The International Journal of Business Management and Technology, Volume 6 Issue 1 January-February 2022
ISSN: 2581-3889

Research Article Open Access

Improving Productivity of PANDU (Integrated Rice and Shrimp Farming System) towards Sustainable Aquaculture of Indonesia

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Abstract: *PANDU (integrated rice and shrimp farming system) is the first research program in Indonesia with the application of rice mina in saline land. This program applies the only commodity of black tiger shrimp (Penaeus monodon) with INPARI 34 Salin Agritan and INPARI 35 Salin Agritan. The PANDU was implemented in the first period (2018) with shrimp production still low, i.e., an average of SR 12% due to biota infected with WSSV and stress due to pesticide effects application. This study aims to increase the value of productivity in the second period (2019) through the kaizen approach and fishbone analysis. The study lasted for three months (4 March-1 June 2019) at the Barru PANDU research site. The number of observation plots was two out of six fields. Some interventions are: improving the quality of human resources, improving water quality, improving feed management, replacing pesticides with biopesticide, and applying biosecurity. Parameters analyzed were: SR, FCR, ABW, SGR, length, and daily growth rate of shrimp, water quality: temperature, salinity, pH, alkalinity, DO, ammonia, nitrate, nitrite, and plankton. The results of implementing the intervention increase the average SR value in 2019 by 27.33% and the productivity value was increasing by IDR 4,571,500.00 from IDR 7,200,000.00 (2018) to IDR 11,771,550.00 (2019).*

Keywords: *Fishbone Analysis, Kaizen, PANDU, Productivity, Sustainable Aquaculture*

I. Introduction

The potential of rice fields in South Sulawesi that are intruded by seawater in high tide conditions is quite large especially those close to beaches or shrimp farms. The land is generally abandoned by the owner because it is considered unfit to be planted by rice so that it becomes idle land. On the other hand, the Government of South Sulawesi Province urges that the development of black tiger shrimp cultivation *(Penaeus monodon)* continues. Black tiger shrimp (*P. monodon)* is a marine crustacean (Rungrassamee et al., 2014) with a source of high-quality animal protein (Pratiwi, 2008), prima donna commodity non-oil and gas export from the fishery sector (Maharani et al., 2009) with important economic value in the world market (Oosterveer, 2006; Chaiyapecharaet al., 2012; Kaur et al., 2012).

Following up on the idle land utilization efforts, the Ministry of Marine Affairs and Fisheries of the Republic of Indonesia (KKP-RI) in 2018 initiated a collaborative research program of "Mina Padi Air Payau dan Udang Windu" (PANDU-KKP, 2018). The application of research through the optimization of the method of overlapping on seawater-intruded land so that it becomes aquaculture and agricultural activity. Through the program, it is expected to optimize the use of potential marginal land in real terms, minimize the transfer of land functions into settlements, and increase fishery production.

The program implemented black tiger shrimp commodity (*P. monodon)* superior research results of Black Tiger Shrimp Seeding Installation or IPUW Barru, RICAFE Maros, South Sulawesi, and genetically engineered rice seeds by The Center for Rice Plant Research (BBP Rice) Sukamandi, West Java which can be used for rice fields in tidal areas with salinity <7 ppt, namely rice varieties INPARI 34 Salin Agritan and INPARI 35 Salin Agritan.

The program was implemented in the first period of 2018 with low shrimp production, which is an average Survival Rate (SR) of 12%. Therefore, the need to increase productivity to increase the production value. Productivity improvement was carried out in the second period in 2019 which is expected to increase SR by 18-22% and achieve a Feed Conversion Ratio (FCR) value of 2.1-2.3. The purpose of this research is to increase PANDU productivity through the kaizen and fishbone analysis approach.

II. Materials and Methods

This research was conducted at the PANDU Barru research site. PANDU research activities consist of location determination, land reconstruction and processing, seeding, rice planting and maintenance, shrimp distribution and maintenance, and harvesting. The number of PANDU maps observed is two out of six maps namely plots 1 and 2. The area of plot 1 is 2,300m^2 (1,610m^2 rice fields and 690m^2 shrimp land) while the 2 plots are 1,200m^2 (840m^2 rice fields and 360m^2 shrimp land) with a water level of 50 cm. The number of shrimp scattered is 1,200 shrimp (plots 1) and 1,000 shrimp (plots 2) with a density of 2-3 shrimp/m^2. Before scattering, black tiger shrimp seed (*P. monodon*) stadia of Post Larva 12 is brought up until the maintenance life (DOC) 50 days (0.03 g, 3 cm). The co-ed seed is equipped with an aeration system and adapted to low salinity slowly (1 g/L per day) up to 5 g/L.

