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# Development of integrated seaweed culture and capture fisheries in Indonesia

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**Abstract.** Seaweed development has had positive impacts on surrounding environments and fisheries resources, even using traditional technologies. The integration of aquaculture and capture fisheries will have a multiplier effect on fish farmer income as well as supporting the development of the aquaculture sector. This research aimed to optimize the utilization of fisheries resources around seaweed culture areas. Two case studies were conducted at Libukang Island, Jeneponto District, South Sulawesi, and at Sarudu village, North Mamuju District, West Sulawesi. Resource use in seaweed culture areas was optimized through the design, construction, and implementation of improved fishing gears: gill nets, bamboo traps, and fyke nets. The study results show that integrating seaweed culture and capture fisheries using these gears can increase fishermen's incomes. The level of additional income depends on fishing intensity. In addition, seaweed culture productivity should be improved through integration with fish cage culture. The cultured fish expel waste to the environment (feed, feces, and urine) that can provide nutrients to the seaweed. The sustainability of fishing depends so much on the sustainability of seaweed culture were used as a fish aggregating device.

## 1. Introduction

Seaweed culture has a high contribution to the environment, reduce global warming [1], reduce CO<sub>2</sub> [2,3]. However, global warming also reduces seaweed productivity [3]. Many areas are suitable for seaweed farming along the coast where seaweed can be farmed, and a relatively small proportion would be enough to neutralize all the carbon from the aquaculture industry [1]. Seaweed cultivation that reduces greenhouse gases can have the greatest potential in achieving local and regional carbon neutrality goals [1–6]

In recent years, seaweed farming has developed rapidly and become highly intensive in some coastal areas; in fact, many people in fishing communities have shifted to seaweed farming as a livelihood activity. The development of seaweed farming technology has evolved and been modified, in line with regional conditions and capacity. Seaweed farming technology dominated by float line systems where within this system, the seaweed farmer could utilize water column up to the bottom. Phenomena at the seaweed farming area were contributing positive impacts on the coastal ecosystem. On the other hand, many coastal areas were degraded due to pollution [7–9]

At the same time, the degradation of coastal ecosystems and fisheries resources is becoming a serious problem, requiring extra effort to protect, prevent, rehabilitate its condition to prepare food for our generation and also the future generation. Area of meeting land and water made coastal areas



became high potential toward pollution issues. For this point, it has become the responsibility of all stakeholders to be wise in selecting and developing programs to implement in a certain area either locally or nationally. In many cases, maximal production pressure and fulfill economic need were bringing to the ecosystem and resource degradation where cost recovery toward carrying capacity recovery of the environment and its resources became very expensive and require a very long time for its recovery. [4,10,11]

Integrated between fish cage farming and seaweed farming and also capture fisheries become one solution to increase fishermen productivity in the coastal area and also improve environment condition [8,12,13]

Ecosystem improvement was the positive impact of seaweed farming and fish farming in the floating cage. Explorative nature of the technology, and integrated with each other and with one another will increase the added value. Small fish traps results will be placed in cages to be raised, and then fish and feeding areas will contribute to the nutrient provider for seaweed, the next seaweed associated with fish off to be caught with traps and nets. Until now unknown to the equilibrium value of each component of the integration, so it is urgent to study [9,11,14,15]

## 2. Material and methods

The research conducted was at Sarudu Village, North Mamuju Regency, and at Libukang Island, Jenepono Regency, with the case study.

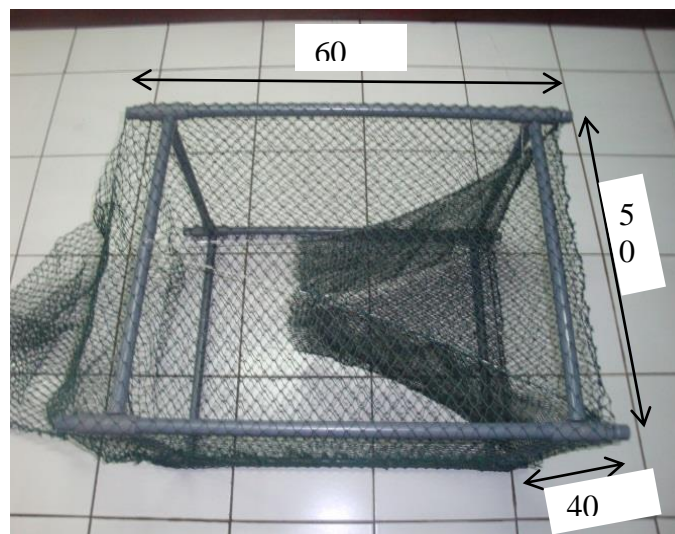
The research at Sarudu conducted in September – October 2012 with geographic position were latitude 01° 40' 25.6" S, and longitude 119° 16' 58.8" E. The research at Libukang Island conducted in June – November 2013 with geographic position were latitude 05° 38' 77" S; and longitude 119° 36' 49" E. Materials use were gill net monofilament ropes, floats, sinkers, needles, and scissor for making gill net. GPS used to determine the seaweed farming position and boat for transportation and fishing operation. Bamboo traps were traditional fishermen made. Seaweed cultivated in the floating long line system with dimensions 50 x 50 m.

