Polyculture seaweed *Gracilaria* sp. and milkfish in the pond

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Abstract. Seaweed *Gracilaria* sp. and milkfish are euryhaline fishery commodities. Both of these commodities can be cultivated by polyculture in ponds. Polyculture is a mixed cultivation technology between two or more commodities that can increase aquaculture production and provide value added cultivators as it can harvest several products in one season. Polyculture seaweed *Gracilaria* sp. and milkfish are done at Marana Experimental Pond Installation, Research Institute for Coastal Aquaculture, Maros South Sulawesi with extensive technology system, using 1 plot of pond size 10,000 m². Preparation of the pond begins with the repair of dikes, patching leaks and repair of sluices. Next is draining ponds, eradicating pests with 20 ppm saponin, pond flushing, subsequent fertilizing and preparation of water for dispersal. Initial fertilization is done by using Urea and TSP fertilizers with doses of 100 and 50 kg/ha. Seaweed seed stocking in ponds as much as 2,000 kg/ha was done in March using a broadcast method, i.e., seed stocked in all parts of ponds. The milkfish seeds are also stocked with a dense stocking of 1,000 tails/ha. The first harvest of seaweed can be done after the maintenance period of 3.5 months. The next harvest can be done every 30-45 days. Total production of dried seaweed reached 8,284 kg/ha (5 times harvest/year) and milkfish harvest reached 375 kg/ha.

Keywords: *Gracilaria* sp.; milkfish; polyculture; pond; production

1. Introduction
The Ministry of Maritime and Fisheries make seaweed as the main superior commodity of aquaculture fishery because besides having strategic value in supporting the national economy, seaweed farming also becomes an effort which has a touch aspect of society empowerment. National seaweed production data within five years (2011-2015) showed a positive upward trend, with an average increase of 22.25%. In 2015 the national seaweed production volume reached ±11.2 million tons with production value reaching 13.2 trillion rupiah or up 9.8% from the previous year which reached ±10.2 million ton [1]. In 2019, the Marine and Fisheries Ministry (KKP) targets seaweed cultivation to reach 19.5 million tons, while in 2014 the seaweed cultivation production is only 10.23 million tons. Efforts are made to achieve these targets, one of them through the monoculture system in the sea and the polyculture system in the pond. The polyculture system in addition to optimizing land productivity also prevents disease attacks on shrimp farming [2].

Polyculture is a mixed cultivation technology between two or more commodities that can increase the production of ponds and provide value-added cultivators. Polyculture is a joint cultivation of various fish species with the same trophic level. These organisms jointly perform biological and chemical processes with several synergistic benefits in the ecosystem. The polyculture system actually brings together a variety of species with dense dispersion and low cultivation management in a pond [3].
**Gracilaria** cultivation can be done in monoculture and polyculture with shrimp and milkfish in ponds. By using the polyculture cultivation system to improve the efficiency of pond farming and sustainable cultivation income [4], it can also improve the quality of pond environment which recently tended to decline.

Important factors that determine the success of polyculture of seaweed and milkfish include location selection, pond construction, pond preparation, use of quality seeds, cultivation methods, handling during maintenance and harvesting. This paper describes the polyculture technique of *Gracilaria* sp. and milkfish which is useful for increasing the production of prior commodities in aquaculture.

2. **Location selection**
Polyculture seaweed of *Gracilaria* sp. and milkfish were done at Marana Experimental Pond Installation, Maros Regency. The location of this pond is adjacent to the Marana River in the north while in the West, East and South borders with ponds of local residents (figure 1). The source of water for cultivation comes from the sea which is about 5 km from the Marana Experimental Pond Installation supplied through the Marana River. The location of ponds should be located in coastal areas that still have tidal influences or are located between the highest and lowest tides as most polyculture farms are extensive ponds that still rely on gravity/tidal for filling and replacing water. Pond land is not a sulphate acid soil or peatland farms. Good soil is a mixture of clay and clay deposits containing organic matter because this type of soil can store water or waterproof and is good for natural feed growth. The location of the pond is not far from the source of production facilities and marketing areas, besides the location of the pond has access to transportation. According to Syahid *et al.* [5] several considerations that must be considered in determining the location of polyculture ponds:
1) Close to both fresh and marine sources.
2) Transportation facilities such as roads are available so as to facilitate transportation from fishponds and ponds.
3) Not flood areas. Sea tide height between 1.5-2 m.
4) Far from pollution waste.
5) The degree of acidity between 7-7.8.
6) Salinity between 10-30 ppm.