The research method is done through the kaizen approach. The initial stage, starting from the statement of problems obtained after identification in the field and from previous research data. Furthermore, the specified problems are analyzed using Ishikawa Diagram (fishbone analysis), including man, method, material, and mother nature (environment). The third phase is followed by the selection of a solution that has been determined based on the principle of ease of cost and impact. The intervention solution is selected, then implemented while collecting data after implementation as a material of monitoring and evaluation of its effectiveness. A successful intervention is measured by increased productivity or achievable targets. If it does not work, another solution is implemented and returned to the implementation stage.

III. Results

The performance of cultivation performance based on crop yields in 2018, obtained an average SR value of five maps is 12% while the value of SR plots 1 and 2 is 0%. The value is still low and does not meet the production target. As for the production target, that is, the average value of SR 18-22%. In addition to the SR value, the problem that occurred in the PANDU research program 2018 is the absence of clear feed recapitulation so is not known the accurate FCR value of the program. FCR target is 2.1-2.3.

Therefore, identification is required to fix these problems. Identification of problems using fish bone analysis is presented in **Figure 1** and the application of intervention in **Table 1**.

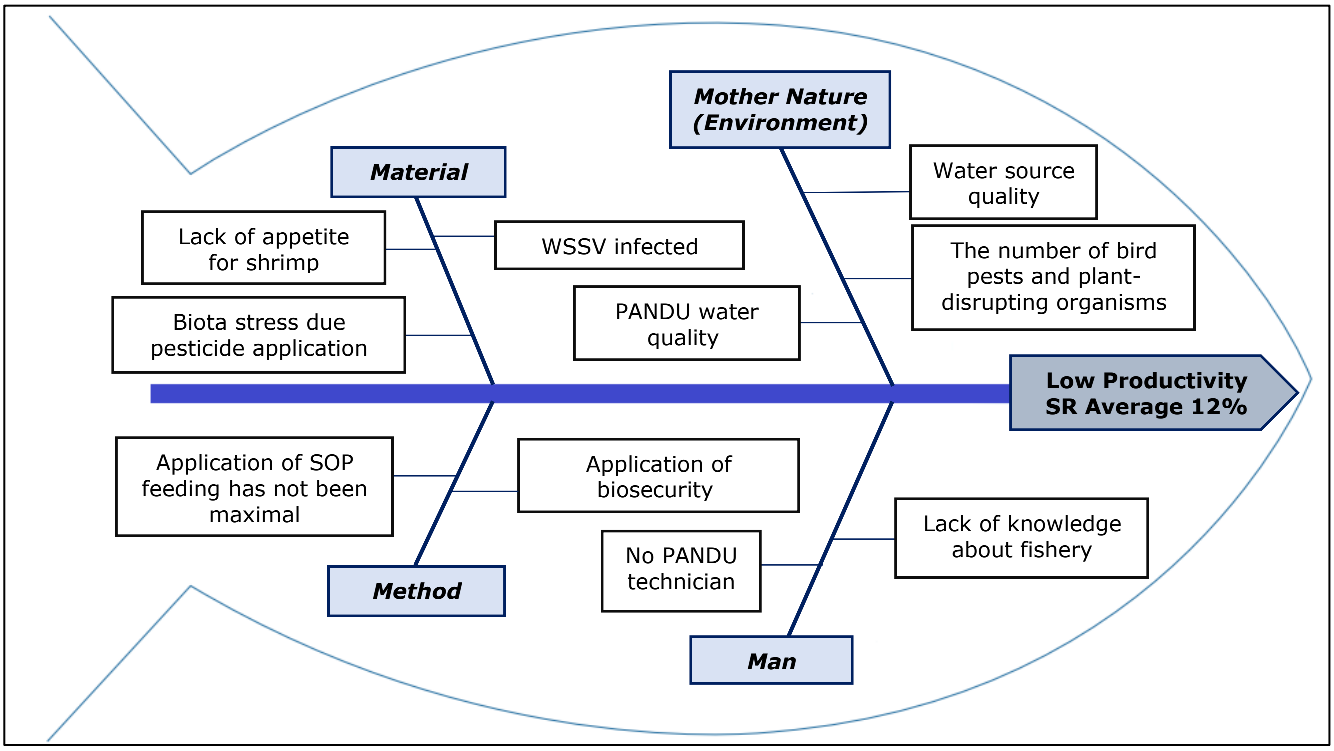

Figure 1. Fishbone analysis of PANDU

Table 1. Application of Intervention

Num.	Application of interventions
1.	Do it now
	1. Improvement of human resources quality:
	a. Socialization and discussion of black tiger shrimp cultivation activities (*P. monodon)* to PANDU farmers
	b. HR recruitment as a temporary technician or field supervisor (field supervisor) for controlled research activities every day
	2. Water quality improvements:
	a. Regular measurement of water quality parameters
	b. Regular water change
	3. Feed management:
	a. Calculation of feed program according to sampling results
	b. Feed weighing according to feed program and given evenly
	4. Other improvements:
	a. Replacing pesticides with biopesticide
	b. Application of biosecurity
2.	Do it if there's time
	1. Application of Bird Scaring Device (BSD)
3.	Planned
	1. BSD implementation
	2. Recruitment of PANDU special technicians not from research/cpractical students

Application of intervention based on fishbone analysis*:*

1. Man

Human resources that are directly involved in the PANDU research program. The human resources that are in the research site are PANDU farmers. The need to improve the quality of human resources through socialization and discussion activities related to the cultivation of black tiger shrimp (*P. monodon)* so that farmers get additional experience. This has had a positive impact on farmers because so far activities have relied on self-taught capabilities. Also, farmers get new knowledge in the field of fisheries, seeing the background of PANDU farmers as farmers. The influx of PANDU around rice fields and ponds gives a new picture of the integrated cultivation activities between rice copy tolerance and