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MODIFICATION OF SMALL SCALE PURSE SEINES FOR INDONESIAN FISHERMEN: A CASE OF SULAWESI FISHERIES

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ABSTRACT

This study considers small scale purse seines in the Gulf of Bone Indonesia using seines of 300m long. The project identifies requirements in terms of net length, net depth, net enforcements, wings-end, buoyancies, ballasts and sinking speed of the gear. The study is based on a literature review, collection and evaluation of data from seiners of Gulf of Bone and was conducted to enhance the knowledge within fishermen and to strengthen the educational institutions. In this study, it is shown how the net's dimension, ropes, net twines, rings and sinkers can affect the performance. The findings of this project can also be used in developing training for fishermen.

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ABBREVIATIONS

BSN	*Badan Standardisasi Nasional* (National Standardization Agency of Indonesia)
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Production
GT	Gross Tonnage
HP	Horse Power
IDR	Indonesian Rupiah (Indonesian currency)
ISSCFG	International Standard Statistical Classification of Fishing Gear
KKP	*Kementerian Kelautan dan Perikanan* (Ministry of Marine Affairs and Fisheries Republic of Indonesia)
MMAF	Ministry of Marine Affairs and Fisheries Republic of Indonesia
MSY	Maximum Sustainable Yield
PA	Polyamide
PE	Polyethylene
PVC	Polyvinyl chlorite
SNI	*Standar Nasional Indonesia* (Indonesian National Standard)
TAC	Total Allowable Catch
UNU FTP	United Nations University, Fisheries Training Program
WPPRI	*Wilayah Pengelolaan Perikanan Republik Indonesia* (Fisheries Management Areas of Republic of Indonesia)

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1 INTRODUCTION

Indonesia is a maritime country, lying between the continents of Asia and Australia as well as between the Pacific and the Indian Oceans with 17,508 islands scattered along the equator with marine area of 5.8 million km^2 and 95,181 km of coastline.

Fisheries and aquaculture play an important role in human life and have the potential to boost economic growth, employment and contribute to poverty reduction. On the contrary, within the last few years, production through capture fishing has stagnated approaching Maximum Sustainable Yield (MSY) of 6.5 million tonnes per year. Management of capture fishery is currently more focused on controlling and structuring of production factors to maintain the sustainability (PPN/Bappenas, 2014). The stagnation of fisheries production is not only prevailing in Indonesia, the FAO report in 2016 revealed that production of the world's capture fisheries tended to be stable since the late 1980s. China is still the largest producer with an average production of 12.7 million tons per year and Indonesia followed in second place with average production of 4.7 million tons per year

The government of Indonesia has been attempting to maintain the marine resources to ensure the sustainability of fish stocks in the sea. Through the minister of marine affairs and fisheries regulations No. 71 of 2016, government regulates fishing areas and fishing gears allowed in Indonesian waters. Especially for purse seine, it is regulated by mesh size, minimum length of floatline, fish aggregating devices (FADs) and the amount of lamp’s wattage allowed in FAD location. Furthermore, the government has issued a national standard for purse seines with the floatline less than 600 m (BSN, 2013). The aim of this standard is not only to unify technical terms and general reference for designers and users, but also to enhance professional skills of net makers, fishermen, students and teachers.

1.1 Status of Indonesian Fisheries

Indonesia has the authority to manage the sea as wide as 5.8 million km^2 with MSY of 6.5 million tons per year and TAC of 5.2 million tons per year. Meanwhile inland water area that can be managed by Indonesia is 54 million hectares including lakes, reservoirs, rivers, swamps, and other puddles, with total production of 0.9 million tons per year. For aquaculture, the potential of the mariculture area is 8.3 million hectares, brackish ponds culture is 1.3 million hectares and fresh water culture covering 2.2 million hectares (Figure 1).

These numbers put Indonesia in second place for fisheries capture production and at fourth place for aquaculture production in the world (FAO, 2016). This shows that fisheries potential needs to be managed well, not only to meet the protein needs of the population but also to support employment, reduce poverty and be a source of income for coastal people.

The graph (Figure 1) shows an increase in the aquaculture production (14.3 million tons in 2014) since 2010 while capture fisheries tend to be stable to its TAC (production in 2014 was 6.48 million tons). Total fish production in 2014 was 20.8 million tons or 7.35% higher than previous year. At the same year capture fisheries contributed 31.11% to national fish production and aquaculture was 68.89%. Total production growth is 15.8% per year with an average growth of annual production is 16.2 million tons.

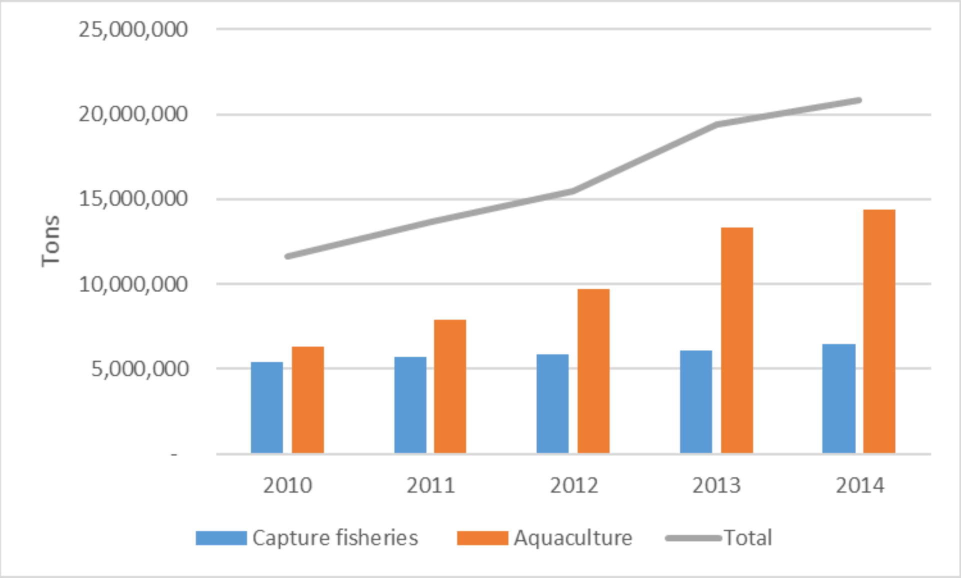

Figure 1: Volume of fish production 2010-2014 (MMAF, 2015)

1.1.1 Fisheries contribution to National GDP

The contribution of fisheries (capture fisheries and aquaculture) to national GDP is 2.34% or 3.25% (all marine and fisheries sectors including salt production, fish processing and trading, and marine tourism services), while the annual growth in fisheries production showed a positive trend with annual average growth 14.55% which is above the average growth of agriculture, forestry and national GDP growth (Table 1).

Table 1: GDP at current price, 2010-2014 (MMAF,2015)

Unit : Billion Indonesian Rupiah (IDR)

Commodity	Year					Trend (%)
	2010	2011	2012	2013	2014	2010-2014
Agriculture	754,434.40	832,513.60	902,125.90	994,778.40	1,088,944.90	9.61
Forestry	58,125.90	62,247.70	65,882.20	69,599.20	74,618.00	6.45
Fishery	143,559.40	163,484.00	184,254.00	210,670.80	247,094.20	14.55
National GDP	6,864,133.10	7,831,726.00	8,615,704.50	9,524,736.50	10,542,693.50	11.34

1.1.2 Fishing boats and fishermen

In 2014 the number of fishermen was 2.74 million people, or it was just about 3.78% higher than previous year. Marine fishermen in 2014 were around 2.2 million people four times than those who fished at inland waters (Figure 2).

Marine fishermen are fulltime workers that fishing is their only livelihood while inland fishermen have other income such as seaweed cultivators, fish farmer or agricultural farmer.

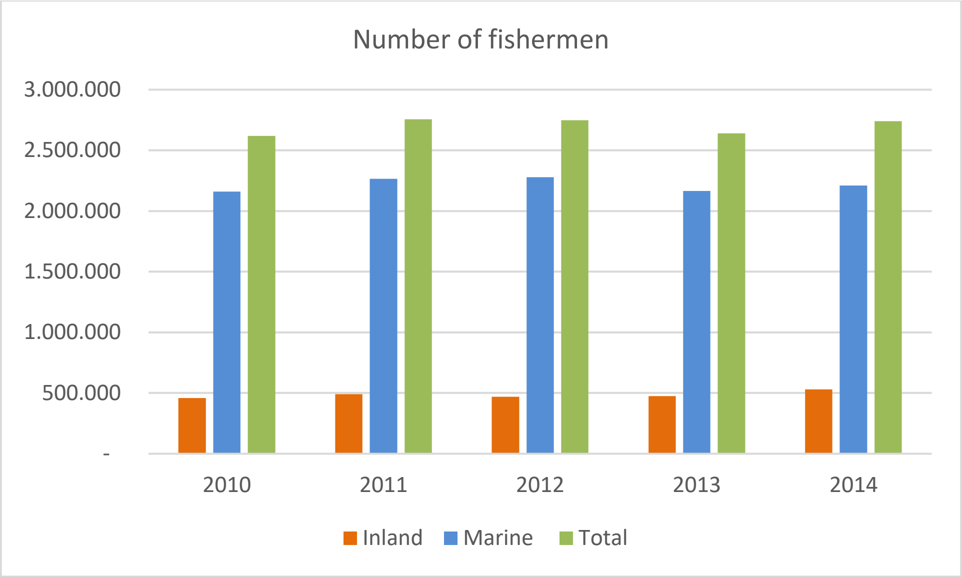

Figure 2: Number of fishermen (MMAF, 2015)

In the period of 2010-2014 there has been a considerable increase in the number of boats with inboard motor (Table 2). The biggest change is seen in boats less than 5 GT, but inboard motor boats bigger than 5 GT have either stagnated or decreased.

Table 2: Number of boats 2010-2014 (MMAF,2015)

Boat Size and Category		2010	2011	2012	2013	2014
Non powered boat		172,907	170,938	172,333	175,510	165,066
Outboard motor		231,333	225,786	245,819	237,625	238,010
Inboard motor		164,150	185,121	198,538	226,573	222,557
Inboard motor sizes	< 5 GT	110,163	123,748	137,587	151,939	153,493
	5 - 10 GT	31,460	35,877	37,587	46,358	41,374
	10 - 20 GT	10,988	13,201	11,583	15,208	14,301
	20 - 30 GT	7,264	8,022	7,611	8,782	9,578
	30 - 50 GT	857	914	917	1,074	1,029
	50 - 100 GT	1,747	1,801	1,641	1,727	1,766
	100 - 200 GT	1,290	1,204	1,167	1,127	840
	> 200 GT	381	354	338	358	176
Total		568,390	581,845	616,690	639,708	625,633

In 2014 number of boats bigger than 100 GT was decreased. Minister of MMAF through a ministerial decree No 56 of 2014 temporarily suspended giving licenses for fishing vessels that are built outside Indonesia. This is related to the number of IUU fishing (illegal, unreported and unregulated fishing) such as transhipments, double-flagged ships and double standards of crew’s salary, which is Indonesian crews get less than foreign crews.

1.2 Purse seine in Indonesia and the target species

Three types of fishing gears dominated in Indonesian water are hook and lines (hand lines, pole and line, squid angling, squid jigging, and trolling lines), gill nets/entangling nets (including drift net and trammel net) and surrounding nets (purse seine) (Figure 3). From more than 6 million ton of fishes caught in 2014, fifth were fished by purse seiners. From this it can be seen that purse seiners are playing a big role in capture fisheries of Indonesia.

By the end of 2016, the Indonesian government through the minister of marine affairs and fisheries issued the ministerial regulation number 71 of 2016 and entered into force since December 30th 2016. In this regulation type of seine nets (beach seine, boat seine, Danish seine, Scottish seine, pair seines, and bottom seines) and trawls (bottom trawl, beam trawl, otter trawl, pair trawl, nephrops trawl and shrimp trawl) are forbidden to be operated in Indonesian waters.

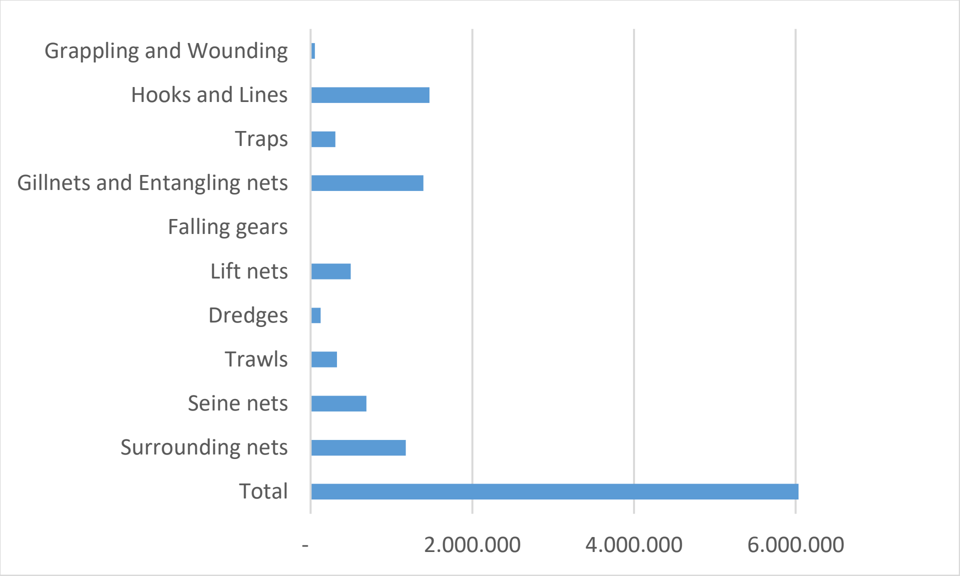

Figure 3: Total catches by fishing gears (MMAF, 2015)

Based on international standard statistical classification of fishing gear (FAO, 1990a), the most common surrounding net is purse seine, these nets catch the fish by surrounding them from the sides and underneath with purse line thus preventing fish from escaping downwards. The other seine nets which are usually set from the boat, can be operated from boat (Danish or Scottish seines) or from shore (beach seines), these are not classified as surrounding net as they are herding fish. The other important fishing gears are trawls, the gear consists of cod end and wings and towed by single or pair boats either for fishing the bottom or pelagic fish.