Gillnet was designed as local condition and feet to seaweed farming frame, materials monofilament number 28, mesh size 2 inch with shortening 40%. For bottom gill nets were putting 1.5 kg lead sinkers, and for the surface, gill nets were putting 0.8 kg lead sinkers. Gillnet was setting at a vertical anchor line with a ring by fulling up and down. Bamboo traps dimensions were length 2 m, wide 1 m and height 0.5 m. Traps were set in the water bottom, joining 3 traps with the distance between around 5 m. Traps were equipped with baited to attract the fish around to enter the traps.

Trap fishing gear is a passive fishing gear and generally placed in the bottom waters. The material is made from woven bamboo, forming a rectangular dimension of space that has an entrance as well as a trap door that allows the fish to enter but difficult to get out from the trap. Fish trap width 100 cm, length 125 cm, and a height of 35 cm assembled using monofilament 600 straps and rope Ø 3 mm PE has woven at the corners of the fishing gear. Strengthening the framework is done with the addition of bamboo that serves as a buffer from the skeleton and body trap.

The bottom fish trap was divided into two groups, where each group consists of the installation of three units. Each unit bottom trap was constructed separately and comes with two bottles of sand weights on both sides as a sinker. At the top of the trap was equipped with a tether for an easy coupling trap collectively. The fish trap was already constructed, then sequenced in parallel and connected to the vertical frame using a ring tin Ø 15 cm on both ends of the rope.

Fyke net was constructed from a plastic pipe of 0.5-inch diameter as a frame and cover with polyethylene net of mesh size 1.5 inch.



**Figure 1.** Construction of fyke net.

The research employed exploratory research toward fishing with a gill net, traps, and fyke net underneath of the seaweed farming area. A fishing operation conducted daily base as seaweed farmers went out to check their seaweed. Fish catches were recorded daily by fishing gear and then analyzed descriptively and graphic.

### 3. Result

#### 3.1. Seaweed farming system

Frame construction of seaweed farming was developed from the local model as normally used by most seaweed farmers in the coastal area. Seaweed frame construction developed in the Maranggapa village, Sarudu District, North Mamuju Regency, is a construction that is commonly used and developed in South Sulawesi. Frame seaweed formed by ropes Polyethylene (PE) in diameter 9-10 mm rectangular. In the mainframe reinforced by the anchor rope PE Ø 9-10 mm with a weight of as much as 4-6 sacks made of plastic sacks filled with sand weighing @ 75 kg, while at the top end of the rope tied to a float of cork material or plastic bottles to provide buoyancy and maintain the position of the frame seaweed and the effect of waves, currents, and waves.

Extents frame seaweed used is different depending on the scale of business and investment that can be done. The average area of cultivation used by the local fishermen has a width of  $\pm 20-35$  m with a length of  $\pm 100-200$  m. Seaweed seedlings are hung on a rope stretch (PE Ø 3-4mm) with a distance of 10 cm between seedlings with a length of rope stretch to fit the width framework of seaweed. It is provided a float plastic bottle (600 ml) at intervals of 5 m to provide buoyancy to the straps stretch with the growth of seaweed.

