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The Position of Silvofishery as a Buffer for Mangrove Exploitation Along the Southern Coast of the Makassar Strait

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Abstract: ***This study investigates the role of silvofishery in buffering mangrove exploitation along the southern coast of the Makassar Strait. Field observations were conducted in five districts, analyzing ecosystem parameters like density, diversity, and dominance to understand the community's structure. The results highlight silvofishery's significance in maintaining mangrove ecosystem stability while supporting sustainable aquaculture practices.***

Keywords: silvofishery, mangrove ecosystems, sustainable aquaculture, Makassar Strait, ecosystem stability

1. Introduction

1.1 Background

The mangrove ecosystem is an open ecosystem from various orientations of human interests in coastal areas, so that its position as a shared property makes this ecosystem vulnerable to all forms of exploitation and environmental manipulation that occur within it. Several areas in South Sulawesi Province have experienced this, some of which represent the coastal areas of the Makassar Strait, namely Takalar, Maros, Pangkep, Barru and Pinrang districts. These areas have areas dominated by mangrove vegetation that have experienced an environmental degradation crisis, at least the negative impacts have been felt since 2 decades ago. The cause of environmental degradation is because the coastal area has changed function to become a fish farming area and residential area. In several sub - districts as coastal areas in 5 districts that are the focus of the research, the community generally gave a positive response to the need for a silvofishery program as a buffer for mangrove vegetation zones that have experienced severe degradation due to aquaculture management that ignores natural ecological values. Expecting a buffer ecosystem that is considered to be able to restore the balance of the original ecosystem that has experienced over - exploitation, a simulation of Alternative Ecosystem Assistance (AEP) was carried out by comparing 5 categories (Buffer Land System Control, KSLP) as follows: 1. SL - PRT, 2. SL - KHY, 3. SL - PTG, 4. SL - KJP, and 5. SL - UPG. And with SEM (Structural Equation Modeling) analysis, the best model can be predicted to determine the position of silvofishery integration in coastal community aquaculture ecosystems (Yunus, 2015). The study aims to evaluate the integration of silvofishery practices as a means to stabilize mangrove ecosystems while sustaining aquaculture productivity in South Sulawesi. This study provides insights for policymakers and aquaculture practitioners on sustainable strategies for managing coastal ecosystems while ensuring economic benefits.

1.2 Problem Formulation

Intensification of fishery ponds due to the conversion of mangrove land since the 1980s, especially in Java, Sumatra, Kalimantan, and Sulawesi, with the aim of spurring exports of fishery commodities. This has resulted in a reduction in natural ecosystem buffer land, as seen from the expansion of shrimp pond areas from around 220.000 Ha in 2004 to 320.000 Ha at the end of the Fourth Development Plan (Directorate General of Reforestation and Land Rehabilitation, 2007). As a further consequence, this has an impact on the loss of the buffer ecosystem that is able to tolerate a stable natural mangrove ecosystem covering an area of 1.818.000 Ha, for the entire mangrove ecosystem area in Indonesia. In response to this phenomenon, there is a need to synchronize the Ecosystem Companion Alternative (AEP) with the Buffer Land System (SLP) control which represents the silvofishery pattern category which is divided into 3 patterns, namely: 1. embankment pattern (TGL), 2. ditch path pattern (PRT), and 3. pond pattern (KLM), so that there are 15 synchronization patterns which are the questions in the problem formulation. These 15 problem formulations were simulated into 3 answer categories based on the previously determined silvofishery pattern (i. e. good = 3; moderate = 2; and bad = 1).

The following are 15 problem formulation synchronization patterns that are questioned to be answered with Structural Equation Modeling analysis which produces predictions of 3 product categories of silvofishery pattern synchronization as a buffer land system (Santoso and Singgih.2014).

Table 1: Design of Alternative Ecosystem Companion (AEP) synchronization with Buffer Land System (SLP)

No.	Land System	TGL Pattern	PRT Pattern	KLM Pattern
1.	SL - PRT	1…?	6…. ?	11…?
2.	SL - KHY	2…?		12…?
3.	SL - PTG			13…?
4.	SL - KJP			14…?
5.	SL - UPG	5…?	10…?	15…?