The seine nets and trawls catch almost 17% of all catches, with banning of these gears then 17% of the TAC will be used with other fishing gears. Fishing gears most likely to take this position are purse seines and gill nets because they are most widely used to catch small pelagic fish.

1.1.3 History of purse seine in Indonesia

Purse seine was first introduced on the north coast of Java in 1968 (McElroy, 1991) in the context of cooperation with the local fishermen in Batang (Central Java). Then it spread to Muncar (East Java) in the 1970s and to the other areas. Furthermore, the purse seine has developed in adjustment to local customs and their practices.

Purse seines in Indonesia are generally divided into three groups: large size; the length of the boat is over 24 m and the boat has more than 240 HP (horse power of engine), medium size; the boat is of 19-24 m length and it has 160-240 HP of engine, and small size boat is of 12-18 m in size of length and it has between 25-30 HP of engine with a fishing trip less than a week (Wijopriono and Samad, 2013). Furthermore, Wijopriyono and Samad (2013) describe the purse seine are the most productive fishing gear, especially after the 1980s, on the island of Java, particularly the northern part of the island. More than 40% of fish landed is caught by purse seiners, most of whom are seiners of small boats with floatline between 200-250 m length and 40 to 60 m depth.

At Apar Bay, East Kalimantan, purse seine has been evolving since 1990 and its usage peaked in 2001 (Mahiswara & Baihaqi, 2013). In the southern part of Sulawesi, at Bone Regency, local fishermen have been using gear that is similar to purse seine known as local name "*Pancang*" since 1975. Then in 1985, The fishermen of Bone started to use purse seine after being introduced by fishermen from Bulukumba regency (Rumpa, 2016). At South Sulawesi province, purse seiner is the most productive gear. For example, the regency of Bone 50% of its catches are landed by purse seiners (Rumpa, 2016). The average purse seine nets which are operated in South Sulawesi have their length between 300-800 m and 40-50 m depth (Najamuddin, 2015).

1.1.4 Fishing ground

Japanese purse seiners operate during nights to adjust to the lunar calendar and the peak season in Japanese is in March-April and October-November (Wijopriono & Samad, 2003). The situation also applies to other areas such as Sulawesi. Distance of fishing grounds very dependent on boat and engine size. Big seiners can do fishing for more than a month with fishing ground far from landing ports, medium boats can go fishing around the islands, as a consequence small purse seiners just will be near the beaches or at the landing ports.

Fisheries management of the fishing ground in Indonesia is regulated in the regulation issued by the Minister of Marine Affairs and Fisheries No. 71 in 2016 and No. 18 in 2014. The regulation addresses regarding fishing zones, the use and the placement of fishing gears on the basis of fisheries management area. In accordance with the regulation, Indonesian fisheries management area divided into 11 areas as seen in Figure 4.

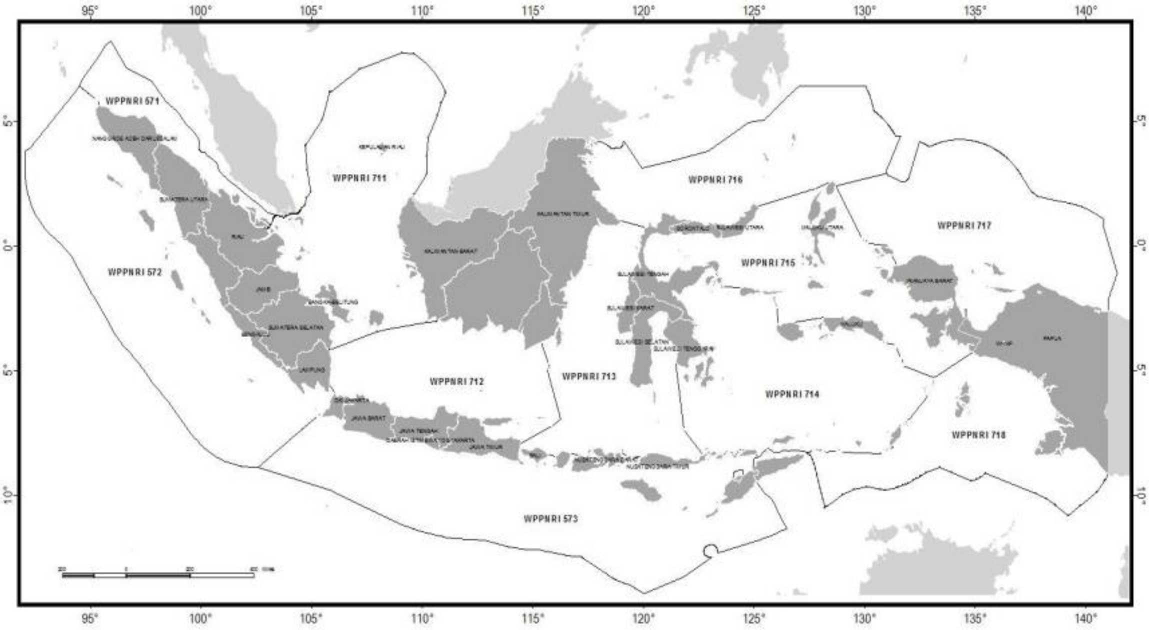

Figure 4: Indonesian Fisheries Management Area (MMAF, 2014)

1.1.5 Fish aggregating devices

Traditionally fishermen know that fish congregate around floating objects. Floating objects have several functions such as place for refuge from predators, as a meeting place, for feeding and orientation place of schooling companions. These not only function as a substrate for species undergoing a change from pelagic to other modes of existence, but also, they function as duplicating natural aggregators such as *sargassum* seaweed (Beverly *et al.,* 2012). Local fishermen in Sulawesi have been using FADs to help them for fishing tunas since long time ago, although there is no official record since when this practice is carried out (Yusfiandayani *et al.,* 2015).

FADs have been being used to attract fish. Those make them easier to catch. Because of using FADs, those could reduce fuel costs when fishermen are searching for schools of pelagic fish. FADs can easily be found in every place where purse seiners are operating from the traditional scale up to an industrial scale. The use of FADs in Indonesia are flourished after a research was conducted by the Indonesian Marine Fisheries Research Institute in 1980 and began a successful commercial basis in 1985 (Yusfiandayani *et al.,* 2015).

FADs used by local fishermen (Figure 5 and 6) generally consists of a bamboo raft as float and coconut leaves as attractors. Coconut leaves will be hung at the bottom of the raft of bamboo, while the depth can be varied.

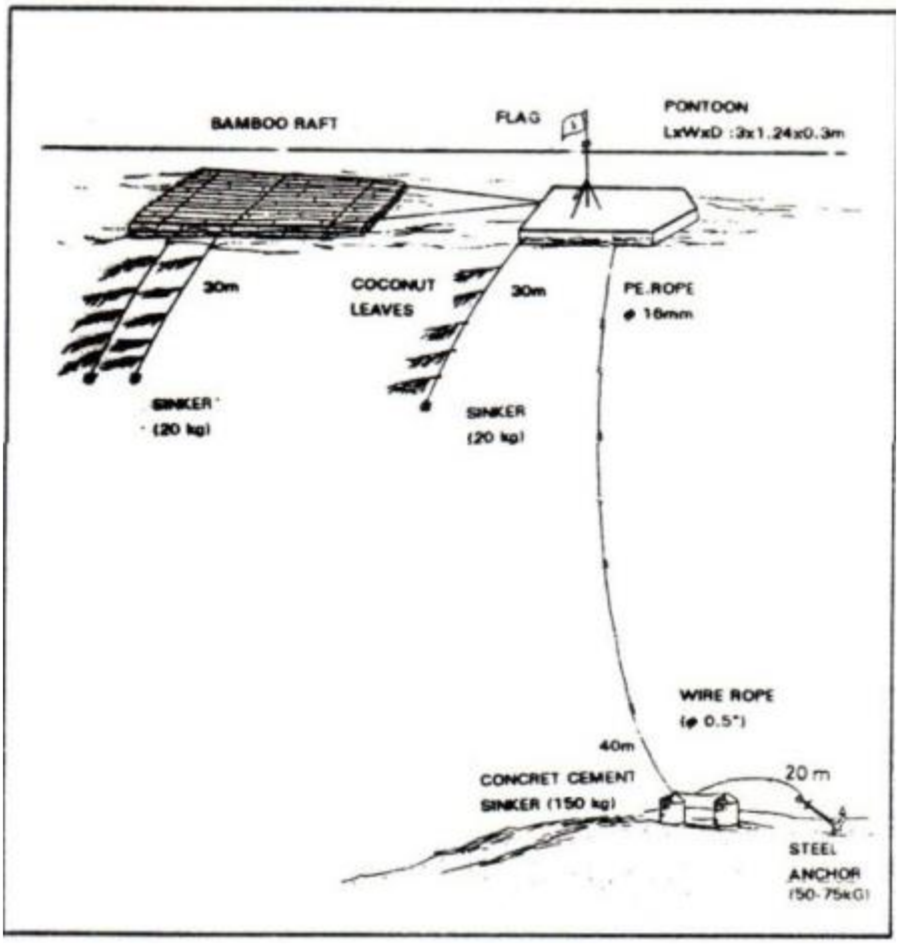

Figure 5: FAD in Gorontalo, Sulawesi (Yusfiandayani *et al.*, 2015)

Figure 6: Fishermen are checking the FAD at Gulf of Bone

1.1.6 Target species

The main target of purse seiners are the shoaling pelagic species. In Sulawesi waters precisely in the Gulf of Bone the dominant fishes caught are small pelagic fish such as Indian scads (*Decapterus russelli*) (Figure 7) and Frigate tuna (*Auxis thazard*) (Figure 8), while Big-eye scad (*Selar crumenopthalmus*) (Figure 9) and Rainbow runner (*Elagatis bipinnulata*) (Figure 10) caught in small quantities (Rumpa, 2016).

Figure 7: Indian scad (http://www.fao.org/fishery/species/3109/en)

Indian scads (*Decapterus russelli*) broadly distributed throughout the Western Indian Ocean and from Japan to Australia in the Western Pacific Ocean. The pelagic fish, the most common Indian Ocean *Decapterusin* coastal waters and on open banks at depths not exceeding 100 meters. Feeds primarily on smaller planktonic invertebrates. Reaches sexual maturity during the first year of life at about 12 cm total length. Maximum largest specimen examined 35 cm fork length; common to about 20 cm fork length. It is range throughout coastal waters and caught with purse seines and trawls. Fish of 15 cm total length has an average weight of 50 g, the most frequent in catches are 2 to 3 years of age.

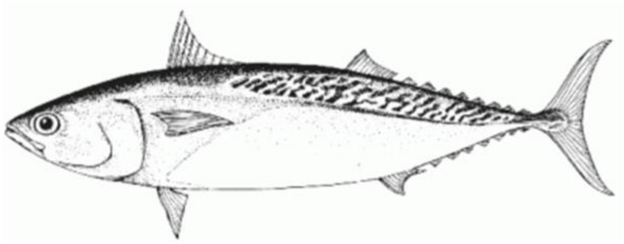

Figure 8: Frigate tuna (http://www.fao.org/fishery/species/2491/en).

Frigate tuna (*Auxis thazard*) is an epipelagic, neritic as well as oceanic species. In the Eastern Pacific, mature fish occur throughout the year while in Japanese waters it peaks in July. In the southern Indian Ocean, the spawning season extends from August to April; north of the equator it is reported from January to April. Fecundity was estimated at about 1.37 million eggs per year in a 44.2 cm long female. Fecundity of fish in Indian waters ranged between approximately 200 000 to 1.06 million eggs per spawning in correlation with size of females. Maximum fork length in the Indian Ocean is 51 cm, the common size in catches ranges between 25 and 40 cm. Size at first maturity is reported at about 29 cm fork length in Japanese waters.

Figure 9: Big eye scad (http://www.fao.org/fishery/species/2326/en)

Big-eye scads (*Selar crumenopthalmus*) are broadly distributed throughout the Eastern Indian Ocean and Western Central Pacific Ocean. It is found small to large schools mainly inshore or in shallow water at times, over shallow reefs, but may reach depths of 170 m. Prefers clean, clear insular waters but occasionally in turbid waters. Mainly nocturnal, it feeds primarily on planktonic or benthic invertebrates, including shrimps, crabs and foraminifers; also on fish. Standard length of 27 cm, common to about 24 cm fork length and 0.23 kg.

Figure 10: Rainbow runner (http://www.fao.org/fishery/species/3122/en).