shrimp black tiger commodity (*P. monodon*). Furthermore, the need for additional human resources in the form of special technicians PANDU or field supervisor to conduct daily control, either feed program, water quality, shrimp condition observation, and others. The arrival of student of semester VIII JTUF in 2019, Angkasa Putra who carried out the research, gave a positive effect on PANDU activities in the second period. In addition to the condition of shrimp can be observed daily in ancho, the application of feed program can be controlled, measurement of water quality parameters especially pH, temperature, and salinity can be done daily (morning and evening).

2. Material

Biosecurity is carried out to prevent biota from being infected with WSSV. Forms of application that have been done include sterilization of the body before descending to PANDU map, using a sieve when putting water into PANDU map as well as sterilization of mesh and plankton net before use with 60% chlorine. Replace pesticides with biopesticides to prevent biota stress (pesticide application effect). This has a positive impact on biota so as not to cause any more poisoning.

3. Method

Generally, water quality parameter checks are only done twice a month so the need to take regular water quality measurements (daily) such as pH, temperature, and salinity. This aims to know the condition of the water every day, so that action can be taken if the value obtained is not optimal. Also, water changes are carried out periodically. The feeding technique must be following the Standard Operating Procedure (SOP) which is to weigh the amount of PANDU maize feed, then given evenly, so that FCR calculation can be more accurate and reach the production target. Previously, the calculation of the feed program was based on sampling results.

4. Mother nature

The implementation of the proposed BSD has not been possible. The alternative applied is the scarecrow. It aims to repel bird pests that attack rice. Also, biopesticide spraying (13 mg/L, 2 times per week) is carried out on rice plants that aim to destroy the invading OPT (rice stem grinder, leaf folding, leaf caterpillar, white butterfly, and bad-smell grasshopper). Both applications have been implemented but the results are not yet maximal.

The application of biosecurity to the PANDU environment, such as the installation of water filters on the inducts in each PANDU map. The application is done because looking at the value of PANDU water source quality parameters is not optimal which impacts the water quality on the PANDU map. The improvement effort is to change the water periodically by maintaining a salinity of 3-5 g/L, both on rice and shrimp land. Also, the measurement of water quality parameters is carried out regularly.

Results of the application of interventions

The results of the intervention conducted in the second period of PANDU research (2019) can be seen from several aspects including: including observation of growth, water quality parameters, crop yields, and profit margin. Growth observations include calculation of Average Body Weight (ABW) value, Specific Growth Rate (SGR), shrimp length, and daily long growth rate of shrimp during maintenance. The results of the ABW calculation are presented in **Figure 2** and SGR in **Figure 3**.