Synchronization 1 – 15…?

1.3 Aims and Objectives

This research is intended as a method to find the form of an integrated mangrove buffer ecosystem (silvofishery) in the midst of the increasingly widespread mangrove land degradation crisis. This aim is to provide information for shrimp farming communities and policy makers in the management and utilization of mangrove ecosystem land in coastal areas.

2. Research Methods

2.1 Time and Location of Research

The research was conducted for 4 months, starting from February 5 to June 5, 2023 in the coastal areas of Galesong Takalar District, Maros Baru District, Bontoa District, Maros Regency, Labakkang, Segeri, and Mandalle Districts, Pangkep Regency, Soppeng Riaja District, Barru District, Barru Regency, and Cempae District, Duampanua District, Pinrang Regency. The mangrove ecosystem area covers 5 districts (Takalar, Maros, Pangkep, Barru, and Pinrang) as research area centers on the coast of the Makassar Strait, South Sulawesi (Figure 1).

Figure 1: Map of Makassar Strait Coastal Research Location, South Sulawesi

2.2 Buffer Land System Control Criteria

The buffer land in question is the mangrove ecosystem resulting from a natural synchronization simulation with the wishes of the community who have long been active in community aquaculture management with good category values (value 3), moderate (value 2) and bad/ugly (value 1). The configuration of the Buffer Land System Control pattern (KSLP) as a value category for the Companion Ecosystem Alternative (AEP) can be referred to based on the synchronization of Table 2.

Table 2: Synchronization of buffer land system (SKP) control with community assessment categories to determine Companion Ecosystem Alternatives (AEP).

No.	Buffer Land System Control (KSLP)	Natural Value Field Observation Results	IP - AEP Category
1.	SL - PRT	• 9 types of vegetation were found well distributed at the seedling, sapling, and tree levels, namely; api - api (Avicenia marina), bogem (Sonneratia caseolaris), buta - buta (Excoecaria agallocha), tingi (Ceriops tagal), dungun (Heritiera littoralis), ketapang (Terminalia catappa), nyiri (Xylocarpus molluccense), tancang (Bruguiera cylindrica), and duduk (Lumnitzera littorea) • The average total density of individuals for all species is 8.76 individuals/10 m2	3
2.	SL - KHY	• 7 types of vegetation were found, spread at tree level, namely api - api (Avicenia marina), bogem (Sonneratia caseolaris), buta - buta (Excoecaria agallocha), tingi (Ceriops tagal), ketapang (Terminalia catappa), nyiri (Xylocarpus molluccense), and tancang (Bruguiera cylindrica).	
3.	SL - PTG	• In this area, coastal vegetation such as coconut (Cocos nucifera), ketapang (T. cattapa), waru (Hibiscus tiliaceus), malapari (Pongamia pinnata) and bidara laut (Ximenia americana) are generally grown. • - Mangroves are only found around river mouths with an area and density of 27 individuals per hectare (not too large).	2
4.	SL - KJP	• A. marina density was found for tree level of 23 individuals/ha with a stem diameter range of 7 - 13 cm, and E. agallocha with a tree density of 11 individuals/ha. The total tree level	

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		density was 34 individuals/ha. The understory vegetation found in this LS was bluntas (P. indica), seruni (W. biflora) and sea sedge (C. maritim).	
5.	SL - UPG	• Mangrove vegetation is generally found growing solitary and isolated on the land and its density is very low. • Based on the information obtained, in this SL previously there were api - api (A. marina), (Ceriop tagal), (Rhizophora spp.), and bogem (Sonneratia spp.), while the vegetation below it is currently found including; C. maritim, Fimbristylus globulosa, Nypa fruticans and W. biflora.	1

2.3 Data Collection

Data on the structure of mangrove vegetation communities include; density, diversity, equitability, and dominance, which with these variables will indicate whether the ecosystem status is good or not as a reference for management.

2.3.1 Density

Density (Ds) = ni/A; Dm = density of mangrove species, ni = number of stands of mangrove species kei, A= area of plot location of mangrove data collection kei. This vegetation density was observed at each research station facing the integrated silvofishery pattern (Brower and Zar, 2007).