Rainbow runner (*Elagatis bipinnulata*) is a pelagic fish, usually found at or near the surface (0-15 m), over coral and rocky reefs or sometimes far offshore; may form sizeable schools. Feeds on crustaceans, small fishes and squid. Pelagic eggs and spawning generally occurs during the summer, common throughout the Western and Eastern Indian Ocean and Western Central Pacific. It has maximum of 107 cm (possibly to 120 cm) fork length and 10.5 kg; common to 80 cm

1.3 Challenges of purse seine in Sulawesi

The purse seine efficiency depends on several factors such as size, shape and operational performance (Ben-Yami, 1994). It has been reported by Mahiswara and Baihaqi (2013), Widagdo *et al.* (2015) and Kefi *et al.* (2013) the operational performance of existing Indonesian purse seine designs could be improved by changing net material and twine diameter, mesh size, depth to length ratio, sinkers and purse lines, and by changing the net shape. In South Sulawesi the fishermen construct their own gear without any design plan. The rectangular shape is most common. The net construction and hanging methods can be approved (Rumpa, 2016) and there are reports of low sinking speeds (Najamuddin, 2015).

1.4 Objectives

This project aims to provide a gear design that follows the national regulation and standards, based on present purse seine design theory and gear calculations. The goal is to increase operational performance and to give net makers, fishermen, teachers and governmental staff better understanding of the matter.

2 LITERATURE REVIEW

2.1 General requirements

Ben-Yami (1994) states that there are three conditions that must be taken into consideration in making purse seine as a fishing gear:

1) The school of fish encircled in horizontal plane. This condition is provided by the length of the net.
2) The schools must be fenced off vertically from the surface to a level below which the fish will not swim. These conditions will be considered when determining the depth and sinking speed. Sinking speed depends on leadline, ballast, hanging ratio, weight and hydrodynamic drag of the netting.
3) The school must be enclosed beneath by the pursed seine – that is, the bottom edge of the purse seine during the pursing operation that must pass below the greatest depth at which the encircled fish swim. This should meet the conditions of weight, ballast, hanging ratio and the pursing arrangement.

2.2 Main elements of purse seine design

Main elements of the net design (Figure 11) consist of the overall dimension, net length and depth, shape, hanging ratios distribution and number of floats and sinkers, material used for nets and ropes, tapering and joining or hanging methods. The overall dimension of the net should be selected according to the size of the vessel carrying the net, the expected size of the schools, the fish swimming speed, the maximum depth to which the fish are expected to dive and their diving speed (Ben-Yami, 1994).

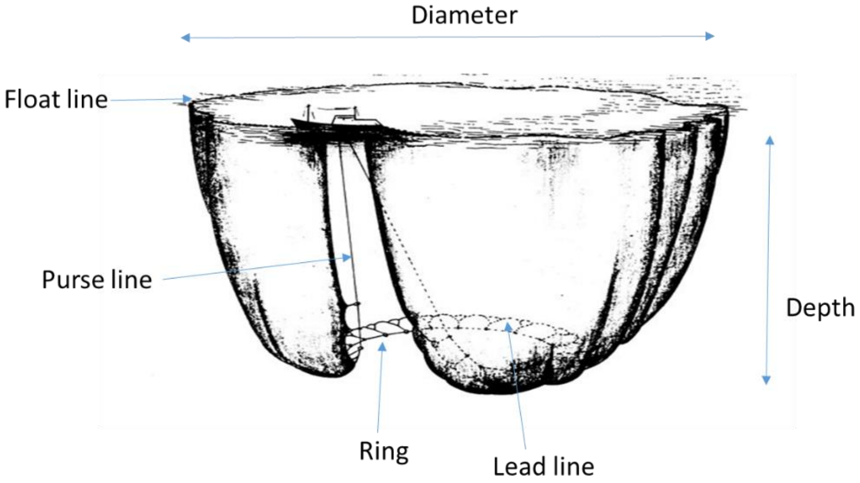

Figure 11: Purse seine

2.2.1. Overall dimension

Physical criteria for selecting seine length is given by Fridman (2013):

$$L = b\ (a + r_s) \qquad \text{equation 1}$$

L = minimum length of purse seine (m)
a = the distance at which the fish react to the net (m)
r_s = the radius of the school (m)
b = seine length coefficient.

Seine length coefficient (b) depends on velocity ratio (Ev) (Figure 12). Velocity ratio is seiner's setting speed (Vs) divided by school's swimming speed (Vf).

Fridman (2013) gives the distances according to fishermen experiences; nearest distance (a) to which a fishing vessel can approach a fish school without affecting its behaviour is 50 to 100 m for a migrating school and 30 to 40 m for a feeding school. The most common diameter (2 r_s) for nearly circular schools and their maximum speeds (Vf) by species is given in Table 3.

Table 3: Characteristic of fish schools (Fridman, 2013)

Species	Diamater, 2 r_s (m)	Speed, Vf (m/s)
Atlantic herring	25	1
Sardine	50	1.1
Mackerel	40	1.3
Belted bonita	30	1.6
Black sea anchovy	60	0.8

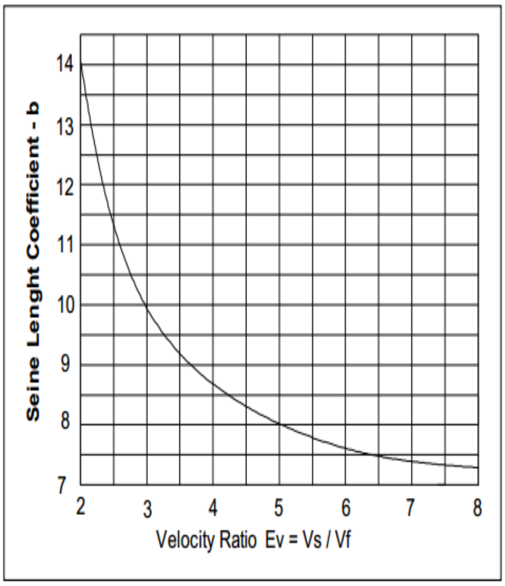

Figure 12: Seine length coefficient as a function of seine setting speed to fish speed ratio (Fridman, 2013)

2.2.2. Net shape

Basically, net shape (Figure 13) ranges from rectangular with end edges gathered at the tips, chokes, shallow rectangular end section, or rarely along gavels to strongly tapered net with a deep central part and much more shallow wing and bunt (Ben-Yami, 1994). The shapes are generally depending on the ratio between the length of the net to the depth and how the ends are tapered.

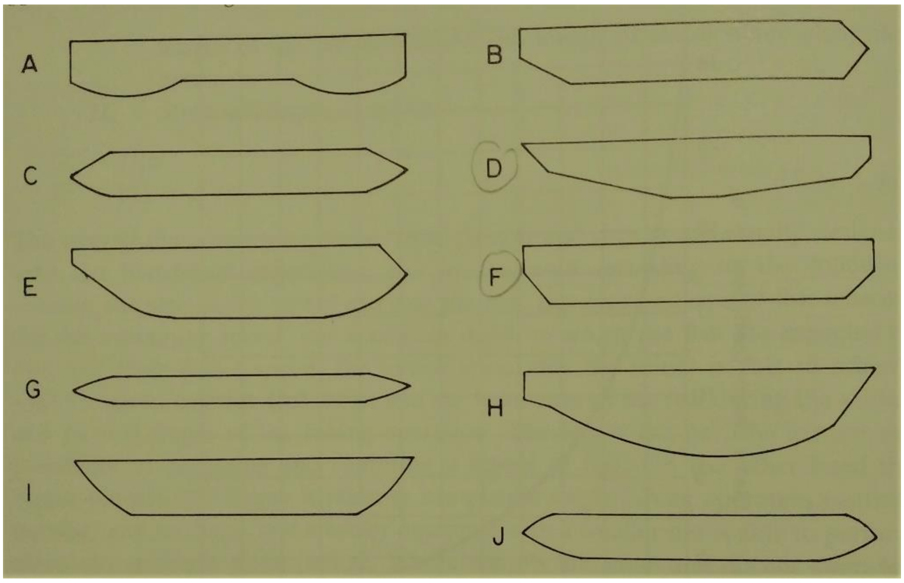

Figure 13: Purse seine's shapes (Ben-Yami, 1994) (a) Two boat purse seine-Japan (b) Mackerel purse seine-Japan (c) California and Mediterranean purse seine (d) Small scale purse seine-Srilanka (FAO) (e) Herring purse seine-Iceland (f) Small scale purse seine (FAO) (g) Salmon purse seine NW America (h) Capelin purse seine-Iceland (i) Mediterranean purse seine-France (j) Anchoveta purse seine-Peru.

2.2.3. Depth to length ratio

Depth to length ratio is an expression of stretched depth of netting at the centre of the net (Ds) to hung length (Lw) or the floatline. So, the volume of water that can be surrounded by netting is proportional to the net in a cylindrical shape.

The first step in making design purse seine is determining the ratio between depth to length because depth to length ratio can affect the fishing performance of the net and the seiner. But in some cases, determining the ratio between the depth to length is also determined by the location of fishing grounds, where the purse seine operates in shallow waters or at certain thermocline where the fish do not attempt to dive under the purse line will have a smaller ratio. The leadline should be designed to reach a depth H that is 20 to 30% deeper than the swimming depth of the schools. According to FAO (1990a), the minimum length of a purse seine should be 15 times of the seiner length and the net depth should be at least 10% of its length. The minimum length of the bunt should be at equal to the length of the vessel.

Ratio less than 0.167 (1:6) brings about leadlines together during pursing and dragging floatline and the netting wall towards the centre of the surrounding area. In this situation the floatline will be puckering and the power skiff or side thrusters will be needed to overcome the problem (Figure 14).

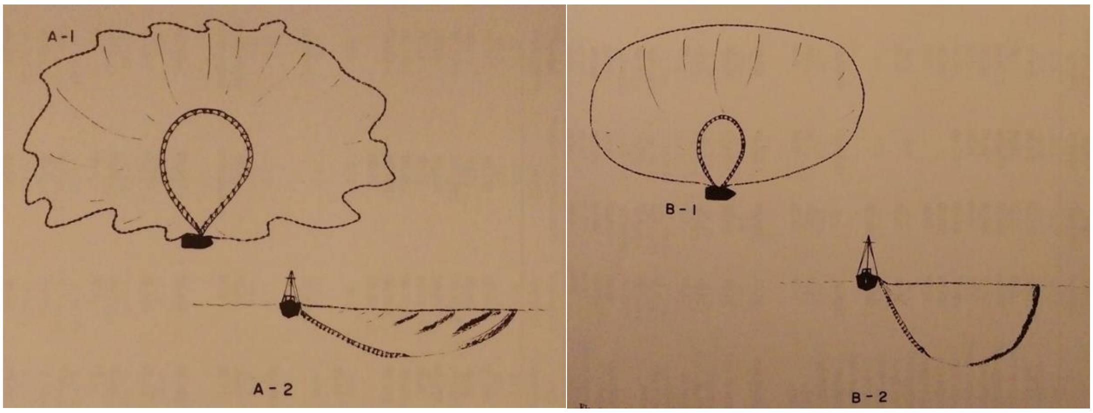

Figure 14: Effect of the depth to length ratio in purse seining performance (Ben-Yami, 1994) (a) Low depth-length ratio (a shallow seine) (b) High depth-length ratio.

2.2.4. Wing and bunt ends

Purse seines are made rectangular with several objectives, among others they should be easy to handle and to repair, this shape with side edges joined to relatively small end pieces (at eye rings) and gathered to a point which floatline and leadline ends meet (Ben-Yami, 1994). Bunt is the part of the net where the fish congregate after the purse line is pulled, bunt can be located in the middle of the net body or at the end of one side it depends on how the net is pulled (from one side only or from both sides). Purse seine net which is the net pulled in one side, the end of which fish are crowded before they are taken out is called the bunt-end and the other side one is wing end.

At least there are six various patterns of the purse seine ends (Figure 15), each pattern developed in accordance with local preferences and method of the net handling (Ben-Yami, 1994). Ben-Yami (1994) proved on how a much better shape of the net ends was obtained and the escape gap under the seiner reduced in a gavelled hybrid seine as compare with the conventional gavel less California tuna purse seine.

2.2.5. Floatline to leadline ratio

The design of the working dimension (working length, L_W and the working depth, D_W) should be made so the leadline is longer than floatline or purse seine equipped with gavels (Ben-Yami, 1994). This is to avoid purse seine puckering during the setting.

The ratio of floatline to leadline also affects the sinking speed. Ratio of 1 or greater than 1 significantly reduce the sinking speed, because the leadline cannot assume the shape required to reach the working depth until the floatline become shorter by puckering, conversely a lower ratio, leadline is free to sink to designed working depth without need for horizontal motion of the netting wall and floatline puckering (Ben-Yami, 1994).

2.2.6. Buoyancy

Purse seine is the surface operated gears. To keep the gear floats the floatline should be buoyant under all conditions and sufficient to resist downward pull of the net weight, sinkers, the catch and the other forces acting on the net through their downward resultant (Ben-Yami, 1994). Number of the floats to be fitted to a floatline can be calculated by formula:

$$\frac{\mathrm{L}\,(S+\mathrm{E})}{\mathrm{b}} \quad \text{or} \quad \frac{\mathrm{K.\ S.\ L}}{b} \qquad \text{…………………………….…………… } \textit{equation 2}$$

L = floatline length (m).
S = sinking power of the net per 1m (kgf)
b = buoyancy of one float (kgf)
E = required extra buoyancy per metre (kgf)
K = flotation factor (between 1.5 – 3, most commonly k = 2)

2.2.7. Ballast

Ballast is all part of the net gear which is sunk during the operation mode; leadline purse ring, steel wire-rope and chain purse ring bridles. Ballast determines the sinking speed and the pursing depth of the purse seines (Ben-Yami, 1994), ballast is expressed by weight per meter of the leadline.

$$\mathrm{Wn} = \mathrm{WA} \times \mathrm{Af} \qquad \text{…………………………………………….….} \textit{equation 3}$$

$$\mathrm{Af} = \frac{An}{(E1\ x\ E2)} \qquad \text{……...……………..…………………………………} \textit{equation 4}$$

Wn = the weight of netting (grams)
WA = Weight in grams per square metre of the fictitious area
Af = Fictitious area of the netting.
An = Working area of a rectangular net.