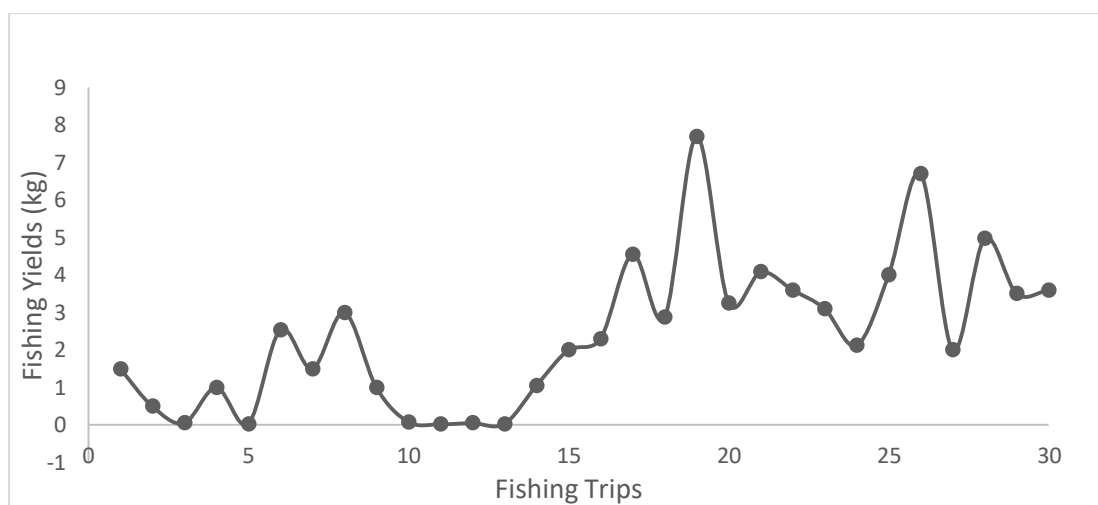
The results of observation of the construction that has been used by local fishermen found several advantages including 1) investment made relatively small, 2) the material used is easily available and can be obtained at local shops, 3) to construct and install it does not require a lot of energy with a low level of complexity. While finding weaknesses in cultivation technology that they do are: 1) the age of economic unit seaweed farming is relatively short, where every  $\pm 2$  years always do repairs and replacement of certain parts of the framework of seaweed, 2) are found and known in the area under seaweed cultivation there are much fish that come, go and play but fishermen cannot catch these fish, 3) the materials used are very limited in the quality framework of seaweed that is used so that when seaweed grow up (towards 35-45 day of the maintenance period), order seaweed tends to sink under the weight of the seaweed is getting heavier and cause difficulties in operation and maintenance of seaweed cultivation.

Based on observations on seaweed farming and its impact on fishery resources and ecological impacts created, this research becomes important. The basic thing to do is inventing and innovation to

the appropriate fishing technologies that can be operated under the seaweed cultivation area. The operational feasibility of the technical approach to the combination of aquaculture and fishing technology has been developed innovations and modifications to the frame construction seaweed. As for the design, construction, and installation that has been generated in this study is shown in Figure 1, frame construction seaweed produced through this research, consisting of a) the mainframe as a hanger rope stretch of seaweed has a vast size of 50 mx 50 m with material from PE Ø 20 mm. In the mainframe, there are white-plastic float Ø 24 cm by 28 pieces to provide buoyancy to the load resistance and the material underneath. At the corner of the frame is reinforced with 4 buoys and 2 pieces at the center of each of which is connected to the anchor rope.

### 3.2 Fish catch of Fyke net

Fyke net weights of the catch based on the time during the study are shown in Graph Figure 2 as follows.



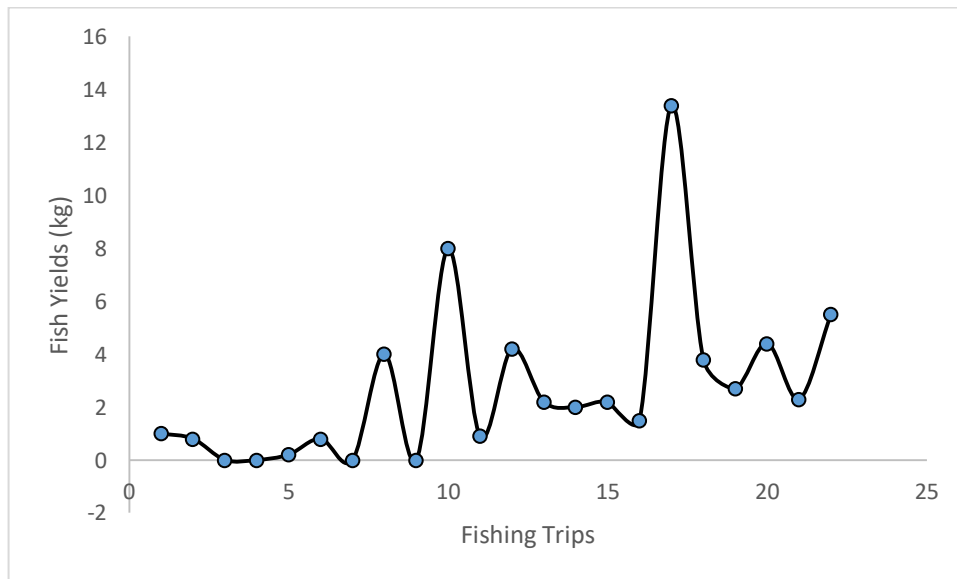
**Figure 2.** Fishing yields of Fyke net by fishing trips during observation.