![Figure 1](image-url) Location of polyculture seaweed *Gracilaria* sp. and milkfish.

3. **Construction of pond**
Ponds used for polyculture of seaweed and milkfish measuring 0.25-1 ha/plot, rectangular or square, there are entrance doors and water discharge doors. Water doors can be made of PVC pipe equipped with upright pipes for water change. Entrance and expenditure doors should be equipped with warnings to prevent wild fish from entering the ponds. Pond bottom is made tilted toward the drainage door for easy drying. Made caren around ± 4 m width and 50 cm depth for easy harvesting and draining of ponds.
To facilitate the replacement of water in the pond in need of a main drain that serves to drain water from the river. This main channel consists of an inlet and outlet which must be separated in different places.

The main embankment is a building that surrounds ponds that are useful for retaining water and protecting pond units from flood, erosion and tidal hazards. Therefore, the main bunds should be built really strong, free from leaks and safe from possible landslides. The embankment between the bunds that separate the plot from one to another or separates the plot from the secondary channel. High embankment ± 1.5 m, width below 3 m and width of at least 1.5 m. The upper surface of the embankment must be neat and flat because it is used as a means of road in the management of ponds and serves as a place of drying seaweed crops.

4. Preparation of pond
Pond preparation aims to optimize the pond land before it is used for polyculture of *Gracilaria* sp. and milkfish seaweed. The preparation of the pond begins with the repair of embankments and patching of leaks. The function of embankment is to hold water in the pond; therefore, bunds should always be repaired before being used for cultivation. Repair of the embankment includes leaching patches and elevation of bunds to prevent the escape of cultivated fish and prevent the entry of pests and diseases from outside the pond. Lifting black mud derived from the cultivation waste (the rest of the feed and other materials that do not decompose or decompose perfectly) to the top of the embankment. This black mud can cause toxic compounds such as H$_2$S gas and ammonia that can harm the viability of fish cultivated. Sludge removal is usually done on the caren (gully). To facilitate the work, this should be done when the water level on the caren has been lowered so that the cultivation waste easily removed to the bund.

Pond drying aims to accelerate the mineralization of organic materials at the bottom of the pond, helping the oxidation of toxic substances and killing the pests left behind. After the pond water is discharged through the exhaust gate, then the remaining water in the surrounding trench is discharged using a pump. Pond bottom is made tilted toward the drainage door for easy drying. Drying is done with the help of sunlight to crack base ground for 1-3 weeks depending on the weather. Redox potential pond bottom soil in dry time should be at least + 50 mv [6].

Pest eradication is an attempt to remove residual predator pests or living compounds even though the pond is already drained. The types of pests in the form of wild fish, eels, snakes, crabs and *Cerithidea* sp. Eradication of pests in ponds other than by way of drying ponds also by using organic pesticides (saponins) with a dose of 20 ppm. Saponin is a pulp of tea seed that has been squeezed oil. The toxicity of saponins will disappear by itself within 2-3 days in the water. Before applied, first soaked until the active ingredient (saponin) can come out. Furthermore, the immersion is applied in ponds whose water has been lowered to as high as 5-10 cm. The use of saponins will be more effective during the day (between 12 am to 13 pm), when the weather is sunny (not rain).

The eradication of pests in the pond is done by the application of Good Fish Cultivation Method (CBIB) which does not recommend the use of banned pesticides such as: Brestan 60 EC, Basudrin 60 EC, Diazinon 10 G, Diazinon 90 ULV, Thiodan 25 ULV, Bayluside, Rotenon powder, Sumithion 50 EC, Sumit L 100, Aquatic, Aquadyne, Treflan, Brantas 450 EC and Brantas 1300 EC. Use of prohibited pesticides can reduce soil fertility and precipitate residues long enough in the soil [7].

After 3 days of pest eradication then the next activity is rinsing ponds. The pond is rinsed by entering new water from the feeding channel until the entire pond is submerged, then the soaking water is discharged back through the sewer. This process is repeated up to 3 times. The submerged water is discharged at low tide so that the immersion water containing toxic elements can be completely rinsed.