Weight per gram of fictitious area (Af) can be found in the table for Kapron (PA) netting in appendices 3 and 4 of Firdman's book (2013) pp 230-234

Weight of ballast material can be calculated by the formula:

$$\mathrm{P} = A\left(1 - \frac{Dw}{DM}\right) \qquad \text{………………………………..……………..…} \textit{equation5}$$

P = weight (Kg) in water.
A = weight (Kg) in air.
DW = density (g/cc) of water (fresh water =1, seawater =1.026)
DM = density (g/cc) of material.

Sinkers should be distributed unevenly along the leadline. Some practices reported by Ben-Yami (1994) was in the former USSR, fishermen decreased the ballast from the wing end of the seine, Icelandic fishermen used to reduce the ballast steeply towards the bunt and in salmon seiners of the Canadian pacific coast.

2.2.8. Netting and ropes materials

The two most suitable material used for netting according to Thus Klust in Ben-Yami (1994) are *polyester* (PES) and *polyamide* (PA) or commonly called nylon. *Polyvinylidene* such as Saran and Kurehalon sink very fast but much weaker than PES and PA.

Strength and thickness of the ropes are usually selected by experience depending on net size, vessels and the prevailing sea conditions. Floatline carries more load than leadline, usually leadline is longer by 1.02 to 1.38. In some places, fishermen use floatline and leadline with the same diameter of the ropes (Senegal-sardine, Iceland-capelin, USA-pacific salmon and France/Mediterranean-tuna) but on the other places they use bigger diameter of floatline than leadline (Italy-anchovy, USA/California-sardine, Peru-anchovetta and Japan-small fish) (Ben-Yami, 1994).

The purseline is usually made of steel wire ropes with 1.1 to 1.75 times the length of the leadline, about 1.5 times the length of the purse seine (FAO, 1990b). The purseline must have a good resistance to abrasion and the breaking strength can be calculated by the formula (Fridman, 2013):

$$T = 0.06 \,.\, A_1 \,.\, V_w^2 + 30 \,.\, A_2 \,.\, V_h^2 \quad \text{......................................} \textit{equation 6}$$

$$Tr = f \,.\, T \quad \text{..} \textit{ equation 7}$$

T = The pull on the purseline while pursing (kgf)
Tr = The required breaking strength of the purseline (kgf)
A_2 = the side area of the submerged part of the vessel (m^2)
V_w = broadside wind velocity at the vessel (m/s)
V_h = total linear velocity (m/s)
f = load safety factor, between 5 and 6.

2.2.9. Gathering and tapering

Both sides of the edges normally will be tapered at wing-end and bunt-end. Tapered can be done by reducing the number of the meshes and joint it to the wing section. The other way is by applying the cutting combination to get the specific shape of the end (Figure 15).

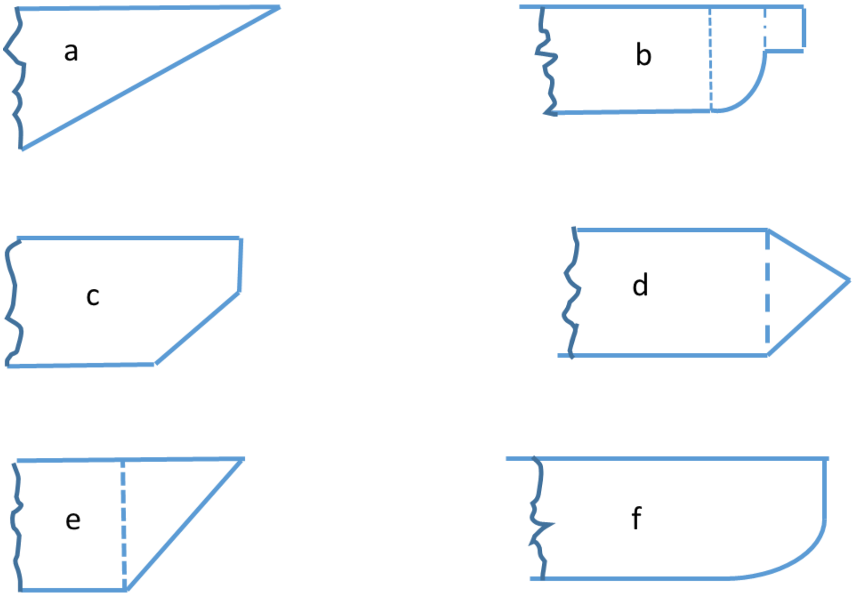

Figure 15: Common methods for tapering and gathering seine ends, Ben-yami (1994) (a) Tapered from bottom of the end (b) Gathered at the bunt into a square end (c) Tapered at the bottom but finishing in a square end (d) Tapered from top and bottom (e) Tapered at the bunt (f) Gathered at the bunt with a square end.

Both tapered and gathered end section have the same purpose, reducing the deep body of the net gradually to the less deep gavel or even gavel-less tip to a single point, gathering means the reduction of the depth of a net by joining a deeper section to a shallower one by taking up or “stealing” meshes from the deeper edge. (Ben-Yami, 1994).

2.2.10. Hanging ratio

Hanging ratio is the ratio between the length of the rope on which a net panel is mounted (L) to length of stretched netting hung on the rope (Lo).

$$E = \frac{L}{Lo} \qquad \text{…………………………………………………………..…..............……} \textit{equation 8}$$

Example of hanging ratio for 200 meshes of 50 mm stretched mesh size hung on the 8 m rope is presented in Figure 16 and calculated as follows:

$$E = \frac{8\ m}{0.050\ m\ x\ 200} = 80\ \%$$

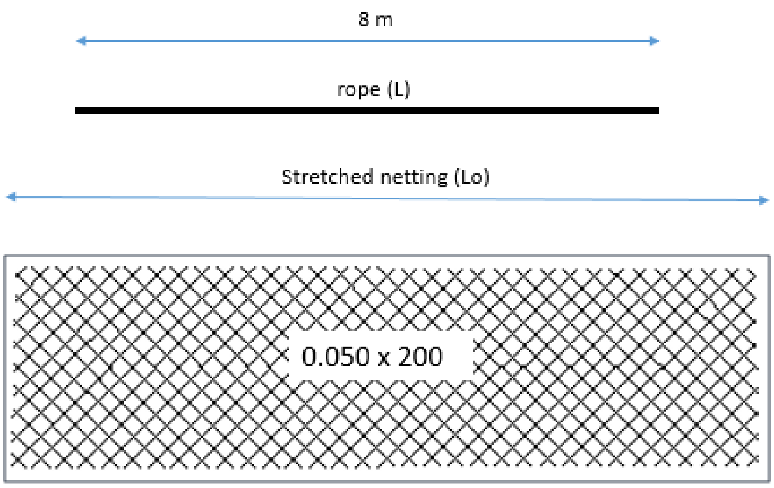

Figure 16: Example of hanging ratio

Example of horizontal hanging ratio is presented in Figure 17.

E2 = $\sqrt{1-(E1)^2}$ ....*equation 9*
E1 = Horizontal hanging ratio
E2 = Vertical hanging ratio

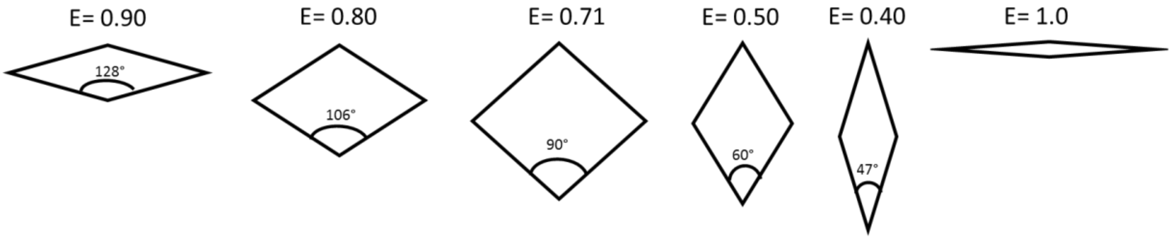

Figure 17: Example of common horizontal hanging ratios (FAO, 1990)

2.3 2.3. Purse seiner operation mode

The success of a purse seine operation is highly dependent on the speed of the leadline sinks and on reaching the specified depth. Baranov (1976) in Ben-Yami (1994) expressed the relation between the ballast and the sinking speed of the net in the formula:

t = $0.9\,D\sqrt{\frac{D}{b}}$……………………………………………..……………. *equation 10*
D = fishing depth of the lead line (m).
t = time for the lead line to sink (s)
b = weight in the water of sinking force per unit length of lead line (kgf/m).
= weight of leadline, purseline, purse rings, bridle, etc. plus 60% of net weight in water per 1 linear metre of the leadline

Fs = $\frac{W}{l}$ ……………………………………………………………*equation 11*
W = total ballast of the purse seine (kgf)
l = total length of the lead line (m).

3 METHODS

To do this project, the necessary data were derived from purse seiners in the Gulf of Bone and personal documentations. The data were also coupled with journals and reports which are relevant to the project. Samples were taken from purse seine net of Fishing Vessel (FV) Hikma Jaya.

Main elements of the net were analysed and calculated on the basis of Ben-Yami (1994) and Fridman (2013).

Data collected from existing gear were calculated and will serve as a benchmark in modifying a new design. Design comprise the main elements of purse seine design, overall dimension, net shape, depth to length ratio, wing and bunt ends, floatline to leadline ratio, buoyancy, ballast, netting and ropes materials, gathering and tapering and hanging ratio. The new design then will be drawn by using a software of Design CAD 3D max 2016.

The net design also will be based on the ministerial regulation No 71 2016 about the fishing lanes and placement of fishing gears and the ministerial regulation No 18 year 2004 concerning fisheries management area (see Appendices).

4 RESULTS

4.1 Analysing the existing gears

Purse seine net which is taken as an example is the gear used by purse seiners in the Gulf of Bone. Fishermen at the regency of Bone make their own purse seine nets by combining multiple panels. Panel is a form of basic net before becoming a purse seine, the size of one panel is a 100-yard length (90 m) or 3600 meshes of T (transverses) and 400 meshes of P (points). There are no specific rules used by local fishermen in determining the number of panels.

The size of the purse seine often made by Sulawesi fishermen is 4/5, 5/6 or 5/7 (Figure 18). Purse seine nets model of 5/7 means is composed of 5 panels horizontally and 7 panels vertically.

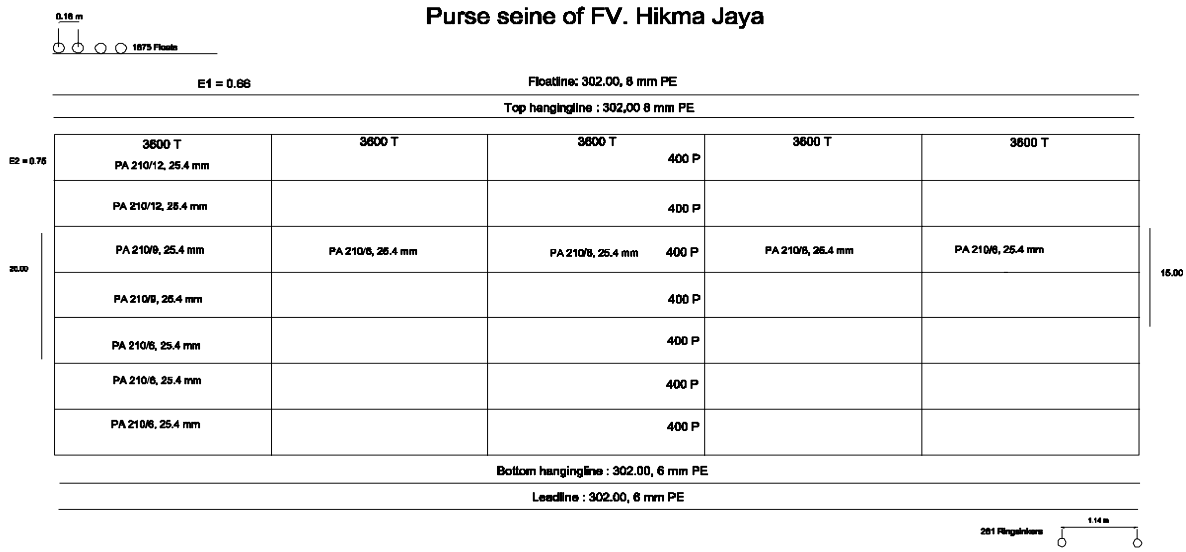

Figure 18: Purse seine of model 5/7

1.1.7 The Seiner Dimension

Seiners operating in Gulf of Bone varied from 18-24 m in length, 3- 4.6 m in width, 15-36 gross tonnage, and 90-280 Horse Power engines.