2.3.2 Diversity

Species diversity as a reflection of species heterogeneity is calculated using the Shannon - Wiener formula (Brower et. al., 1990); H' = - Σ Pi log Pi or –Σ [ni/N] log2 [ni/N]; H' = Shannon biodiversity index, Pi = proportion of the total number of individuals of species i to the total number of individuals of species captured kei, ni = number of individuals of species kei, N = total number of individuals of species obtained.

2.3.3 Equitability

Equitability or evenness of species is calculated based on the Shannon - Wiener species equivalence index (Brower et. al., 1990), as follows; E = H'/Hmax = H'/log2S; E = evenness index, S = total number of species.

2.3.4 Dominance

Dominance is calculated using the Simpson index formula (Brower et. al., 1990) as follows: D = Σ ni (ni – 1) /N (N - 1) where; D = dominance index, ni = number of individuals of the i - th species, N = total number of individuals of the species found.

2.4 Data Analysis

A set of research instruments to extract primary data aimed at community members consists of several research questions with the substance of responses about the condition of the mangrove ecosystem with its integrated management policy towards the community's aquaculture ecosystem, including aquaculture production produced in terms of quantity and quality over the past 3 years. The quantity data obtained was inputted into the split - plot synchronization design of the AEP Buffer Ecosystem Alternative (Table 1) which was then analyzed through the design of a structural equation modeling model. The Structural Equation Model (SEM) design used as a reference in this study is as follows (Garson, 2012):

$\eta 1 = PyX_1 + PyX_2 + PyX_3 + \mathcal{E}$

Pyi_{1-3} = direct relationship of exogenous variables (AEP) to endogenous variables (KSLP)

$Xi_{1-3} = \lambda_{1-4}\text{€}x + \delta_{1-3}$ (measurement of each exogenous variable)

$Yi_{1-3} = \lambda_{1-3}\,\eta_{1-2} + \epsilon_{1-3}$ (measurement of each endogenous variable).

For the hypothesis test, it is seen based on the comparison between the difference in relationship reliability (Construct reliability = R) as Extracted variance with the t - statistic value (= 1.96). If all indicator factors have a t - statistic value > 1.96, then these factors are considered significant or have good validity. Conversely, if the t - statistic value < 1.96, then these factors are considered non - significant or invalid.

3. Results and Discussion

3.1 Results

3.1.1 Mangrove Density Synchronization of AEP to KSLP

In the coastal areas of 5 districts (Takalar, Maros, Pangkep, Barru, and Pinrang) that have integrated ecosystem management of mangroves and community fisheries.3 of these areas, namely Maros, Pangkep and Barru, have a composition of mangrove vegetation stands consisting of 9 types, namely; api - api (*Avicenia marina*), bogem (*Sonneratia caseolaris*), buta - buta (*Excoecaria agallocha*), tingi (*Ceriops tagal*), dungun (*Heritiera littoralis*), ketapang (Terminalia catappa), nyiri (Xylocarpus molluccense), tancang (*Bruguiera cylindrica*), and tudung (*Lumnitzera littorea*). The existence of 9 mangrove species in these 3 coastal areas makes this area a natural vegetation base for the Alternative Ecosystem Support (APE) exemplary zone, based on community assessments with reference to the Environmental Assessment Index category (IPL=3). Meanwhile, in other coastal areas, namely; Takalar has a vegetation stand composition of 6 mangrove species, namely; tancang (*Bruguiera cylindrica*), tingi (*Ceriops tagal*), dungun (*Heritiera littoralis*), ketapang (*Terminalia catappa*), api - api (*Avicenia marina*), and bogem (*Sonneratia caseolaris*). With the existence of these natural conditions, the community's assessment based on the Environmental Assessment Index (KEMENKLH, 1988) is categorized as IPL = 2. And areas where the composition of mangrove vegetation is below 5 species, as found in the Pinrang area, consist of C. maritim, Fimbristylus globulosa, Nypa fruticans, C. tagal, Rhizophora spp., and Sonneratia spp., which indicates that this area is categorized as SL UPG with IPL = 1.