The next activity is to perform basic fertilization using urea and SP36 fertilizers each with a dose of 100 kg/ha and 50 kg/ha. Do not perform basic fertilization with excessive doses because it can cause rapid growth of moss so that it can disrupt the growth of seaweed and reduce the quality of dried seaweed. Fertilizer is spread evenly on the surface of the pond that muddy, then the pond filled with water to reach the maximum height (± 60 cm from the bottom of the pond pond).
5. Spreading of seeds
Seaweed seed stocking should be done 2 weeks after basic fertilization, when natural food has grown well and water quality is feasible for the life of seaweed and milkfish. Seaweed seedlings stocked in polyculture ponds come from two patches of seaweed ponds located at the Marana Experimental Pond Installation. The first seaweed pond is directly adjacent to the polyculture pond, while the second seaweed pond is located approximately 1 km from the polyculture ponds so that the seaweed seeds that have been put into the sacks must be transported first to the dock by motorcycle and then transported to the polyculture pond by using a boat through the Marana River. Seaweed seed stocking conducted in March (before dry season) because salinity water condition still optimal for growth of seaweed and milkfish. Seaweed seedlings planting in the pond is done by 4 people using broadcast method, i.e., the seeds are distributed evenly throughout the bottom of the pond. The advantages of spreading in this way are the cost, power and time spent more efficiently. Seaweed seed stocks are stocked as much as 2,000 kg/ha. *Gracilaria* sp. seed and milkfish seed can be seen in figure 2.

Good seaweed seeds are [8]:
1) Have high adaptation and high daily growth rate.
2) Seeds are 20-30 days old.
3) Appearance of cylindrical rod/thallus, clean, fresh, hard, not slimy, no smell fishy and not pale.
4) Seeds with many branches and grow centered from one part of the base and spread.
5) Seed should be homogenous, not mixed with other types.
6) Choosing seeds with elongated thallus ranging from 15-30 cm.

In the selection of grass seeds try to use the seeds from the cultivation itself or the seeds that come from the nearest location because the seeds are suitable with the location and the time required for transportation is not long. When transporting seedlings, avoid seeds from heat (direct sunlight) and keep the seeds always wet. Use cover if the sun is hot. Make a hole in the cover so that air circulation occurs. Seeds should not be exposed to fresh water. Avoid transporting seeds during rain or use tarps to protect seaweed from rain. If transporting seedlings from neighboring farms, then transport can be done by inserting seeds into sacks or placed on a canoe and taken to a pond through a water channel/canal. Try seaweed in the sack always in humid/wet conditions and there is air circulation by making a hole in the sack. Do not press the seaweed inside the sack. If the seedlings are transported remotely, before stocking the seedlings need to be adapted first by soaking the seeds with pond water [9].

![Gracilaria seeds](image1)
![Milkfish seeds](image2)

Figure 2. *Gracilaria* sp. seeds (a) and milkfish seeds (b).

Two weeks after the spreading of seaweed seedlings (seaweed has been adapted to the condition of pond waters and mosses begins to grow), the stocking of milkfish seed size ± 20 g/tail with a density of 1,000 fish/ha. Moss/green algae that are often found in *Gracilaria* sp. seaweed pond is *Enteromorpha* sp. and *Chaetomorpha* sp.. This attachment plant is competitor in absorbing nutrients for growth and
blocking the process of seaweed photosynthesis so that it can disrupt the growth of seaweed. In addition, the sticking plants found in dried seaweed can reduce the quality/price of seaweed. Milkfish is a fish that is herbivore (plant eaters) so that the presence of milkfish in polyculture ponds can reduce/control the growth of moss that can disrupt the growth of seaweed. *Gracilaria* sp. seaweed polyculture with milkfish is a business developed with the aim not only to remove moss/green algae, but to increase land efficiency and increase income. Seaweed also plays a role in the process of providing oxygen and as an absorbent carbon dioxide is expected to help improve milkfish survival.

6. Maintenance

To maintain salinity and increase dissolved oxygen levels and provide the nutrients needed for grass growth in ponds, pond water is replaced frequently and continuously, especially during the dry season. In the rainy season the water change should be set to keep the salinity in the ponds not too low. Substitution of water is done by utilizing the tides of sea water (gravity) by opening the entrance and the exit of water.