Fyke net catches, as shown in the graph, have shown an increase in tangible results by the time of observation (Figure 2). However, be aware that the location of seaweed farming is a new location, so that the fish has not been much. At the location has long been developing seaweed, fish also will develop well, and fish catches are being targeted. Therefore, it takes a rather long time to prove the effectiveness of Fyke net fishing as a means of earning on the location of seaweed cultivation.

The results of the evaluation of the operation of the Fyke net shows there are two ways of installation, which is tied to a rope frame seaweed and plug in the bottom waters. Installation on the order of seaweed a little trouble on the installation and removal of the Fyke net, but the Fyke net is relatively safe from the ravages of stuck on the reef. Installation of the bottom waters are relatively easy to do either installation or removal of the Fyke net, but many suffered damage as a result of nets snagging on coral reefs. Therefore, the placement location Fyke net needs to be evaluated in advance so as not placed on the coral reef.

### 3.3 Fish catches of Gillnet

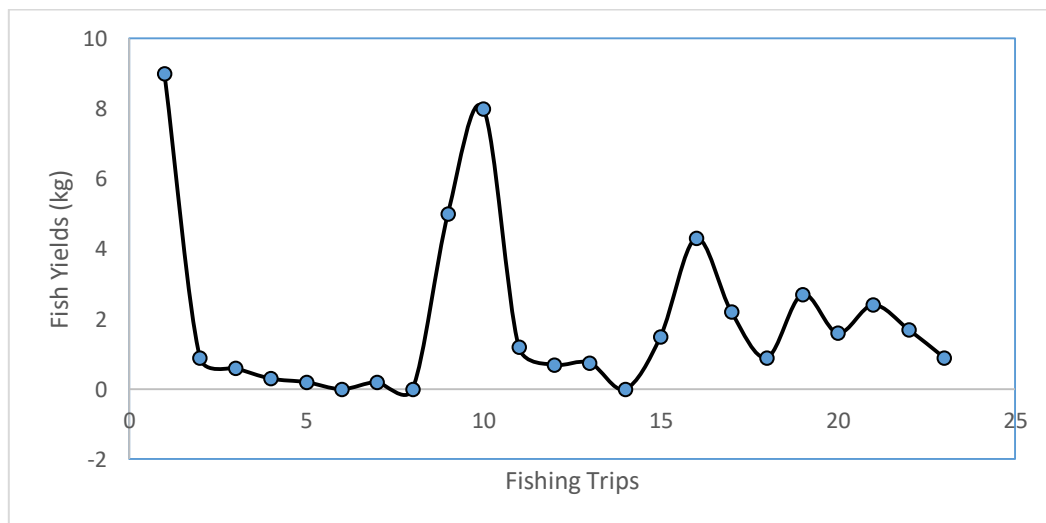
Gillnet operated on a modified frame seaweed consists of two types, namely surface gill nets, and gill net basic types. The catches are obtained on the surface of the gill net, such as tuna, giant trevally fish, black pomfret, Saury fish. At the same time, catches were obtained on the basis of gill nets such as grouper, eels, snapper fish, rabbitfish, blue parrotfish, and reef fish.



**Figure 3.** Fish catch of Gill net based on trips.

Catch species composition showed that the location of the placement of the frame seaweed and technological innovation arrest gill nets and Trap the water areas that are still good. It is detected from direct observation of the condition of ecosystems and habitats that still exist for the monitoring study. One biological indicator proposed is still the presence of catches of tuna in coastal waters not far from the shoreline. In addition, during the study, several times in schools of fish playing surface water up to the surface with a relatively long time ( $\pm 3-5$  minutes). The mounting location gill net is also located area of coral reefs are still healthy, although it was realized that there are still remnants of the bombing waters around the reef.