Fishing vessels are made of wood with one deck. On average each vessel has only one fishing gear without any backup. In case net problems occur, fishermen usually repair it at sea or the vessel has to return to home base for major repairing. Table 4 shows the 10 out of 183 existing seiners with landing port at Regency of Bone.

Table 4: Dimensions of purse seiners at Gulf of Bone (Rumpa, 2016)

No	Seiner's name	Gross	Boat Dimension			Net (m)		Speed (Knot)		Engine Power
		Tonage	LOA	B	D	Length	Depth	Average	Shooting	(HP)
1	Bintang Harapan	14	20	3.2	1.2	240	29.50	10	5.4	150
2	Mardi Jaya 01	17	18	4.2	1.2	248	41.00	9.5	5.3	150
3	Paddecangi 02	21	22	4	1.25	300	42.20	9.00	4.9	150
4	Nirmalasari	26	23	4.4	1.4	330	37.60	8.00	4.8	160
5	Hikma Jaya	33	24	4.2	1.5	300	53.70	10.00	5.4	190
6	Iswan Neydar 02	34	24	4.6	1.6	300	53.70	12.50	6.7	280
7	Paddecangi 01	31	23	4.2	1.5	267	57.70	10.00	5.2	200
8	Dahlia	31	23	4.5	1.3	262	44.40	10.00	5.2	180
9	Dia Lagi 02	36	24	4.6	1.6	262	42.60	11.00	4.6	200
10	Iswan neydar 01	19	20	4	1.2	300	53.70	13.00	7.6	240
AVERAGE		26.2	22.1	4.2	1.4	281	45.61	10.3	5.51	190

4.1.2 Net Dimension and Hanging Ratio

The length of the purse seine net in the Gulf of Bone water varies from 240 to 330 m and the depth of the nets between 30 to 58 m. Below are the technical data of the representative gear of FV Hikma Jaya (Table 5).

Table 5: Netting of representative purse seine (Rumpa, 2016)

Part		Netting	Hanging Ratio		Number of meshes		Mesh size	Dimension	
		Material	E1	E2	Points	Transverse	(mm)	Length (m)	Depth (m)
Body		PA (210/6)	0.66	0.75	2800	18000	25.4	301.75	53.34
Right wing		PA (210/6)	0.66	0.75	2800	3600	25.4	60.35	15.00
Left wing	Bunt	PA (210/12)	0.66	0.75	800	3600	25.4	60.35	20.00
	Middle	PA (210/9)	0.66	0.75	800	3600	25.4	60.35	
	Bottom	PA (210/6)	0.66	0.75	1200	3600	25.4	60.35	
Enforcements									

Fishermen in the Gulf of Bone do not apply cutting combination in making tapered ends of their purse seines. It is seen from the same number of meshes between the wing ends and body of the net but differs in terms of the depth of the net.

Wing-end and bunt-end will be narrowed down to 15 and 20 m from 53.34 m, not by cutting combination but through reducing the hanging ratio. Representative gear also does not apply the enforcement net, either net on the wing or on the body while bunt was directly being hung to the floatline ropes (Figure 19).

Hanging ratio that is used is the same as each net part, body, wing, and bunt. E_1 is 66% and E_2 is 75%. Hanging ratio on the float line and lead line are the same.

Figure 19: Wing end of representative purse seine net

4.1.3 Frame lines

FV Hikma Jaya used the same material ropes for all parts of frame rope (Table 6). Types of ropes used are same at all sections which is *polyethylene* with different diameters. Based on *equation 5*, multiplication factor (1- D_W / D_M) of PE in the sea water is -0.08. Negative buoyancy means that PE is floating in the sea water. Frame ropes weight in the sea water is 6.69- kgf.

Table 6: Dimension of the frame lines of FV Hikma Jaya (Rumpa, 2016)

Ropes	Material	Diameter (mm)	Length (m)	Weight (kg)		
				Per meter	in air	in sea
Float line	Polyethylene	8	302	0.043	12.986	1.039
Top hanging line	Polyethylene	8	302	0.043	12.986	1.039
Lead line	Polyethylene	6	302	0.025	7.55	0.604
Bottom hanging line	Polyethylene	6	302	0.025	7.55	0.604
Purse line	Polyethylene	20	400	0.209	83.6	6.688

4.1.4 Type of netting and weight of netting

Netting material used for making purse seine in Gulf of Bone is a *polyamide* (PA) or for commercial names also known as *Amilan* (Japan), *Kapron* (Russia) or *Nylon* in many countries. Right wing (Figure 18) uses the same material entirely, which is PA (210D/6), same as used for the body of the net. While the left wing consisted of a bunt, which uses PA (210D/12) then middle left wing uses PA (210D/9), and the bottom left wing uses PA (210D/6) (Table 7).

Table 7: Estimation of netting weight

Part		Netting				Hanging Ratio		WA	An	Af	WN	W in sea
		Material	Length (m)	Depth (m)	Mesh size (mm)	E1	E2	(gr/m²)	(m²)	(m²)	(kg)	(kgf)
Body		PA (210/6)	181.05	53.45	25.4	0.66	0.75	17.38	9677.123	19549.742	339.775	33.9775
Right wing		PA (210/6)	60.35	53.34	25.4	0.66	0.75	17.38	3219.069	6503.1697	113.025	11.3025
Left wing	Bunt	PA (210/12)	60.35	15.24	25.4	0.66	0.75	43.19	919.734	1858.0485	80.249	8.0249
	Middle	PA (210/9)	60.35	15.24	25.4	0.66	0.75	27.84	919.734	1858.0485	51.728	5.1728
	Bottom	PA (210/6)	60.35	22.86	25.4	0.66	0.75	17.38	1379.601	2787.0727	48.439	4.8439
Total											633.216	63.3216

Estimation of net weight starts from converting the PA numbering system from Denier to Tex system. Example of netting in the body part of the net is PA (210D/6) means netting twine made of nylon with 210D fibres in each of the 6 folded yarns. Titre (denier) is weight in gram of 9000 metre of fibre and international system of tex is weight in gram of 1000 metre of fibre (FAO, 1990b).

210D/6 means 210 gr of fibre in 9000 m of length.
Conversion to tex system is = $\frac{210}{9000}$ x 1000 = 23.33 tex
For six folded yarns = 6 x 23.33 = 139.98 tex
Resultant tex (R tex) of rough estimation can be found by adding 10% (FAO, 1990b).
R tex = 139.98 + 10% = 152 tex.
PA (210D/9) and PA (210D/12) are calculated in the same way.
WA, weight in grams per square metre of the fictitious area then can be found from table properties of Kapron (PA) light, laid netting based on OST (standard) appendices 3 and 4 of Firdman (2013) pp 230-234.
working area of a rectangular net (An) is multiplication of netting area.

From *equation* 9, we can find the second hanging ratio (E_2). Then using *equation* 4 and 3 to can find the Af (fictitious area of the netting), in this calculation wing-ends are considered rectangular and Wn (weight of the netting in panel expressed).

From *equation* 5, weight of netting in water is:

$$P = A \text{ x } (1 - D_W / D_M)$$

The multiplication factor of PA is 0.10+, means that PA will sink in the sea water. Weight of netting in the sea water is 10% of weight in the air, net weight in the sea water is 63.32 kgf.

4.1.5 Flotation

Floats used at FV Hikma Jaya are plastic floats (Figure 20) with one “ear” attached to the floatline as much as 1875 and distributed evenly every 16 cm of the line. Weight per one float in the air is 25 grams and its diameter is 10 cm.

Volume of each plastic float can be calculated with volume formula

$$V = \frac{4}{3}\pi R^3 \text{ or } \frac{1}{6}\pi \varnothing^3$$

$$V = \frac{1}{6} 3.14\ (10)^3 = 523 \text{ cm}^3 \text{ or equivalent to 523 grams.}$$

Estimation buoyancy of the float is
b = volume – weight of float in the air.
b = 523 – 25 gr
= 498 gf or about ≈ 0.5 kgf.

Total buoyancy of all floats is 937.5 kgf. The estimations are presented in Table 8.

Table 8: Estimation of floats buoyancy

	Length (m)	Number of float	Buoyancy per float (kgf	Total Buoyancy (kgf)
Body	181.05	1125	0.5	562.50
wing	60.35	375	0.5	187.50
Bunt	60.35	375	0.5	187.50
	301.75	1875		937.50

Figure 20: Floats of FV Hikma Jaya

4.1.6 Ballast

Generally, in making their purse seine net, fishermen of Bone's regency do not use rings and lead sinkers separately. Fishermen make their own rings which is larger than brass-rings available in the markets. Leads are casted and then also serve as sinkers (Figure 21 and 22).

Ring sinkers are hung on lead line using a single bridle line. FV Hikma Jaya has ring sinkers as much as 261 and evenly distributed every 1.15 m along the leadline with weight per ring sinker is 1.5 kg. To speed up to the sinking speed fishermen mounted on each wing ends, the additional weight is 4.5 kg of ballast. So the total ballast of purse seine in FV Hikma Jaya is 364.46 kgf.

Figure 21: Rings which also serve as sinkers

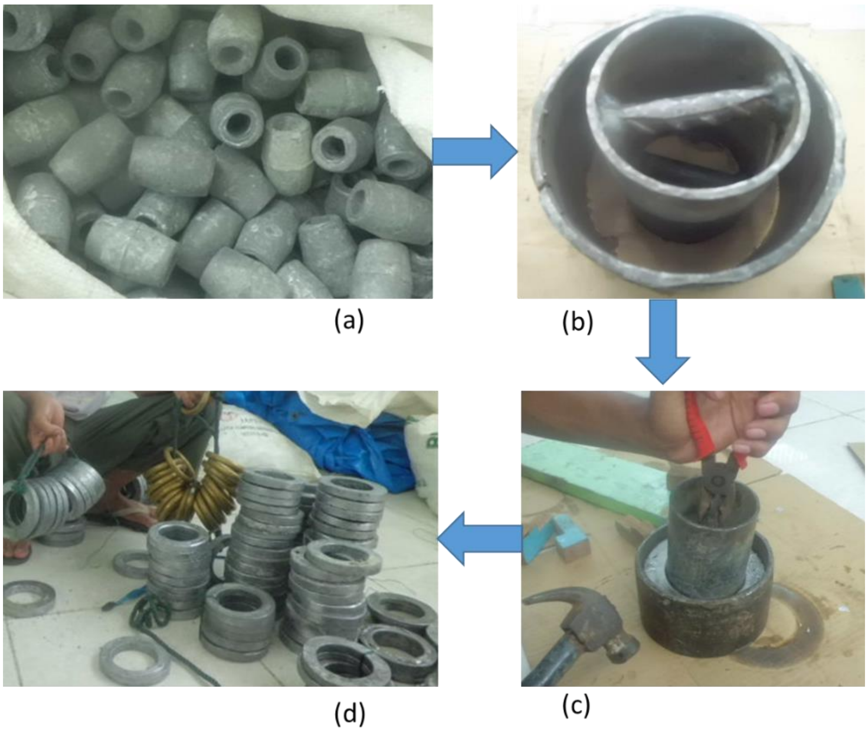

Figure 22: Process of making rings

4.1.7 Sinking speed

Sinking speed is calculated by firstly finding the sinking force (*equation* 11) and the ballast. Ballast for the representative gear is the weight of the ring sinkers in sea water (Table 9) and netting weight in sea water (Table 7).

Ballast of sinkers = 364.46 kgf.
Ballast of net = 60% of net weight in water
= 60% x (63.32)
= 37.99 kgf
Total ballast = 402.452 kgf

From the *equation* 11, the sinking force per unit length of 300 m leadline:

$$Fs = \frac{402.45}{302} = 1.33 \text{ kgf/m.}$$

The sinking time then can be estimated by using *equation* 10.

$$t = 0.9\ x\ 53.6 \sqrt{\frac{53.6}{1.33}} = 306.24 \text{ second.}$$

It is meant that the leadline sinks at a gradually decreasing speed until it stops in 306 seconds ≈ 5 minutes and 6 seconds or around 10.7 m/minutes.

Table 9: Calculation of lead sinkers

Part	Length (m)	Number of sinker	Weight per sinker (kg)	Total weight	
				In air (kg)	In sea (kgf)
Body	181.05	157	1.5	235.50	214.31
wing	60.35	52	1.5	78.00	70.98
Bunt	60.35	52	1.5	78.00	70.98
Ekstra sinker		2	4.5	9.00	8.19
	301.75	263		400.50	364.46

4.2 Modifying a new model

In modifying the existing purse seine, Fridman (2013) gives some manual steps as follows;

4.2.1 Design objectives and procedures

Under government regulations issued by the Minister of MMAF, Indonesian waters are divided into 11 fisheries management areas. Modification is intended primarily to Gulf of Bone fishermen, which is accordance with regulation No. 18 of MMAF issued in 2014 located in the area of 713 (Appendix 3). Then reiterated by the ministerial decree No. 71 in 2016, there are several criteria that must be met to conduct fishing activities in particular area (Appendix 4). For targeting small pelagic fish, the minimum of mesh size permitted is equal to or greater than 1 inch (25.4 mm). Number of lamp wattage that used for attracting fish depend on floatline length.

There are three groups of gear selectivity and capacity for purse seine targeting the small pelagic fish, respectively are gear with floatline ≤ 300 m, gear with floatline ≤ 400 m and gear with floatline ≤ 600 m.

All types of gear must have the mesh size ≥ 1 inch. While the gear for targeting the big pelagic fish is not permitted to operate in this area.