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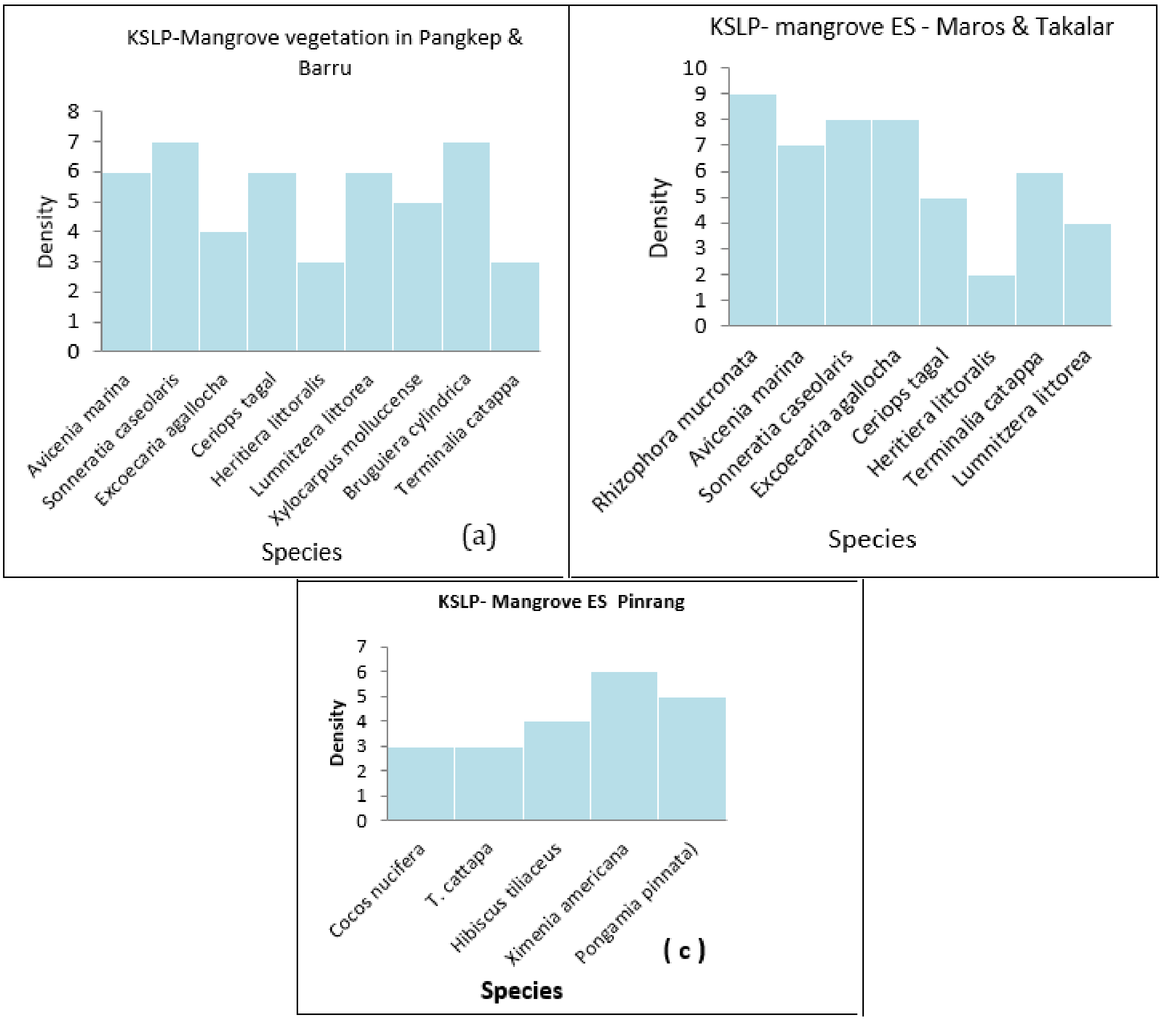

Figure 2: Graph of synchronized mangrove vegetation of the Integrated Alternative Companion Ecosystem (AEP) Buffer Land System Control (KSLP) with (a) IPL= 3 in Maros and Takalar; (b) IPL= 2 in Pangkep and Barru; (c) IPL= 1 in Pinrang.

