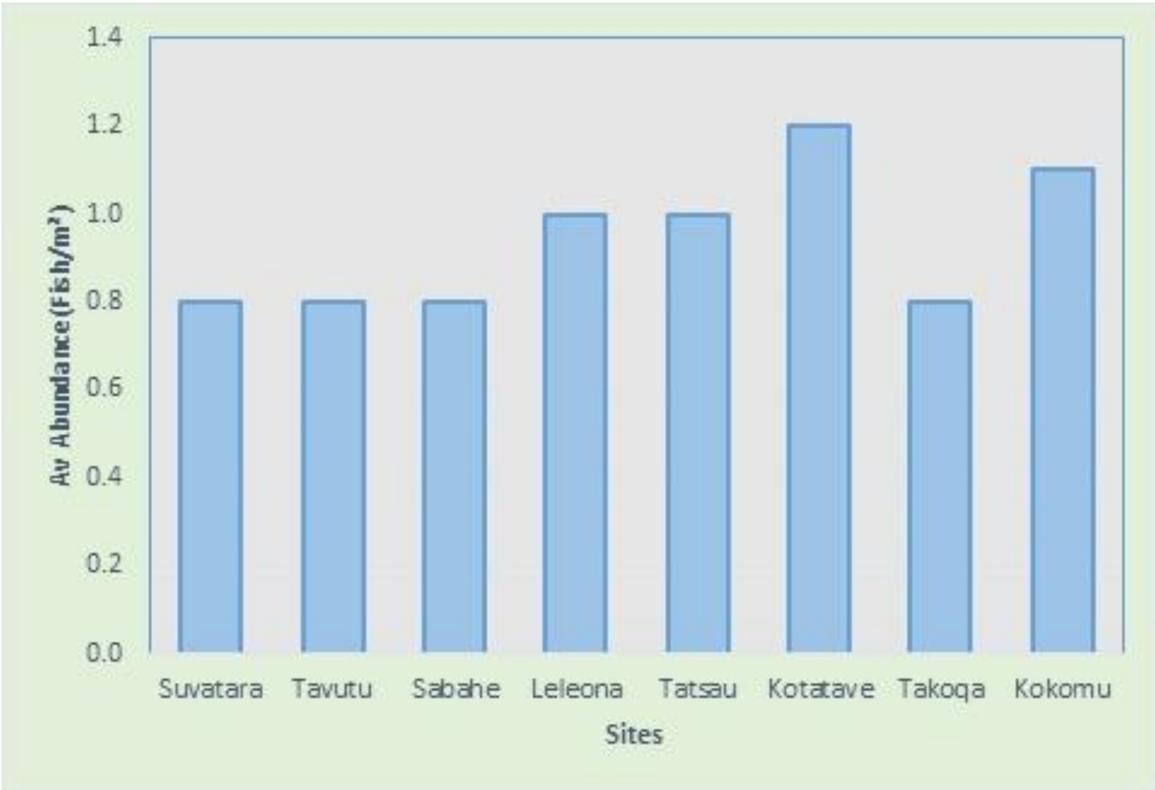

Figure 5. The abundance of fish in the coral ecosystem of Tiaro Locally-Managed Marine Area, West Guadalcanal – Solomon Islands.

The absence of large predatory fish in Tiaro LMMA suggests that further conservation efforts are necessary to enhance the enforcement of fishing regulations and restore predator populations. For comparison, some studies have shown that overfishing in seagrass habitats has led to a decline in fish biomass, affecting the sustainability of small-scale fisheries (Jones *et al.* 2004; Wahyudin *et al.* 2018). Overfishing has resulted in significant reductions in predatory fish populations worldwide, with estimates demonstrating that up to 90% of large predatory fish have been depleted in certain countries (Norse *et al.* 2012; Graham *et al.* 2015). Ecologically, this decline disrupts marine ecosystems, as the removal of top predators is believed to lead to imbalances and cascading impacts all over the food web (Myers *et al.* 2007; Goetze *et al.* 2018; Robinson *et al.* 2023). These findings reinforce the importance of protecting predator species to maintain ecosystem balance in Tiaro LMMA (Pratchett *et al.* 2011b; Graham and Nash 2013).

3.3. Seagrass distribution, coverage and health

Seagrass distribution varied significantly among sites, with *Cymodocea rotundata* being the most dominant species across all surveyed sites. Tabani recorded a total seagrass meadow of 4,353 m^2, with *Cymodocea rotundata* covering 696 m^2 (16%), followed by *Enhalus acoroides* (827 m^2, 19%) and *Thalassia hemprichii* (522 m^2, 12%). Meanwhile, Leleona exhibited high seagrass cover (72%), predominantly *C. rotundata* (1,443 m^2 ±19 SD), with *Enhalus acoroides* covering 421 m^2 (**Table 3**).

Table 3. Seagrass distribution and condition in Tiaro Locally-Managed Marine Area, West Guadalcanal – Solomon Islands.