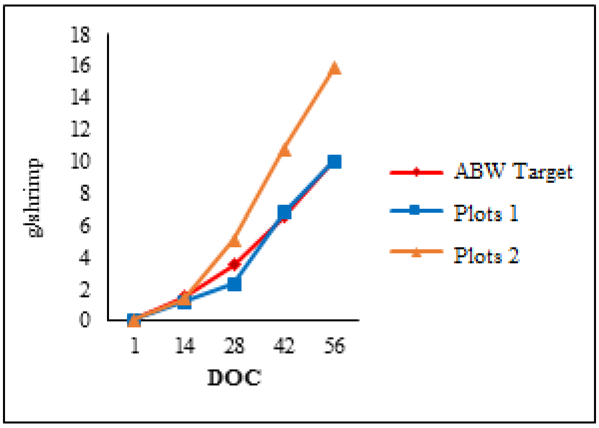

Figure 2. ABW value of black tiger shrimp (*P. monodon*)

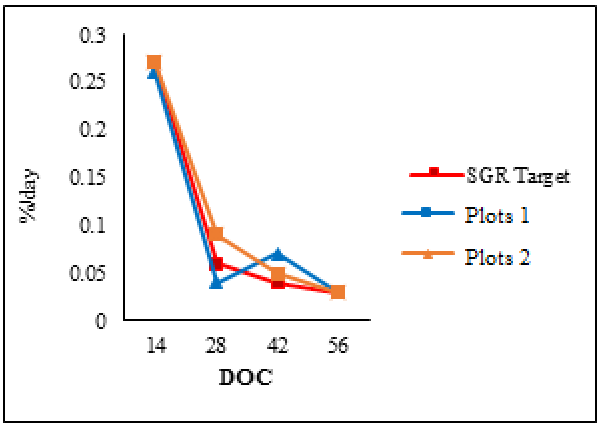

Figure 3. SGR value of black tiger shrimp (*P. monodon*)

The average value of shrimp length measurement is presented in Table 2, with the daily length growth rate during maintenance being 0.17 cm/day (plot 1) and 0.20 cm/day (plot 2).

Table 2. The average length of black tiger shrimp (*P. monodon*)

Day of Culture	Plots 1 (cm)	Plots 2 (cm)
14	5,37	5,65
28	6,95	7,95
42	8,29	10,60
58	11,02	13,01

Based on Figure 2 and 3 and the growth rate of the daily length and average length of prawns, it can be concluded that the growth of shrimp plots 2 is faster than with plots 1. This is due to the appetite of shrimp on a plots 2 higher than that of a plots 1 shrimp. Evidenced by the state of feed on ancho plots 2 faster depleted and often found a feed that does not run out on ancho plots 1. Furthermore, the average result of measuring PANDU water quality parameters is presented in **Figure 4**.