This project will be using floatline with 300 m of length, this is consistent with the average floatline used by local fishermen in the Gulf of Bone to make their purse seines.

4.2.2 Characteristic of target fish and the fishing grounds

Knowing the characteristic of target fish will help in determining the required dimension of modified gear. Main catches of small pelagic fish in Gulf of Bone is Indian scad (*Decapterus russelli*) and frigate tuna (*Auxis thazard*) which is school during daytime and disperse at night, the concentration of the fish in the surroundings FADs occurs each night and this concentration is then fished at dawn.

Commonly, Indonesian purse seiners operate in the locations of FADs. Fishermen find out the number of schools of fish beneath the FAD using a hand line during the night. Number of fish caught by hand line fishing becomes an indication for fishing with purse seine.

Based on the fishermen’s experiences, *Decapterus spp* can dive up to 20 m depth and *Auxis spp* about 30 m. So, the net depth should be 20-30 % deeper than the maximum swimming depth. The swimming speed of the Sardine is considered to be in the vicinity of 1.1 m/sec (Fridman, 2013), almost the same, maximum swimming speed expressed by the fishermen for *Decapterus spp* is around 1.3 m/s and 1.6 m/s for *Auxis spp*.

4.2.3 Vessel characteristics

In designing or modifying a purse seine, the dimension of the net must be matched to the size and performance of the seiner, including the deck machinery and other facilities (Fridman, 2013). This design is intended to operate in the Gulf of Bone, which typically seiners in that area pull the purse line manually without power block. This will affect the ratio of floatline to leadline, but in the cases of power block system will be applied then the ratio should be changed.

Deck machinery that is used is a Mitsubishi engine 20 HP to drive the winch drum made of wood. This drum serves as purse line hauler (Appendix 8).

From Table 4, we get the average dimension of the seiners which are operating in the Gulf of Bone. Minimum length of the purse seine should be longer or same with 15 times of the seiner length (FAO, 1990b). With the average seiners length of 20 m, the net length chosen for this project will be ± 300 m length. The depth of the net will be at least 10% (30 m) from the net length, and minimum length and depth of bunt should at least be as long as length of its seiner ($\geq$ 20 m). The net depth will be 44.4 m and the bunt will be 22.23 m for its depth and length.

4.2.4 Selecting the prototype seine

The type, shape, rigging, *etc.* of the purse seine for prototype were analysed. This prototype will serve as the basis for subsequent work. Purse seine is operated by one vessel; the bunt is placed at one end of the seine. Leadline is longer than floatline and theoretically will sink faster than shorter leadline to floatline.

Hanging ratio affects the cost of the netting, $E_1 = 0.70$ for this project will give the lowest weight for a given style of netting and working area (Figure 23).

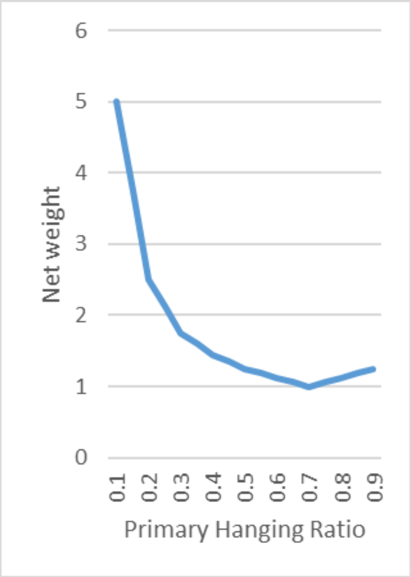

Figure 23: Effect on hanging ratio on netting weight for a given working area (Fridman, 2013).

4.2.5 Calculating the seine length

From Table 5, the average shooting speed of purse seiners is 5.5 Knot.
Vs converted from Knot to m/s is = 5.5 x 0.514 m/s.
Vs = 2.77 m/s.
Velocity ratio of target species (*Sardine*) from Table 4 is
Ev = 2.77 / 1.1 = 2.52

From Figure 12, if Ev is 2.52 then seine length coefficient (*b)* will be ≈11.2
The length of the seine net from *equation 1* is:
L = 11.2 (15* + 7.5)
= 252 m. The minimum required net length by calculation is 252 m, this project will use 300 m net length.

The distance ((a), for *Sardines, Decapterus russelli and Auxis thazard*) in which a fishing vessel can approach a fish school without affecting its behaviour is an estimated number by fishermen's experiences.

4.2.6 Determining the depth of the seine

There are two factors in determining the depth of the seine (Fridman, 2013). First is the maximum possible depth to which the fish are capable of descending and the speed of their descent. Second, is the ratio of depth to length of seine needed to preserve the required shape during the pursing operation.

For the first factor, it is suggested that the net depth should be 20 – 30 % deeper than the maximum swimming depth of the schools. Based on the fishermen's experiences, *Decapterus spp* can dive up to 20 m depth and *Auxis spp* about 30 m. For the second factor, the depth of the net should be between 0.1 to 0.2 of its length about 30 – 60 m. The average depth of the existing purse seine is 45.5 m (see Table 4), or 0.15 of its length.

This project will use depth of 0.15 of its net length (see 4.2.3). This depth also covers the maximum possible depth of the fish descending.

4.2.7 Determining the time, depth and sinking speed

Sinking speed of purse seine has been measured in range from 2.4 to 16 meters per minute, with average of 9 m/min (FAO, 1990b).

From *equation 10*, $t = 0.9\,D\sqrt{\frac{D}{b}}$, if the sinking time is about 5 minutes (estimation for the modified gear) and depth of the net is about 44.4 meters, by transposing the *equation 10*, the required ballast per meter will be:

$$b = \frac{0.81\,D^3}{t^2} = \frac{0.81\,(44.4)^3}{300^2} = 0.788 \text{ kgf.}$$

The expected weight of ballast per meter for this project will be at last 0.788 kgf.

4.2.8 Selecting the mesh size and twine diameter for seine netting

Mesh size must be small enough not to gill the fish in any part of the seine. Especially in the bunt where the fish crowd the netting, but a larger mesh is satisfactory in the other parts where it herds the fish (Fridman, 2013). As discussed at 3.2.1 the minimum allowed mesh size allowed is 25.4 mm.

Widagdo et al. (2015) suggested to improve the gear performance; net made of braided knotted sink slower than knotless one. Bigger mesh size sink faster and it is suggested to use PES knotless net instead of PA to get maximum performance. However, market availability of gear materials is the most important thing to consider. PES is hard to find in the local market; this project will use PA knotted net of 210D/9 and 210D/12 with mesh size of 1 and 2 inches (Table 10).

Table 10: Net parts of the modified gear

No	Part	Netting	Mesh size	Number of mesh		Net (m)		Hanging Ratio	
		Material	(mm)	Transverses	Points	Depth	Length	E1	E2
1	Body 1	PA 210D/6	25.4	3600	2400	42.67	64.01	0.70	0.70
2	Body 2	PA 210D/6	25.4	3600	2400	42.67	64.01	0.70	0.70
3	Body 3	PA 2106/6	25.4	360	2400	42.67	6.40	0.70	0.70
4	Body 4	PA 2106/6	25.4	3600	2400	42.67	64.01	0.70	0.70
5	Bunt	PA 210D/12	25.4	1200	1200	21.34	21.34	0.70	0.70
6	Wing end	PA 210D/6	25.4	1200	1200	21.34	21.34	0.70	0.70
7	ABs	PA 210D/6	25.4	1200	1200	21.34	21.34	0.70	0.70
8	Enforcement floatline	PA 210D/12	50.8	16800	50	1.78	597.41	0.70	0.70
9	Enforcement leadline	PA 210D/24	50.8	7250	25	0.89	257.81	0.70	0.70
10	Enforcement gavels	PA 210D/24	50.8	25	600	21.34	0.89	0.70	0.70
11	Enforcement Abs	PA 210D/24	50.8	25	600	21.34	0.89	0.70	0.70

Estimation of net weight in the sea water is 41.86 kgf (See Appendix 5)

4.2.9 Hanging netting to the breastline

Breastline is employed to border the vertical ends of the seines. When the vertical ends of the seine are hung to breastline the gap between the wings during pursing is greatly reduced. The breastlines for this project will be same for both ends, 22.23 meter.

4.2.10 Specifying the main lines

Floatline is subjected to larger tensile loads than the leadline. It is also suggested to have purseline and leadline made of other than PE as PE is floating in sea water. But the availability of the ropes other than PE is hard to find in the local market, so that this project will continue to use the same material as Table 7.

4.2.11 Calculation for the rigging of the seine

Weight per meter of rigged leadline (Fs) is weight in the water of leadline, bridles, purse rings, purseline and sinkers.

A. Leadline, bridles and purseline

All ropes used in this project are made of PE. Calculation of weight ballast shows at Table 11. Total ballast for ropes is 10.326- kgf.

Table 11: Ballast of the main ropes

Ropes	Material	Diameter	Length	Weight (kg)	
		(mm)	(m)	in air	in sea
Float line	Polyethylene	8	300	13.04	1.043
Upper hanging line	Polyethylene	8	300	13.04	1.043
Lead line	Polyethylene	6	300	7.56	0.605
Bottom hanging line	Polyethylene	6	300	7.56	0.605
Purse line	Polyethylene	20	400	83.33	6.666
Bridles	Polyethylene	6	180	4.54	0.363
				129.07	10.326

B. Purse rings and sinkers.

First time purse seines were introduced to fishermen in the Java island, the gears came with rings and bridles. When the gear reached the local fishermen in the Gulf of Bone, the fishermen made some changes to adapt to their practices. As see in Figure 22 rings are no longer used and they are changed into lead rings.

This project will use both, rings and leads. The aims are to provide a gear design based on theory and calculations, to increase the gear performance and to give better understanding of the matter to net makers, fishermen, teachers and governmental staff.

Purse ring is made of Brass with outer diameter of 150 mm and weight 650 gr. Sinker is made of Lead weight of 300 gr. Total ballast of purse rings and sinkers are 290.36 kgf (Table 12).

Table 12: Ballast of the modified gear

Parts	Number of sinkers	Weight of sinkers (kg)		Number of rings	Weight of rings (kg)		Ballast (kgf)
		in the air	in the sea		in the air	in the sea	
Body	150	52.5	47.775	18	11.7	10.296	58.07
Wing	450	157.5	143.325	54	35.1	30.888	174.21
Bunt	150	52.5	47.775	18	11.7	10.296	58.07
	750	262.5	238.875	90	58.5	51.48	**290.36**

C. Floats

From *equation 2,* number of floats (N) can be calculated as follow:

L = 300 m
S = (Wn + Wb + Wg) / L
= (41.86 + 290.36 – 10.33) / 300
= 1.073 kgf per meter.
b_1 = 0.74 kgf (float model F 803 A, white)
b_2 = 1.9 kgf (float model D 8 T, yellow)
N $= \frac{K.\ S.\ L}{b}$, if using one type of float ;
N $= \frac{2\ x\ 1.073\ x\ 300}{0.74}$ = 870 floats (if using b1 only), or
$= \frac{2\ x\ 1.073\ x\ 300}{1.9}$ = 339 floats (if using b2 only)

In this project, both types of floats will be used in the modified gear (Table 13). In practical, buoyancy needed should be equal to about 1.5 to 2 times the weight of the ballast (FAO, 1990).

Table 13: Floats distribution of modified gear

Part		Length (m)	Number of floats	Buoyancy per float (kgf)	Total Buoyancy (kgf)
1	Bunt	22.2	60 of b2	1.9	114.00
2	Body 1	64	180 of b1	0.74	133.20
3	Body 2	64	180 of b1	0.74	133.20
4	Body 3	64	180 of b1	0.74	133.20
5	Body 4	64	180 of b1	0.74	133.20
6	Wing	22.2	60 of b1	0.74	44.40
Total		300.4	840		691.20

4.2.12 Specifying the purseline

Purse line will be 450 m or 100 – 150 m longer than the seine (Fridman, 2013). Purseline can be calculated by *equation 6 and 7:*

A_1 of the FV Hikma Jaya is 22 m^2, A_2 is 36 m^2 (A_1 and A_2 are estimated). Wind velocity at the Gulf of Bone on March 2016 is 2-15 knot or maximum speed of 7.7 m/s (http://maritim.bmkg.go.id), Vm is 0.8 m/s.

$$
\begin{aligned}
T \quad &= 0.06 \,.\, A_1 \,.\, V_w^2 + 30 \,.\, A_2 \,.\, V_h^2 \\
&= (0.06 \text{ x } 22 \text{ x } (7.7)^2) + (30 \text{ x } 36 \text{ x } (0.8)^2) \\
&= 769.46 \text{ kgf} \\
Tr \quad &= 5 \text{ x } T \\
&= 3847{,}3 \text{ kgf.}
\end{aligned}
$$

From the breaking strength table (FAO, 1990 pp 16), the suggested PE rope for 3847 kgf is with diameter of 20 mm.

4.2.13 Drawing the design

In drawing the design, the computer software DesignCAD 3D Max 2016 was used. Unit measurement of the drawing use the number of meshes. Hanging ratio for the drawing purpose is E_1 = 0.5 and E_2 = 1 (Figure 24).