Table 3: Average Density of Mangrove Species based on AEP Synchronization to KSLP in vegetation groups in categories $IPL_{3,\ 2,\ \text{and}\ 1}$

AEP community synchronization			Ds: (∑Pi/m²)	Average (%)	BNT $_{(0,\ 05)}$ = 1, 96
KSLP Community Group	Vegetation Singkr. AEP to KSLP				
	Sv Pattern	Species of mangrove			
Maros & Takalar	sl - prt	*Rhizophora mucronata*	9	6, 00	a**
	sl - khy	*Avicenia marina*	7		
	sl - ptg	*Sonneratia caseolaris*	8		
	sl - kjp	*Excoecaria agallocha*	8		
	sl - upg	*Ceriops tagal*	5		
		Heritiera littoralis	2		
		Terminalia catappa	6		
		Lumnitzera littorea	4		
Pangkep & Barru	sl - prt	*Avicenia marina*	6	5, 20	a*
	sl - khy	*Sonneratia caseolaris*	7		
	sl - ptg	*Bruguiera cylindrica*	4		
	sl - kjp	*Ceriops tagal*	6		
	sl - upg	*Terminalia catappa*	3		
		Xylocarpus molluccense	6		
		Excoecaria agallocha	-		
Pinrang	sl - prt	*Cocos nucifera*	3	3, 60	b
	sl - khy	*Terminalis.*	3		
	sl - ptg	*cattapa*	4		
	sl - kjp	*Hibiscus tiliaceus*	6		
	sl - upg	*Pongamia pinnata*	2		
		Ximenia americana	-		

Buffer Land System Control (KSLP) Information
sl - prt: ditch pattern land system
sl - khy: pond pattern land system
sl - ptg: embankment/bank pattern land system
sl - kjp: ditch line pond pattern land system
sl - upg: ditch embankment combination pattern land system

3.1.2 Dominance

Dominance in a community reflects the presence of one or two biota populations that have the status of controlling an area (home range) and outperforming competition against several ecological factors (Yunus, 2015). In the case of this research, the dominance in the mangrove community of the synchronization of the AEP pattern against the KSLP at each research station base (Takalar, Maros, Pangkep, Barru, and Pinrang) was relatively not found to have vegetation dominance. Figure 3. Because in the buffer land system control (KSLP) the ditch (PRT) and pond (KHY) patterns in the AEP Maros, Pangkep and Barru synchronization areas are more prominent and have the main mangrove vegetation, the study of community dominance was calculated in this study (Figure 5).

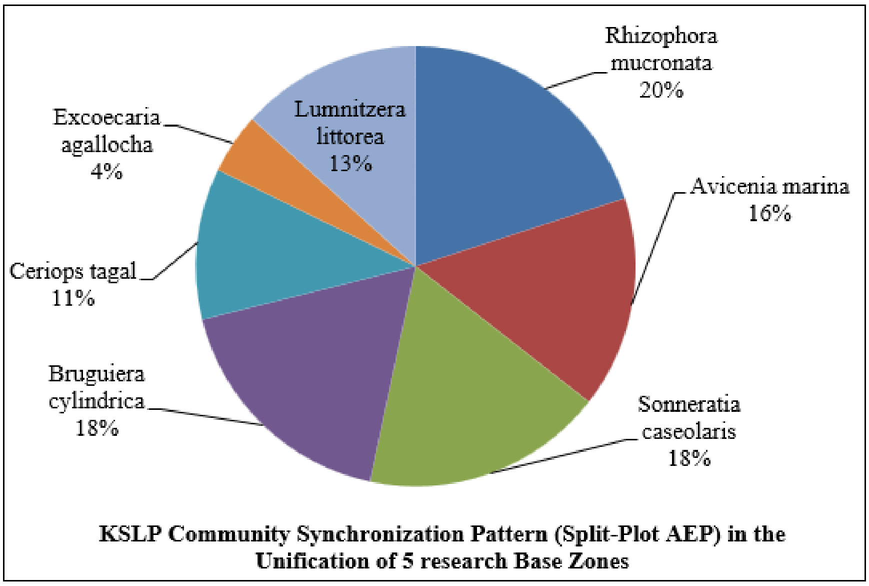

Figure 5: Mangrove Density of Community Synchronization Patterns of KSLP Takalar, Maros, Pangkep, Barru and Pinrang on the Coast of the Makassar Strait