Water height in ponds of at least 50 cm. Shallow ponds can cause fluctuations in water temperature especially in the dry season. High water temperature fluctuations accompanied by increased salinity can cause seaweed thallus to be broken, resulting in seaweed growth declining even death.

Generally, the peak of growth occurs after the fourth week. The increase in growth is evident from the growing number of enlarged seaweeds grown together (not spread evenly on pond bottom). This seaweed clump of each seaweed should be spread evenly to the pond that has not been filled with seaweed. Every three weeks this activity is repeated three times. If the condition of seeds and pond water is good enough, within 3-4 months of pond bottom will be filled with seaweed.

Subsequent fertilization can be done in the second month of maintenance if the pond conditions are less fertile or seaweed growth shows slow growth. The fertilizer used is urea+SP36 with sufficient dose (each with a dose of 10 kg/ha and 5 kg/ha). Subsequent fertilization is done after the change of water by dissolving the fertilizer first and then spread evenly in the pond. Experiences obtained by the authors in the field showed that continued fertilization using urea fertilizer with a dose of 50 kg/ha can cause the seaweed thallus to wither and turn off the moss type *Enteromorpha* sp. and *Chaetomorpha* sp. Further subsequent fertilization using urea fertilizer with doses above 100 kg/ha can cause mass mortality in seaweed, so in the conduct of aftershocks in the pond must use the appropriate dose of fertilization. After subsequent fertilization, water in the pond should not be replaced immediately, but left for one week for the fertilizer to be absorbed by the seaweed.

During maintenance, water quality monitoring and management is conducted to prevent and mitigate water quality degradation. Water quality measurements during maintenance include temperature, dissolved oxygen (DO), pH and salinity performed every week. Water quality data during maintenance can be seen in table 1.

| Time       | Temperature (℃) | DO (mg/L) | pH    | Salinity (ppt) |
|------------|-----------------|-----------|-------|----------------|
| July       | 28.3-29.8       | 1.01-4.07 | 8.0-9.0 | 20-27          |
| August     | 25.6-28.9       | 1.38-2.91 | 8.0-8.4 | 34-40          |
| September  | 28.0-31.0       | 2.22-3.36 | 8.0-8.7 | 35-45          |
| October    | 28.0-29.31      | 1.99-3.99 | 8.1-8.6 | 39-44          |

The water temperature during maintenance ranges from 28.0-31.0 ℃, dissolved oxygen 1.01-4.07 mg/L and pH ranges from 8.0 to 9.0. This value is still within reasonable limits for the maintenance of seaweed and milkfish. The water temperature required for seaweed cultivation in ponds ranges from 18-30 ℃, with an optimum temperature of 20-25℃, dissolved oxygen ranges from 3-8 mg/L and pH ranges from 6-9 with an optimum range of 6.8-8.2 [10]. According to [11], the good water temperature for milkfish is 27-31 ℃, the dissolved oxygen range is 3-8 mg/L and the pH of water is 7.0-8.5.
The results of salinity measurements on polyculture ponds of seaweed and milkfish in July ranged from 20-27 ppt, this value is optimal for the growth of seaweed and milkfish. In August, the measured salinity ranged from 34 to 40 ppt, this range was still tolerable by *Gracilaria* sp. grass, but the measured salinity value > 40 ppt in September and October was high and less feasible for *Gracilaria* sp. Eligible salinity for seaweed growth in ponds ranges from 12-30 ppt with optimum value is 12-25 ppt. Maximum growth of *Gracilaria* seaweed originating from the Atlantic and Eastern Pacific at the time of cultivation is at salinity 15-38 ppt with optimum 25 ppt [10]. Euryhaline milkfish is resistant to large salinity changes, so the milkfish can live in brackish water (salinity 10-25 ppt) and even in fresh water [12]. In addition, milkfish are adaptable and have high tolerance to salinity (0-60 ppt) [13].