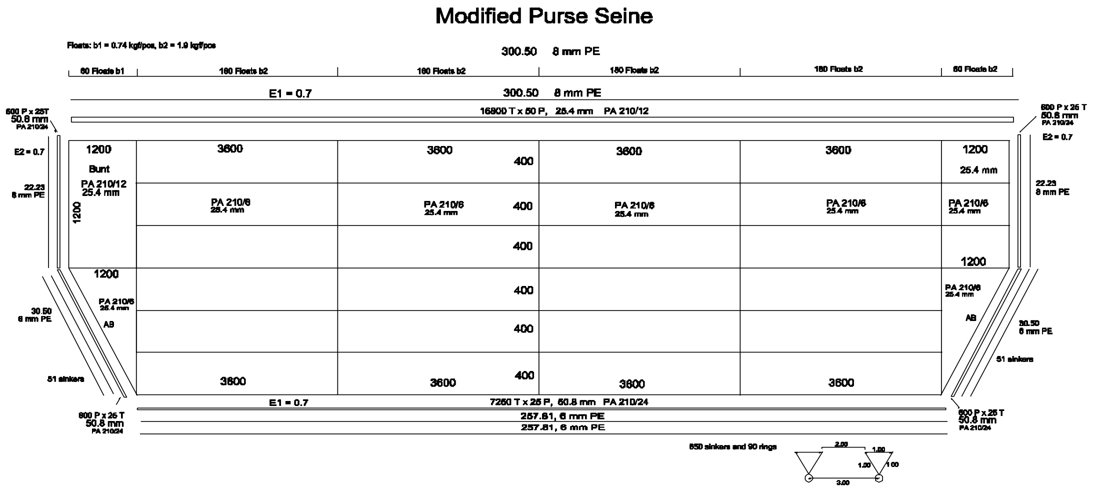

Figure 24: Drawing of the modified purse seine

The modified purse seine net consists of body, wing end, bunt and guardings. Body of the net made of 5 panels horizontally and 6 panels vertically. The net was made of PA twine D210/6 with mesh size of 25.4 mm and it is same to what in the wing end and AB cuts. Bunt section uses thicker twine than body parts made of PA D210/12 and same mesh size of 25.4 mm.

Guarding or enforcement consist of 6 sections which are made of 25.4 mm mesh size of PA D210/12 at floatline guarding and 50.8 mm mesh size of PA D210/24 at both gavels guardings made, both AB cut guardings, leadline guarding.

5 DISCUSSION

Each region and each fisherman have their own different practices adapted to the environment and their habits. These also deal with the availability of certain fishing gear materials on the market. Thus, this project gives an idea about the design of the purse seine that is appropriate to FAO guidelines referring to Ben-Yami (1994) and Fridman (2013). Moreover, this project also refers to the rules of the Indonesian government based on the location of fishing ground and fishing gear selectivity.

Dealing with the design of fishing gears, the availability of materials in the local market or net suppliers is crucial. Theoretically, net materials of PES are better than PA, as they sink faster so the fish have less time to escape and they may also last longer, since PES are not being weakened by the sun exposures.

Rectangular is the common shape of purse seine net found in Indonesian waters. Distance of floatline of the net are equal to that of leadlines, then the part of wing end and bunt end is not cut but are gathered together to the one end. As a result, the net will have a lot of material that is not required in the construction. These uncut parts of the net will affect the rate of sinking speed and could interrupt the joining part between wings-end and body. The joining parts (usually by lacing) might be torn apart and cause fish to move out while pursing (Kefi *et al.*, 2013). Dimension of the existing seines in general is in accordance with the recommendation of FAO (1990b) about the minimum length of the net compare to the seiner, ratio of minimum depth to the seine length and the minimum length and depth of the bunt.

PE rope material is used in all parts of the ropes frame. Since PE has lower density than seawater, PE will float in water. Although PE will be useful for the floatline and gives extra buoyancy, but on the sinking part, those part of purseline and bridleline, may cause a trouble. The use of wire rope material for purseline needs to be considered. Meanwhile, the twist direction of the ropes is often ignored by fishermen (Najamuddin, 2015; Rumpa, 2016). During fishing operation, these ropes could turn causing the ropes to become tangled.

Using of PA material for netting is good as its cheaper than PES and easily found in the local markets/net suppliers. Twine material and the thickness is not an important issue rather than the uses of enforcements. Kalimantan’s fishermen use PE net for their gavels guarding (Mahiswara & Baihaqi, 2013), meanwhile, fishermen in Sulawesi do not pay much attention to guardings, their main focus is on the bunt part. They use twine thicker on bunt part compared to other parts of net. Net which is directly attached to the ropes (without guarding), may easily get torn as the ropes are pulled with a lot of force. Rumpa (2016) confirms this often happens on the lower part of the body that are attached directly to the bottom line. The modified gears are suggested to have guardings between the main body and the ropes frame.

Almost all purse seines operated in the Gulf of Bone use plastic floats with ball shape (Figure 20) (Najamuddin, 2015; Rumpa, 2016). These floats have low buoyancy, so that fishermen need them in large quantities. In addition, the plastic ball floats are not resistant to sun exposure and easily broken. Fishermen in Northern Sulawesi use plastic foam floats for their purse seines. This could be adapted for better performances.

Fishermen in the Gulf of Bone do not use the rings and sinkers separately, but they make their own rings that also serve as ballast. Rings that are available in the market have a weight of less than 1 kg each, while fishermen want rings that are heavier than 1 kg (Najamuddin, 2015).

Furthermore, separate rings and sinkers will need more space on deck. Fishermen are also not accustomed to operating rings and sinkers separately, since that causes the net to twist by leadline or rings (Rumpa, 2016). Extra sinkers are needed to increase the speed of the net sink. Those are made of cement, each of which has a weight of 4.5 kg. These extra sinkers are not recommended because the sinking speed is not evenly distributed in all parts of the leadline but only at the sections where extra sinkers placed.

The minimum mesh size allowed for purse seine targeting the small pelagic fishes is 25.4 mm (Appendix 4). Existing purse seine use the same mesh size at all parts of the net without guardings. This project adds guardings on the wings, AB cuts and the bottom part using a mesh size of 50.8 mm except at the top guarding that using the same mesh size of 25.4 mm.

Performance of the purse seine is highly dependent on the sinking speed. Sinking speed of the purse seine has been measured in a range from 2.4 to 16 m/minutes, with an average of 9 m/minutes (FAO, 1990). The analysed gear has a sinking speed around 10 m/minutes, which means that in theory, its performance has been good while other gears experienced low sinking speed in the Region of Barru, South Sulawesi Province (Najamuddin, 2015). Adding of two extra sinkers at the ends of the wings would accelerate time to sink but the sinking force is uneven throughout the leadline; they are only effective on both wing ends which is about 300 m between them. The use of sinkers and rings evenly is suggested because it is more effective to share equitably the sinking force to every part of leadline.

6 CONCLUSION

The study shows that simple purse seine carried out by fishermen are in line with their experiences and needs. The addition of extra sinkers and ring sinkers are examples of that.
To avoid losses due to net damage during the fishing, enforcements or guardings are needed on floatline, leadline and gavels. Knowledge and experience in designing a gear can be obtained from handbooks, literatures or trainings.

Purse seine, as a productive fishing gear in Indonesia, has an important role for the local economy. Research is needed produce ideal gear needs, coupled with the deployment of skills to fishermen. Mechanization of the vessels can improve the performance of seiners and should be considered for the future. Use of purseline winch and power block can be an alternative for efficiency.

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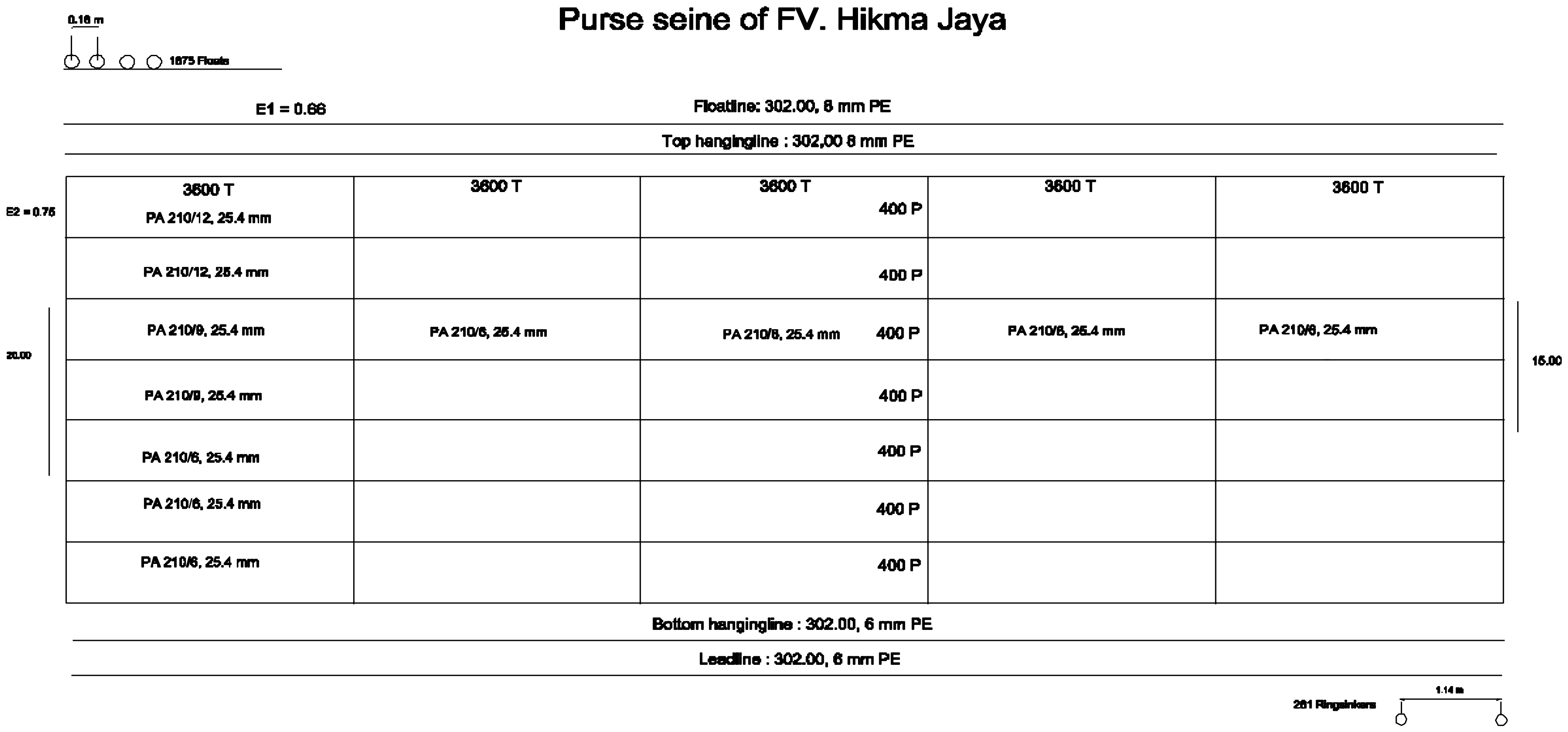
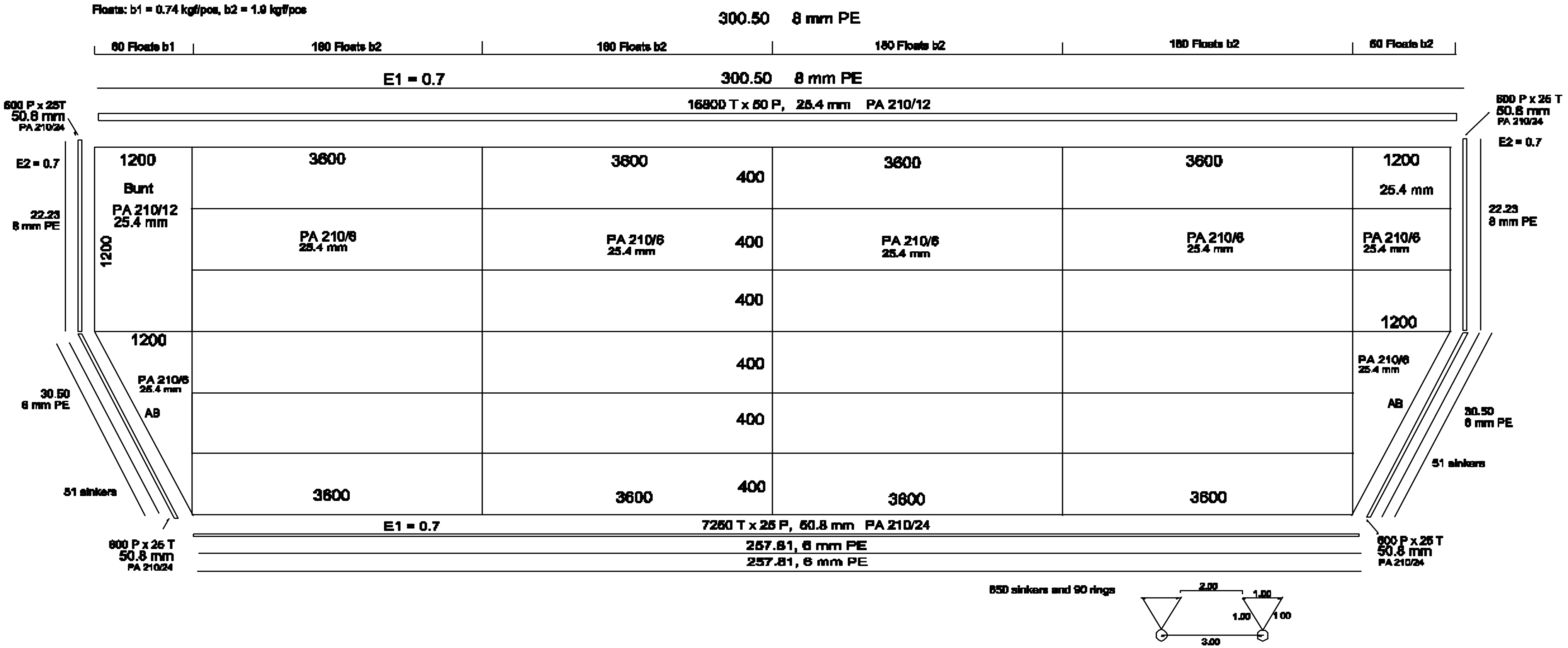
APPENDIX 1. PROTOTYPE OF PURSE SEINE NET USED IN THE GULF OF BONE, SOUTH SULAWESI-INDONESIA.