Table 4: Dominance and Average Biomass Production of AEP Split Plot Synchronization of KSLP Community Groups on the Coast of the Makassar Strait, South Sulawesi

AEP community synchronization				Dominance: $\sum n_i (n_i - 1) / N (N - 1)$	Average (Ton) Biomass Production Split Plot ACEP - KSLP
KSLP Community Group	AEP's synchr. to KSLP				
	Ds	ni (ni - 1)	N (N - 1)		
Takalar, Maros, Pangkep and Barru	7	42	1560	0, 027	*C. chanos* (0, 435) *Penaeus Spp.* (0, 350) *Scylla serrata* (0, 190)
	8	56		0, 036	
	8	56		0, 036	
	5	20		0, 013	
	2	2		0, 001	
	6	30		0, 019	
	4	12		0, 010	
Amount	**0, 1420**				
	0, 975				

3.1.3 Diversity and equitability

Diversity or variety of biological resources in an integrated management activity with other units (silvofishery) will provide an increase in biomass production (tons/ha). This production unit is influenced by the quality of the community structure of the resources that interact in the integrated management (silvofishery). Diversity (H'), equitability (E), dominance (D) and biomass production (the result of synchronization of the silvofishery land system with community aquaculture, are shown in Table 5.

Table 5: Community structure of AEP mangrove vegetation synchronization patterns against KSLP in the IPL $_{3,2,1}$ categories

AEP community synchronization				Diversity Index H'	Equitability E = H'/ H_{max}	Average (Ton) Biomass Production Split Plot ACEP - KSLP	BNT $_{(0, 05)}$ =1, 96
KSLP Community Group	AEP Syngchronization with KSLP						
	Ds	P_I	Log P_i				
Maros, Takalar	7	0, 33	- 0, 48	0.16			
	8	0, 27	- 0, 57	0, 15			Difference per100 >>
	8	0, 27	- 0, 57	0, 15 } 0, 6776	0, 9694	0, 9750*	
	5	0, 17	- 0, 77	0, 13			
	2	0, 07	- 1, 15	0, 08			
Pangkep, Barru	6	0, 23	- 0, 64	0, 15			
	7	0, 27	- 0, 57	0, 15			
	4	0, 15	- 0, 82	0, 12 } 0, 6800	0, 9729	0, 7250**	
	6	0, 23	- 0, 64	0, 15			
	3	0, 12	- 0, 93	0, 11			
Pinrang	3	0, 12	- 0, 93	0, 11			
	3	0, 12	- 0, 93	0, 11			Difference per 100 <<
	4	0, 15	- 0, 82	0, 12 } 0, 6600	0, 9442	0, 6570	
	6	0, 24	- 0, 62	0, 15			
	2	0, 30	- 0, 52	0, 17			