7. Harvest
Seaweed harvest can be done after the planting time reaches 3.5 months. How to harvest is done by taking and putting seaweed on a styrofoam raft or boat, walking forward while leaving the seaweed as a seed for the next harvest (figure 3). Seaweed washing is done when harvesting seaweed from ponds by dipping back the seaweed into the water while being shaken before being raised on the raft. This leaching aims to remove the mud that attaches to the seaweed that can reduce the quality of dried seaweed. The number of seaweed harvesters for a 1 ha pond is 2 people. Each person can harvest dried seaweed up to 100 kg per day, depending on the weather. Harvesting time is done in the morning until the afternoon. In general, harvesting is done by leaving some of the seaweed to be used as seeds. After harvesting of seaweed, then carried out the maintenance of seaweed seeds until the next harvest. The next stage of harvest takes about 40 days depending on the density of the stocked seedlings.

The next process is drying seaweed on pond embankment by using black net (mesh size 1 mm) as a base for 1-2 days (depending on the sun). Seaweed is said to have dried when it has blackish color, stiff and salt granules already attached to the surface. Once dried, the seaweed is cleaned of dirt, a cassette and soil, then packing in a plastic bag weighing 40-50 kg per sack. Depreciation of seaweed from wet to dry after drying is a nine to one (9 tons of wet harvest will be 1 ton of dried seaweed).

The production of dried seaweed in July 2017 was 2,854 kg/ha, in August 2,245 kg/ha, in September 1,185 kg/ha and in October to November estimated at 2,000 kg/ha so total production of seaweed dry reach 8,284 kg/ha/year (5 times harvest/year). In mid-October, rain began causing the harvest and drying of seaweed did not run optimally. High seaweed production usually occurs in July to September because the water quality in the ponds, especially the optimal conditions of salinity and no rain that can interfere with the harvesting and drying of seaweed. The price of dried seaweed at the collecting rate is Rp 4,700-5,200/kg. The yield of milkfish in October reached 375 kg with the sales reach Rp. 5,625,000.

![Figure 3. Harvesting (a) and drying the seaweed (b).](image-url)
Table 2. Economy analysis of polyculture *Gracilaria* sp. with milkfish.

| Description                              | Total | Price (Rp) | Total (Rp) |
|------------------------------------------|-------|------------|------------|
| **INVESTMENT**                           |       |            |            |
| Styrofoam raft (unit)                    | 2     |            |            |
| Equipment for drying/black net (roll)    | 3     | 250,000    | 500,000    |
| **SUB TOTAL**                            | 1,700,000 |          |            |
| **OPERATIONAL COST**                    |       |            |            |
| Seaweed seed (kg)                        | 2,000 | 1,000      | 2,000,000  |
| Milkfish seed (tail)                     | 1,000 | 200        | 200,000    |
| Inorganic fertilizer (kg)                | 250   | 2,300      | 575,000    |
| Saponin (kg)                             | 30    | 10,000     | 300,000    |
| Maintenance of ponds (packages)          | 1     | 500,000    | 500,000    |
| Harvest seaweed wage (kg)                | 8,284 | 1,500      | 12,426,000 |
| **SUB TOTAL**                            | 16,001,000 |          |            |
| **SHRINKAGE OF INVESTMENT**              |       |            |            |
| Styrofoam raft (5 years)                 | 2     | 100,000    | 100,000    |
| Equipment for drying/black net (5 years) | 3     | 240,000    | 240,000    |
| **SUB TOTAL**                            | 340,000 |          |            |
| **TOTALCOST**                            | 1     | 14,350,000 | 16,341,000 |
| Seaweed sales (kg) (5 times harvest/year)| 8,284 | 5,000      | 41,420,000 |
| **D MILKFISH SALES (kg)**                | 375   | 15,000     | 5,625,000  |
| Wages of the pond keepers (20% of profits)| 5,935,000 |          | 6,140,000  |
| **PROFITS/HAA/ YEAR**                    |       |            | 24,564,000 |

8. Conclusion
Polyculture seaweed *Gracilaria* sp. and milkfish with dense seed stock of 2,000 kg/ha and milkfish seed 1,000 fish/ha for 8 months of maintenance (5 times of harvest/year), dry seaweed production reach 8,248 kg/ha and milkfish production reached 375 kg/ha with profit of Rp. 24,564,000 (table 2). Polyculture seaweed *Gracilaria* sp. and milkfish is feasible to be developed because it can increase farmer’s income and can support the increase of seaweed *Gracilaria* sp. and milkfish production national scale.

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