Site	Species	% Of Site Area	Total Area Seagrass Meadows (m^2)	Total Area (m^2)
Tabani	*Enhalus acoroides*	19	4,353	827 ±14
Tabani	*Thalassia hemprichii*	12	4,353	522 ±9
Tabani	*Cymodocea rotundata*	16	4,353	696 ±17
Leleona	*Cymodocea rotundata*	72	2,004	1,443 ±19
Leleona	*Enhalus acoroides*	21	2,004	421 ±18
Tseli	*Cymodocea rotundata*	25	6,614	1,654 ±5
Tseli	*Enhalus acoroides*	21	6,614	1,389 ±9

As mentioned above, seagrass plays a critical role in carbon sequestration, habitat stabilization and nursery grounds for marine species (Duarte *et al.* 2010; Serrano *et al.* 2021). Studies in Gili Maringkik, Lombok, Indonesia, has demonstrated that seagrass beds store significant amounts of carbon, making them crucial for climate change mitigation (Unsworth *et al.* 2012; Rahman *et al.* 2023). Seagrass health assessments in Tiaro LMMA using the Fortes (1990) classification indicated that while most sites exhibited moderate to good coverage, some areas showed signs of degradation, possibly due to increased sedimentation and nutrient enrichment. This problem is similar to that in Indonesia and other part of the world, where coastal development and pollution are key threats to seagrass meadows, particularly in regions where unregulated tourism and land reclamation occur and other relevant causes (Waycott *et al.* 2009; Wawo *et al.* 2014; Syukur *et al.* 2017; Unsworth *et al.*

2018). These results highlight the importance of integrating seagrass conservation into broader marine spatial planning strategies (Lima *et al.* 2023; East *et al.* 2023).

3.4. Interdependence between coral reefs, fish and seagrass ecosystems

The results of this study in Tiaro LMMA indicate that coral reef degradation is influencing fish community composition, with herbivorous fish increasing in abundance in areas with higher coral bleaching and mortality. While this shift may provide temporary resilience by controlling algal overgrowth, long-term coral decline is likely to negatively affect reef-associated fish diversity (Bellwood *et al.* 2004; Wilson *et al.* 2006; Mumby and Steneck 2008; Pratchett *et al.* 2011a; Graham and Nash 2013; Graham *et al.* 2015; Adam *et al.* 2015).

In this study, Suvatara recorded the highest coral cover at 52%, classified as 'Good', whereas Takoqa had the lowest at 26%, falling into the 'Fair' category. Meanwhile, Kotatave and Kokomu, which experienced higher levels of coral bleaching and disease (11% ± 4 and 10% ± 3 respectively), also showed increased fish abundance (1.2 and 1.1 fish/m^2). These sites were dominated by herbivorous fish such as Pomacentridae (850 individuals) and Acanthuridae (394 individuals), suggesting a trophic shift following coral degradation. This supports the assertion that algae-grazing fish become more prevalent as coral cover declines and algae becomes more abundant, compensating partially for the loss of structural complexity but potentially undermining long-term biodiversity.

Similarly, seagrass meadows contribute to the stability of the marine ecosystem, providing habitat for juvenile fish and buffering sedimentation impacts on coral reefs. In this study, *Cymodocea rotundata* was the most dominant across all three surveyed sites. Leleona exhibited the highest coverage at 72%, with *C. rotundata* covering 1,443 m^2 (±19 SD), indicating a relatively healthy seagrass bed. In contrast, Tabani showed more moderate coverage (16%–19%), with three co-existing species. These meadows serve as essential nursery habitats and act as sediment traps, reducing turbidity and thereby indirectly supporting nearby coral reefs and inhabiting organisms.

Research in the Indo-Pacific region highlights the strong ecological connection between coral reefs, seagrass beds and fish populations. Seagrass meadows play a vital role in reducing sedimentation on nearby coral reefs while providing crucial nursery habitats for juvenile fish (Powell *et al.* 2014; Unsworth *et al.* 2018). Similarly, a study in Fiji emphasizes that seagrass enhances fish recruitment and supports biodiversity, reinforcing the importance of integrated management across these ecosystems (Jupiter *et al.* 2014). These findings collectively stress the need to preserve interconnected habitats to maintain the resilience of marine ecosystems in Locally Managed Marine Areas (LMMAs).

The spatial pattern in Tiaro LMMA, where coral degradation coincides with herbivore dominance and variable seagrass health, demonstrates how disturbances in one component of the ecosystem can cascade into others. For instance, sites with moderate coral cover but poor fish diversity (e.g., Takoqa) may indicate that reef structure alone is insufficient to sustain fish populations without ecological balance. On the other hand, areas with healthier seagrass beds (e.g. Leleona) may help maintain ecosystem services such as fish recruitment and sediment control even as adjacent coral reefs experience stress.

These conditions in Tiaro LMMA reinforce the need for integrated marine resource management, where conservation efforts consider the interdependence of coral reefs, fish populations and seagrass ecosystems (Unsworth *et al.* 2015; Unsworth *et al.* 2018). Given the success of LMMAs in other regions, Tiaro LMMA could benefit from strengthened community engagement and long-term monitoring to enhance ecosystem resilience (Govan *et al.* 2008; Govan 2009; Jupiter *et al.* 2014; Arkema *et al.* 2017; Wahyudin *et al.* 2018; Pelletier 2020).

4. CONCLUSIONS AND SUGGESTIONS

This study revealed varying coral cover, fish abundance and seagrass distribution across Tiaro LMMA. Herbivorous fish dominance and low predator presence indicate trophic imbalance linked to coral degradation. Seagrass meadows, particularly *Cymodocea rotundata*, support ecosystem stability. These findings highlight the ecological linkages among coral, fish and seagrass, reinforcing the need for integrated, community-based management and ongoing monitoring to sustain ecosystem health.

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