3.2 Pembahasan

3.2.1 Density, diversity, equitability and dominance

Mangrove communities are spread across several areas along the coast of the Makassar Strait, especially in the southern part. Five coastal areas, including; in Takalar, Maros, Pangkep Barru and Pinrang Regencies, are the basis for this research because these areas are the centers for the development of integrated pond fisheries patterns with mangrove ecosystem management for approximately 2 decades. Vegetation density still shows stable conditions with a relatively even percentage with a dominance value (D = 0.1240) (Figure 5). The mangrove vegetation zone in this area has a species composition as a natural indicator of ecosystem buffers, so it is selected as an example of the Buffer Land System Community (KSLP) which is then synchronized as a silvofishery development area (AEP standard). The composition of the vegetation in question, among others: Rhizophora mucronata (20%), Sonneratia caseolaris (20%), Avicenia marina (17%), Bruguiera cylindrical (18%), Excoecaria agallocha (20%), Ceriops tagal (11%), Lumnitzera littorea (13%). The percentage of species shown is an even abundance of individual mangrove stands with an equitability index E = 0.96. Likewise, the suitability of the buffer land community in the Alternative Companion Ecosystem AEP3.2 category shows a mangrove diversity index H'= 0.67 (Table 5). The values shown reflect the suitability of stable community land. Calculation of the Shannon - Wiener diversity index shows that in the five research locations in general have a moderate level of species diversity. This level of diversity indicates environmental stability. Likewise, the species evenness index shows that in all five locations, the evenness index is relatively homogeneous at around 0.9, indicating that the distribution of vegetation along with other biota in the community is relatively even, which means that the condition of the mangrove community in the integrated silvofishery aquaculture management is in a stable state (Yunus, 2015). The even distribution of mangroves with a dominance index of D=0.1420 is supported by a synchronization system in silvofishery management based on the selectivity of the vegetation of the companion land ecosystem community (KSLP) which is applied in each development area. This is in accordance with the statement that in a community of organisms with a dominance index approaching zero, it shows that in the community there is no monopoly of superiority of organisms regarding their needs for ecological limiting factors, which means that there is ecological balance in the community (Kusmana et. al., 2002).3.2.2 Target biota production. The success of integrated fisheries management with mangrove communities developed by the community in 5 coastal areas of the Makassar Strait is determined by the amount of target biota production chosen by the community. The target biota in question is *Chanos chanos* from the fish group, along with shrimp and crab from the crustaceae group. The average production per harvest (during the research period) from this biota group is shown in Table 6 below.

Table 6: Composition of target biota production resulting from the development of silvofishery synchronization patterns in 3 groups of buffer land system community areas (KSLP) during the research

No.	KSLP Community Group	Species	Production (Kg / Ha)
1	PRT & KHY combination pattern	*Chanos chanos*	495
2		*Penaeus monodon*	315
3		*Scylla serrata*	165
∑	**975**		
1	PTG & KJP combination pattern	*Chanos chanos*	325
2		*Penaeus monodon*	290
3		*Scylla serrata*	110
∑	UPG & PTG Combination Pattern		**725**
1		*Chanos chanos*	290
2		*Penaeus monodon*	215
3		*Scylla serrata*	152
∑	**657**		

The alternative split - plot configuration of the companion ecosystem (AEP) for the buffer land system community (KSLP) in each group of mangrove vegetation community areas on the coast of the Makassar Strait provides meaning to the production of target biota (fish, shrimp and crabs) for local residents, especially coastal residents. Fish and shrimp biota, especially in the post - larva to juvenile phases, require shade from extreme temperatures. With integration in the buffer land system community (KSLP), namely with the presence of mangrove vegetation, the water temperature and other water quality (pH, chemical waste) that are extreme will become stable. Sulia et. al., (2010) explained that the aquaculture system with integrated mangrove vegetation management in it will increase the production of fish and shrimp cultivated in it. It was continued that the function of mangrove in the system acts as an ecological barrier and bio - filter against extreme ecosystem quality conditions and water waste.

Conclusion and Suggestions

4.1 Conclusion

1) Vegetation density shows a stable condition with a relatively even percentage, where the composition of all types of mangroves that appear is an indicator of ecosystem support, so it can be selected as an example of a buffer land system community in silvofishery management.
2) In the five research locations (Takalar, Maros, Pangkep, Barru and Pinrang) in general, the level of diversity and uniformity of species is moderate (normal), this shows that the stability and stability of the ecosystem is still good in supporting an integrated aquaculture system together with the management of the mangrove ecosystem in the coastal areas of the region.
3) Synchronization of community - selected aquaculture patterns (AEP) with the buffer land system community (KSLP) in each group of mangrove vegetation community areas on the coast of the Makassar Strait has meaning for increasing the production of target biota (fish, shrimp and crabs) for local residents, especially coastal residents.
4) The position of the silvofishery management pattern is very important as an alternative buffer against the manipulation of ecosystems that are over - exploited and are increasingly widespread along coastal areas.

4.2 Suggestions

The importance of implementing policies on regulations for opening shrimp ponds accompanied by the integration of buffer communities that accompany the ecosystem so that ecological homeostasis in the shrimp pond system is maintained as a natural ecosystem that continues for the habitat of biota life, and coastal areas are not saturated with vegetation that is over - exploited.

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