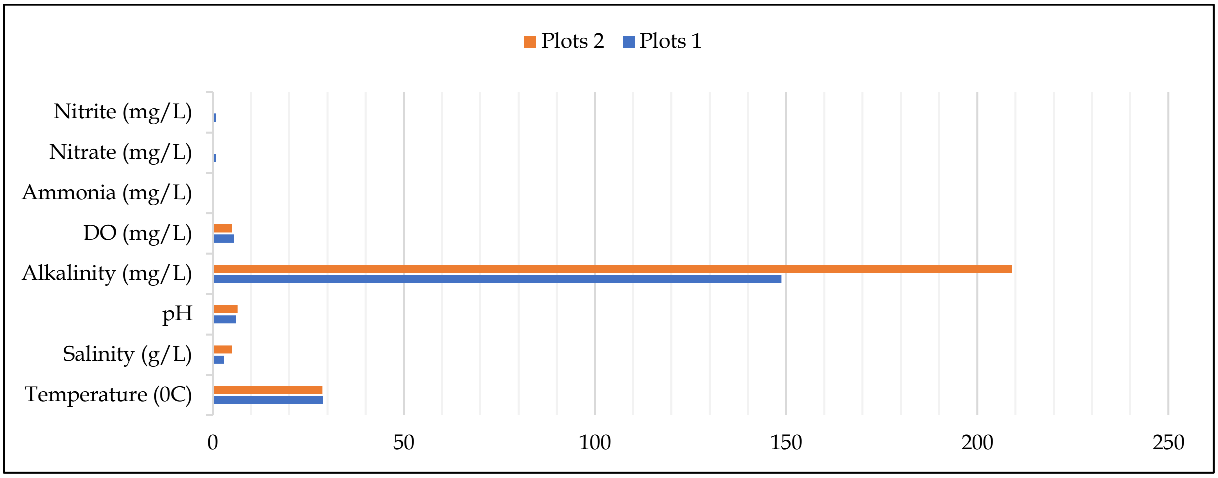

Figure 4. The average measurement of PANDU water quality parameters

Based on the results of these measurements, there are two less optimal parameters (salinity and alkalinity) and six optimal parameters (temperature, pH, DO, ammonia, nitrate, and nitrites), but shrimp can still survive in those conditions and support rice growth. The average value of the measurement of water quality parameters in plots 1 and 2 is: temperature 28.8^{0}C and 28.7 0^{0}C, salinity 3 g/L and 5 g/L, pH 6.1 and 6.5, alkalinity 148.74 mg/L and 209.04 mg/L, DO 5.6 mg/L and 5.0 mg/L, ammonia 0.35 mg/L and 0.39 mg/L, nitrate 0.84 mg/L and 0.32 mg/L, and nitrites 0.84 mg/L and 0.32 mg/L. Besides, some types of plankton found to consist of seven types of phytoplankton namely: *Coscinodiscus* sp., *Navicula* sp., *Nitzschia* sp., *Oscillatoria* sp., *Protoperidinium* sp., *Plagiotropis* sp., *Pleurosigma* sp. and five types of zooplankton namely: *Brachionus* sp., *Apocyclops* sp., *Nauplii copepoda*, *Tortanus* sp. and *Echinocamptus* sp. Furthermore, the PANDU harvest of 1 and 2 plots in 2019 is presented in **Table 3**.

Table 3. Black tiger shrimp harvest (*P. monodon*)

		Yields	
Parameters	Target	Plots 1	Plots 2
Age (day)	60	62	62
Size (shrimp/kg)	100	100	63
ABW (g/shrimp)	10	10,00	15,87
SGR (%)	0,03	0,03	0,03
Length (cm)	10-13	11,02	13,01
Cumulative feed (kg)	18-30	23,24	18,07
Biomass (kg)	15-28	0,27	8,32
SR (%)	18-22	2,25	52,4
FCR	2,1-2,3	86	2,1

The yield of plots 2 is better than plots 1. SR acquisition after the intervention is good enough when compared to SR in 2018, which is 0% on plots 1 and 2. SR values increased from the previous period, by 2.25% (plots 1) and 52.4% (plots 2), with an average SR of 27.33%, so it can be concluded that the average target value of SR is 18-22% or an increase of 5.33-9.33% in 2019 (**Figure 5**).

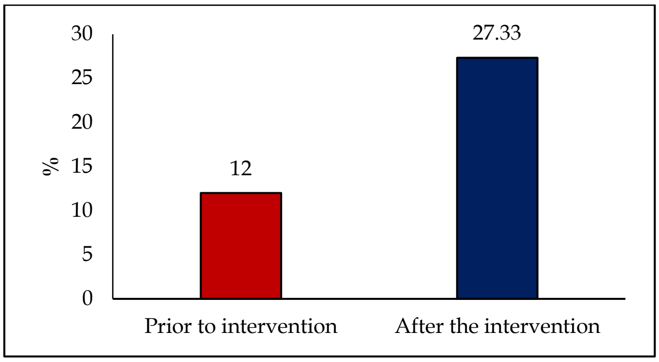

Figure 5. Comparison of SR black tiger shrimp (*P. monodon*)

The FCR value in plots 2 is in line with the production target of 2.1 while the high FCR gain in plots 1 is due to the number of dead shrimp. The death was caused by suspected environmental pollution from community shrimp farms around PANDU. During the maintenance of doc shrimp 50-53 in PANDU map, the community of owners of the pond around doing the harvest of vannamei shrimp (*L. vannamei*). The waste of organic material from the pond flows towards the rice fields of the community through the PANDU map. The waste line is directly adjacent to plots 1 while plots 2 are isolated by plots 1. Departing from this, the waste of the community's ponds seeps into plots 1 resulting in the number of dead shrimp. Water quality checks are not carried out on the waste line so there is no water quality value to support the assumption of the death of shrimp plots 1.