Operation of bottom trap base on frame construction seaweed was done using a model Up & down system. Trap basic horizontal frame hung on the rope (PE  $\varnothing$  16 mm), and the groove movement of fishing gear on the vertical frame is controlled by a ring tin  $\varnothing$  15 cm 6 pieces @ 500 g associated with PE hanging rope  $\varnothing$  12 mm. The position of fishing gear on the frame seaweed traps dependent and always built-in water. Withdrawal trap performed in the morning or late afternoon when the fishermen to control the cultivation of seaweed. Withdrawal hanging rope made by fishermen to the hull (length 700 cm x width 80 cm x height 80 cm) to the basic traps to surface water. Examination and catches done while noting the weight and species of fish caught. After all three units of the traps have been lifted and the catch is obtained, then gradually all three basic traps the back lowered into the waters, and automatically tool will be installed and installation work at the starting position.



**Figure 4.** Figure of fish yield of traps by trips.

Bottom fish trap located at a depth of  $\pm 20$  m giving catches fish in the form of the base, including groupers, reef fish, rabbitfish, parrotfish, and others. The catch is dominated by the bottom trap were reef fishes due to the location of the bottom traps located around the reef. Some of the bottom trap catching fish are economically important valuable and captured fish still alive, so the potential for business development of floating net cages. Average catches of bottom trap about 4-6 fishes per trip with an average weight of  $\pm 2$  kg. The catch is generally still the consumption of the family, and a few others are sold directly to households around.

#### 4. Discussion

All fishing gear used can catch fish and varied day by day. This potential could be expanding to the other seaweed farmer around the local community. The problem in the traditional system is very difficult to operate fishing gear around the seaweed farming site, so the fish community developed very well and tended to eat seaweed [8,16,17]. The abundance of fish around the seaweed farming has several reasons, namely: hiding places, feeding habitat, and natural fish aggregating device (FAD). Seaweed farming becomes a new habitat for some fishes. The sustainability of those fish community depends upon the seaweed farming activities [18,19]

Student t-test results showed no significant differences ( $P < 0.05$ ) between the catch of fyke net on seaweed cultivation area and area without seaweed. Figure 3 shows a very different thing between a position on seaweed (brown) with a position without seaweed (blue). The results of the study, Najamuddin et al. (2012) showed catches gill nets and traps were more fish on seaweed farming [7]. Some researchers indicate an increased abundance of fish in seaweed farming, where the seaweed used as a natural FAD. Seaweed farming activities with commercial value has more advantages because it has high-efficiency capabilities bioremediation and nutrients are absorbed can be converted into biomass products (e.g., nutrient sink) used for growth. In addition to functioning as an agent absorbing nutrients, seaweed promising sources of nutritious food for other organisms in the vicinity (such as abalone and fish) [11,20], There are several types of seaweed has a function to provide feed on carnivorous fish [11,21]. Integration of seaweed cultivation with fishing increased incomes, seaweed farmers, in North Mamuju [7]. Several investigators have reported the integration of seaweed cultivation with aquaculture to reduce environmental impact and improve the productivity of seaweed in a region [22]. Sustainability depends on business activities integrated with each other. In this case, the integration of cultivating seaweed and oyster cultivation, as is already done in some developed countries [23].

#### 4.1 Development of the sustainable integrated system

Sustainability of the integrated system depends on the extent to which the activity of seaweed cultivation can be done. The problem faced by the farmers that seaweed cultivation is not conducted during the year due to poor environmental conditions supports seaweed cultivation. A major factor is the availability of nutrients as the main needs of seaweed growth. In general, nutrients only depend on the environmental conditions that are supplied from the flow of water from the mainland, so that in the rainy season tends to good water conditions, and the dry season is problematic. Anticipate this problem, an already developed system of integrated, commonly known as IMTA (integrated multitrophic aquaculture).

IMTA integrates raising plants and/or animals (which are usually lower on the food chain), with salmon in the same enclosure in an attempt to reduce organic waste. Waste is mostly fish feces, uneaten food pellets, and the dust or "fines" from food pellets broken during shipping and handling that are released into the water from open net-cage salmon farms. Species like seaweed, mussels, and other invertebrates are able to take up some of these organic wastes and, therefore, potentially reduce their accumulation. IMTA is an interesting effort at lessening some waste-related impacts of salmon farming. However, IMTA fails to address some of the key environmental impacts like sea lice and diseases that are causing so much trouble for wild salmon, nor does it stop escapes of farmed fish into the wild.

#### 5. Conclusion

Gillnet, bamboo traps, and fyke nets were potential fishing gear used underneath of seaweed farming and can upgrade the seaweed farmer income. Fish caught around seaweed farming contributed significantly toward fishermen's income. Improving seaweed farming productivity due to removing fish from the seaweed farming area conducted through an integrated aquaculture system.

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