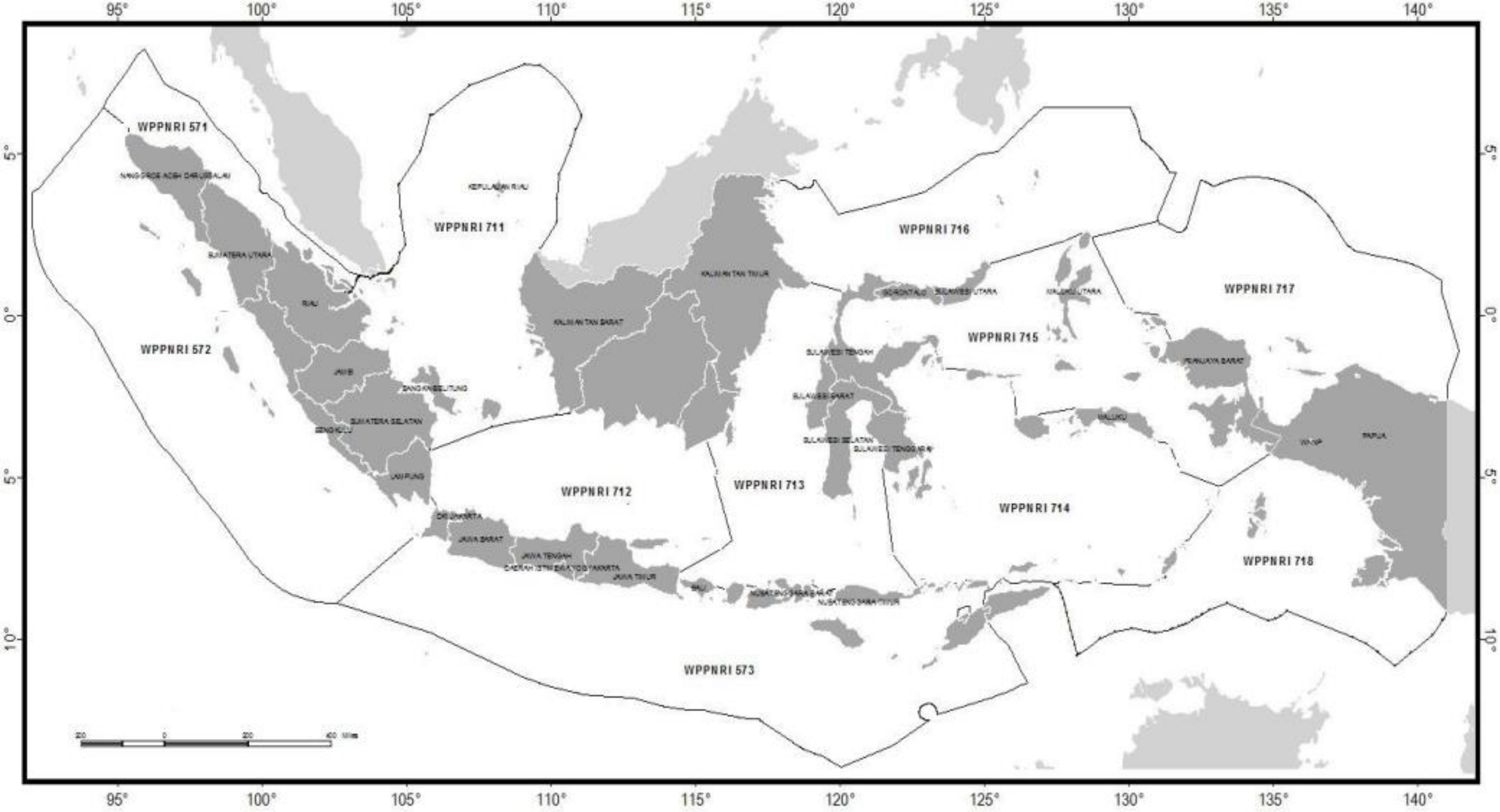


APPENDIX 2. THE MODIFICATION GEAR FOR SMALL SCALE PURSE SEINE IN INDONESIA

Modified Purse Seine



APPENDIX 3. MAP OF FISHERIES MANAGEMENT AREA. MINISTERIAL DECREE OF MMAF NO 18 2014



APPENDIX 4. FISHING GEARS SELECTIVITY. MINISTERIAL DECREE OF MMAF NO 71 2016

No	Fishing Gears								Fishing boat					Fishing zone				Fishery Management Areas											Notes
	Category	Abv	Code	Nature of gears			Gear size, selectivity and capacity	Fishing gear equipment	Non motorized	≤ 5 GT	6-10 GT	11-30 GT	> 30 GT	IA (0-2 mile)	IB (2-4 mile)	II (4-12 mile)	III (> 12 mile)	571	572	573	711	712	713	714	715	716	717	718	
				Static	Pasive	Active																							
1	Surrounding net		01.0.0																										
1.1	Purse seine	PS	01.1.0																										
1.1.1	Purse seine operated by one boat	PS 1	01.1.1																										
1.1.1.1	Targeting small pelagic fish	PS 1-K	01.1.1.1			√	Mesh size ≥ 1 inch Floatline ≤ 300 m	FAD with lamps ≤ 4000 wattage	NA	√	√	NA	NA	NA	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
							Mesh size ≥ 1 inch Floatline ≤ 400 m	FAD with lamps ≤ 8000 wattage	NA	NA	NA	√	NA	NA	NA	√	√	√	√	√	√	√	√	√	√	√	√	√	
							Mesh size ≥ 1 inch Floatline ≤ 600 m	FAD with lamps ≤ 16000 wattage	NA	NA	NA	NA	√	NA	NA	NA	√	√	√*	√*	√	√	√	√*	√	√*	√*	√	√* boat ≤ 300 GT
1.1.1.2	Targeting big pelagic fish	PS 1-B	01.1.1.2			√	Mesh size ≥ 2 inch Floatline ≤ 700 m	FAD with lamps ≤ 16000 wattage	NA	NA	NA	√	NA	NA	NA	√	√	NA	√	√	NA	NA	NA	√	NA	√	√	NA	
							Mesh size ≥ 2 inch Floatline ≤ 1500 m	FAD with lamps ≤ 16000 wattage	NA	NA	NA	NA	√	NA	NA	NA	√	NA	√	√	NA	NA	NA	√	NA	√	√	NA	
1.1.2	Purse seine operated by two boats	PS 2	01.1.2																										
1.1.2.1	Targeting small pelagic fish	PS 2-K	01.1.2.1			√	Mesh size ≥ 1 inch Floatline ≤ 600 m		NA	NA	NA	√	NA	NA	NA	√	√	√	NA	NA	√	√	√	NA	√	NA	NA	√	
1.1.2.2	Targeting big pelagic fish	PS 2-B	01.1.2.2			√	Not Allowed																						
1.2	Surrounding net without purse line	LA	01.2.0			√	Mesh size ≥ 1 inch Floatline ≤ 150 m		NA	NA	√	NA	NA	NA	√	√	√	√	√	√	√	√	√	NA	√	NA	NA	√	

*) NA = Not Allowed

No	Fishing Gears							Fishing gear equipment	Fishing boat					Fishing zone				Fishery Management Areas											Notes
	Category	Abv	Code	Nature of gears			Gear size, selectivity and capacity		Non motorized	≤ 5 GT	6-10 GT	11-30 GT	> 30 GT	IA (0-2 mile)	IB (2-4 mile)	II (4-12 mile)	III (> 12 mile)	571	572	573	711	712	713	714	715	716	717	718	
				Static	Pasive	Active																							
2	Seine nets		02.0.0																										
	2.1 Beach seines	SB	02.1.0			√	Mesh size ≥ 1 inch Floatline ≤ 150 m		√	√	NA	NA	NA	√	NA	NA	NA	√	√	√	√	√	√	√	√	√	√	√	
	2.2 Boat seines	SV	02.2.0																										
	2.2.1 Danish seines	SDN	02.2.1			√	Not Allowed																						
	2.2.2 Scottish seines	SSC	02.2.2			√	Not Allowed																						
	2.2.3 Pair seines	SPR	02.2.3			√	Not Allowed																						
	2.2.4 *Payang*	SV-PYG	02.2.0.1			√	Mesh size ≥ 1 inch Floatline ≤ 100 m Anchovy mesh size >1mm		NA	NA	√	NA	NA	NA	√	√	√	√	√	√	√	√	√	√	√	√	√	√	For anchovy seasonally adjusted
	2.2.5 *Cantrang*	SV-CTG	02.2.0.2			√	Not Allowed																						
	2.2.6 *Lampara dasar*	SV-LDS	02.2.0.3			√	Not Allowed																						
3	Trawls		03.0.0																										
	3.1 Bottom trawls	TB	03.1.0																										
	3.1.1 Beam trawls	TBB	03.1.1			√	Not Allowed																						
	3.1.2 Otter trawls	OTB	03.1.2			√	Not Allowed																						
	3.1.3 Pair trawls	PTB	03.1.3			√	Not Allowed																						
	3.1.4 Nephrops trawls	TBN	03.1.4			√	Not Allowed																						
	3.1.5 Shrimp trawls	TBS	03.1.5			√	Not Allowed																						
	3.1.5.1 *Pukat udang*	TBS-PU	03.1.5.1			√	Not Allowed																						
	3.2 Midwater trawls	TM	03.2.0			√	Not Allowed																						
	3.2.1 Otter trawls	OTM	03.2.1			√	Not Allowed																						
	3.2.1.1 *Pukat ikan*	OTM-PI	03.2.1.1			√	Not Allowed																						
	3.2.2 Pair trawls	PTM	03.2.2			√	Not Allowed																						
	3.2.3 Shrimp trawls	TMS	03.2.3			√	Not Allowed																						
	3.3 Otter trawls	OTT	03.3.0			√	Not Allowed																						
	3.4 *Pukat dorong*	TX-PD	03.9.0.1			√	Mesh size ≥ 1 mm		NA	NA	NA	NA	NA	√	√	NA	NA	√	√	√	√	√	√	√	√	√	√	√	

*) NA = Not Allowed

APPENDIX 5. ESTIMATION OF MODIFIED NET WEIGHT.

No	Part	Netting	Mesh size	Number of mesh		Net (m)		Hanging Ratio		Stretched	Twine	Correction	R tex	W in air
		Material	(mm)	Transverses	Points	Depth	Length	E1	E2	length (m)	Dia (mm)	factor (k)		(gram)
1	Body 1	PA 210D/6	25.4	3600	2400	42.67	64.01	0.70	0.70	91.44	0.40	1.40	0.16	98,316.29
2	Body 2	PA 210D/6	25.4	3600	2400	42.67	64.01	0.70	0.70	91.44	0.40	1.40	0.16	98,316.29
3	Body 3	PA 2106/6	25.4	360	2400	42.67	6.40	0.70	0.70	9.14	0.40	1.40	0.16	9,831.63
4	Body 4	PA 2106/6	25.4	3600	2400	42.67	64.01	0.70	0.70	91.44	0.40	1.40	0.16	98,316.29
5	Bunt	PA 210D/12	25.4	1200	1200	21.34	21.34	0.70	0.70	30.48	0.60	1.40	0.31	31,747.97
6	Wing end	PA 210D/6	25.4	1200	1200	21.34	21.34	0.70	0.70	30.48	0.40	1.40	0.16	16,386.05
7	ABs	PA 210D/6	25.4	1200	1200	21.34	21.34	0.70	0.70	30.48	0.40	1.40	0.16	16,386.05
8	Enforcement floatline	PA 210D/12	50.8	16800	50	1.78	597.41	0.70	0.70	853.44	0.60	1.24	0.31	32,806.23
9	Enforcement leadline	PA 210D/24	50.8	7250	25	0.89	257.81	0.70	0.70	368.30	0.85	1.24	0.62	14,157.45
10	Enforcement gavels	PA 210D/24	50.8	25	600	21.34	0.89	0.70	0.70	1.27	0.85	1.24	0.62	1,171.65
11	Enforcement Abs	PA 210D/24	50.8	25	600	21.34	0.89	0.70	0.70	1.27	0.85	1.24	0.62	1,171.65
												Total Net weight =		418,607.54

W = $H \ x \ L \ x \ \frac{Rtex}{1000} \ x \ K$ (FAO, 1990)

W = estimated weight (g) of netting
H = number of rows of knots in the height of the netting
L = stretched length (m) of netting
Rtex = the size of twine in the netting
K = knot correction factor

APPENDIX 6. PURSE SEINERS OF GULF OF BONE

Training vessel of Bone Fisheries School

APPENDIX 7. THE CATCHES

APPENDIX 8. ENGINES AND DECK EQUIPMENT

Purseline hauler