The success of the improvement based on the interventions made can be seen in the economic aspects. Calculation of economic value using the assumption of the price of black tiger shrimp (*P. monodon)* size 63 and 100 in May 2019, IDR 90,000.00/kg and IDR 75,000.00/kg respectively and grain price of IDR 4,500,00/kg. Biomass obtained, namely 0.27 kg (plots 1) and 8.32 kg (plots 2) with grain yield on each plots is 1,300 kg (plots 1) and 1,145 kg (plots 2). So the result is IDR 5,870,250.00 (plots 1) and IDR 5,901,300.00 (plots 2).

Previously in the first period of 2018, the total biomass of shrimp obtained, each 0 kg (SR 0%) and grain yield is 1,200 kg (plots 1) and 600 kg (plots 2). The price of grain/kg in 2018 is lower which is IDR 4,000.00/kg because rice production in PANDU activities is carried out in the dry season. So that the result obtained is IDR 4,800,000.00 (plots 1) and IDR 2,400,000.00 (plots 2), it can be concluded that the difference in profit from before the intervention and after intervention is IDR 1,070,250.00 (plots 1) and IDR 3.501,300,00 (plots 2) or increased by IDR 4,571,500.00 from IDR 7,200,000.00 (2018) to IDR 11,771,550.00 (2019) (**Figure 6**). An illustration of the impact of the intervention on productivity improvement is presented in **Figure 7**.

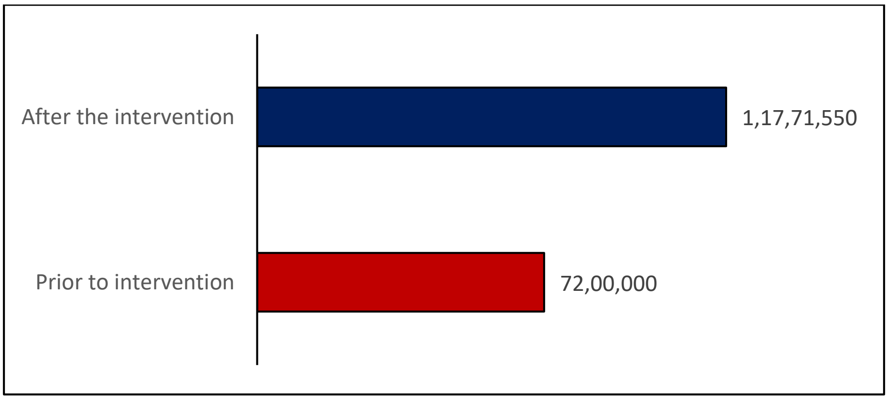

Figure 6. PANDU productivity value comparison

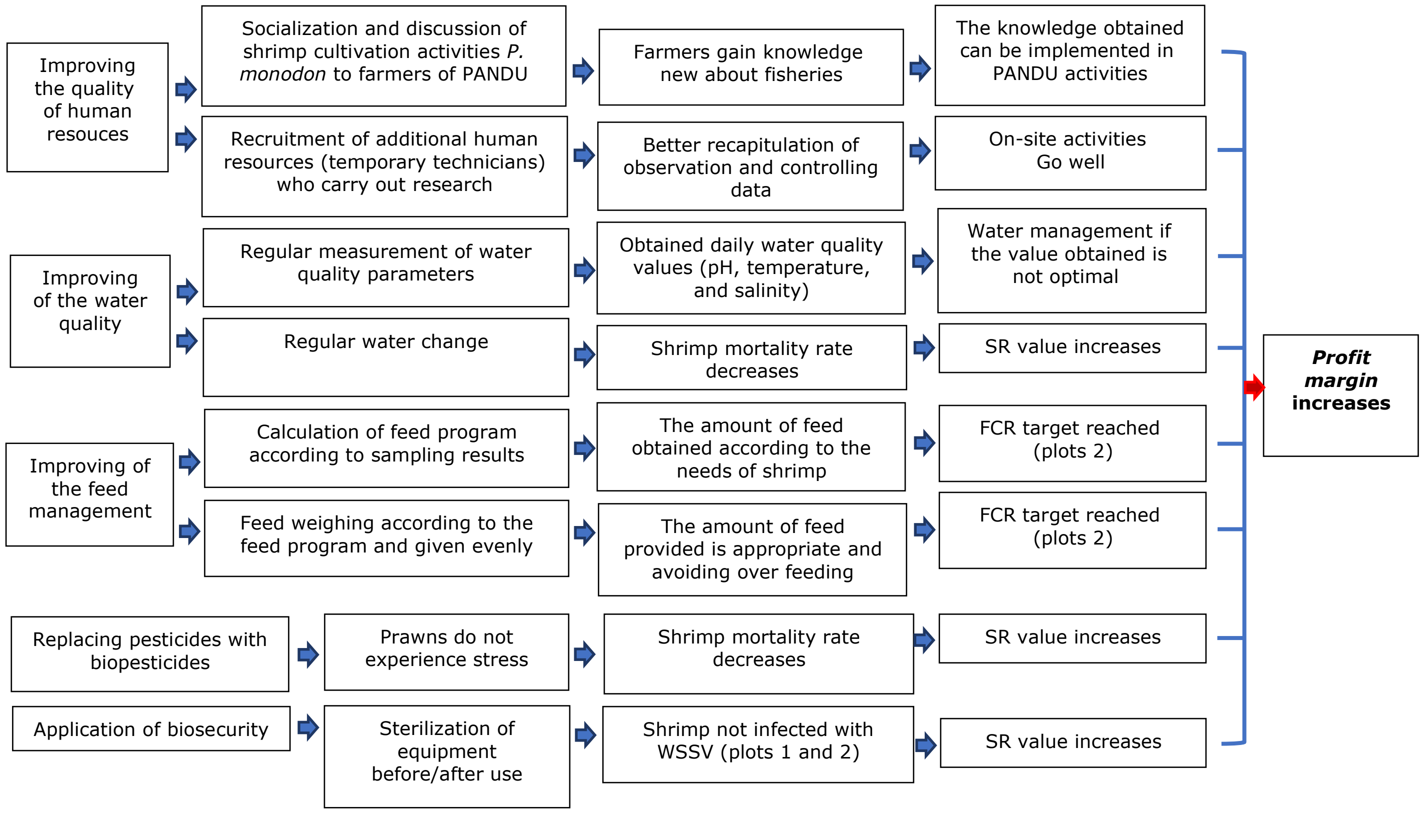

Figure 7. Illustration of the impact of the intervention on improving PANDU productivity

IV. Discussion

The SR value is an indicator of the production value of black tiger shrimp (*P. monodon)* in South Sulawesi Province with an average SR of at least 18% and a maximum of 22%. According to Supono (2017), SR of black tiger shrimp (*P. monodon)* is lower than vannamei shrimp (*Litopenaeus vannamei*) because black tiger shrimp seed (*P. monodon)* does not belong in the category of Specific Pathogen Free (SPF). Until now, black tiger shrimp brood (*P. monodon)* is still obtained from nature so it has not been able to produce seeds that are SPF while shrimp seed vannamei (*L. vannamei*) can already be obtained from the mother that has been successfully domesticated so that the resulting seed is not wild and the level of cannibalism low.

The low SR value obtained in 2018 is due to biota infected with White Spot Syndrome *Virus* (WSSV) disease and pesticide application effects. This is supported by research (Muliani et al., 2007), that 90% of the areas in South Sulawesi have been infected with WSSV. Soto et al. (2001) added that the low SR is influenced by the resistance of black tiger shrimp (*P. monodon)* which is weaker against disease when compared to shrimp vannamei (*L. vannamei*).

Based on the literature, FCR on shrimp farming (*P. monodon)* is 2.18. The high value of FCR is influenced by the use of inefficient feed (Supono, 2017) and environmental conditions that are less supportive e.g. changes in salinity that have a high effect on the utilization of energy in the shrimp body (Ye et al., 2009). In contrast to Syafaat et al. (2017), it has an FCR value of 1.82-2.26 while according to Banun et al. (2007), the good FCR range for shrimp cultivation is 1.30-2.02.

Regular measurement of water quality parameters aims to prevent shrimp from contracting the disease. The measurement as a control, if clinical symptoms are found in the disease in cultivated biota, preventive measures can be taken. This is supported by Sahrijanna & Septiningsih (2017), that inadequate water management will adversely affect the cultivation biota and can lead to the development of diseases so that the quality of the environment is disturbed.

Some libraries mention that the temperature range in black tiger shrimp cultivation (*P. monodon*) between 25.5-37.2^{0}C (Ratnawati et al., 2014), 27.0-30.5^{0}C (Hardanu et al., 2016), and 28-30^{0}C (Hartinah, 2015). The salinity range is 3-5 g/L. The range helps rice varieties in their growth. This is supported by the research of Karawang Aquaculture Production Business Service Center (BLUPPB), that black tiger shrimp cultivation (*P. monodon)* with low salinity (3-5 g/L), can grow well and does not show lower growth than growth in media with normal salinity. This is done to minimize WSSV attacks and become the hope of sustainable shrimp cultivation (*P. monodon*) (Prihutomo et al., 2016). During maintenance, the lowest pH value reaches 2.9 and the highest at 9.2. The low pH value is due to the location close to the mangrove area as well as the state of the newly used land so that no remediation has been carried out.

Conversely, the high pH value leads to an increase in the concentration of ammonia that indirectly harms shrimp. This is supported by the statement of Utojo et al. (2009), that the new pond is mainly in the mangrove area and has not been remediated, the water pH is very low i.e. below 5. The direct effect of low pH on shrimp cultivation activities is that shrimp become porous and always mushy because they cannot form new skin, otherwise a high pH causes an increase in the concentration of ammoniac that indirectly harm shrimp and can be toxic to the organism. The pH value in shrimp cultivation ranges from 7.3 to 8.7 (Utojo et al., 2009). According to Hardanu et al. (2016)and Prihutomo et al. (2016), pH >9 is a less optimal condition for black tiger shrimp cultivation (*P. monodon)*and optimal in the range of 7.6-8.9 while according to Ratnawati et al. (2014) ranges from 4.3 to 9.3. According to Prihutomo et al. (2016), the value of alkalinity in black tiger shrimp cultivation (*P. monodon)* ranges from 130-214 mg/L or 120-400 mg/L. According to Utojo et al. (2009), the concentration range of DO 2.6-11.0 mg/L is still in the category of good for pond cultivation activities whereas according to Ratnawati et al. (2014), ranging from 1.3-19.5 mg/L. According to Hartinah (2015), the ammonia concentration ranges from 0.003-0.039 mg/L. Izzati (2011) argues that, the concentration of nitrates in black tiger shrimp cultivation (*P. monodon)* is 0.02-2.25 mg/L. The maximum value of nitrites concentration in black tiger shrimp cultivation (*P. monodon)* low maternity is 0.35-0.37 mg/L (Hardanu et al., 2016). Sahabuddin & Suwoyo (2018) argues that, plankton which is often found in the cultivation of black tiger shrimp (*P. monodon*) consists of phytoplankton and zooplankton. Types of phytoplankton for example *Chaetoceros* sp., *Oscillatoria* sp., *Nitzchia* sp., *Navicula* sp., *Pleurosigma* sp., *Thallasionema* sp. while zooplankton types, for example *Brachionus* sp.

Utojo (2015) added that some types of plankton found in shrimp cultivation in ponds are: phytoplankton consisting of the *Bacillariophyceae class* (*Coscinodiscus* sp., *Navicula* sp., *Nitzschia* sp.), *Cyanophyceae class* (*Oscillatoria* sp.), *Dinophyceae class* (*Prorocentrum* sp.) while zooplankton consists of *Crustacea class* (*Apocyclops* sp., *Copepoda* sp., *Tortanus* sp.) and *Rotator class* (*Brachionus* sp.).

Furthermore, according to Putra et al. (2014), organic material in shrimp maintenance comes from the accumulation of leftover feed, shrimp feces, and dead plankton. The organic load will increase with the increasing feed provided. Putri (2019) also argues that the increase in organic waste at certain concentrations is toxic in shrimp.

Conclusion

Implementation of kaizen with improved human resources quality, improvement of water quality, improvement of feed management, replacing pesticides with biopesticides, and the application of biosecurity was declared successful and provided good results, the average SR increased to 27.33% with a productivity value of IDR 4,571,500.00.

Acknowledgements

Thank you to JTUF, Fisheries Research Center-Agency for Marine Fisheries Research and Human Resources, RICAFE Maros, and Sukamandi Rice BBP-West Java, as well as all stakeholders involved in PANDU research activities.

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