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ARTISANAL PURSE SEINE DESIGN IMPROVEMENTS SUGGESTED FOR MOZAMBIQUE FISHERIES

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ABSTRACT

This study deals with improving the Mozambique artisanal purse seining for small pelagic fish (sardine, trachurus and anchovy) on 8 to 12 m vessels. Artisanal fishermen in Mozambique to catch small pelagic inshore species have used purse seines. The current fishery is inefficient and needs to be improved to increase income in fisheries. This study was conducted in order to enhance the knowledge within artisanal purse seining and to strengthen the present institutional capacity in the field. The paper presents behavioural and technical aspects regarding design of artisanal purse seines, technical analyses of an example of existing purse seine and proposed modification. Using larger mesh and increasing ballast could improve calculated sinking speed. Introducing the use of a purse seine line can reduce manpower (divers) and shorten the closing time. Further mechanization of the vessels (manual or motor driven winches) is important for the further development of artisanal purse seining in Mozambique.

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ABBREVIATIONS

A	Distance at which the fish react
An	Working area of a rectangular net
Af	Factious area of the netting
b	Seine length coefficient
B	Buoyancy
DM	Density (g/cc) of material
DW	Density of sea water
E	Extra buoyancy
E1	Primary (horizontal) hanging ratio
E2	Vertical hanging ratio
FAO	Food and Agriculture Organization
Fs	Ballast of the lead line
GDP	Gross Domestic Production
Hp	Horse Power
IDPPE	National Institute for Development of Small Scale Fisheries
K	Flotation factor
Km	Empirical coefficient of target fish specie
Kgf	Kilogram force
l	Length of purse seine
L	Length of target specie
L_1	Float line length
m	Metre
moC	Mesh opening in the bunt
MoF	Ministry of Fisheries
moB	Mesh opening in the seine bunt
PA	Polyamide
PE	Polyethylene
PVC	Polyvinyl chlorite
r	Radius of the school
s	Sinking power
SADC	Southern African Development Community
t	Time
W	Weight in water
W_A	Weight in grams per square metre of the fictitious area
Wn	Weight of the netting
Vf	School's swimming speed
V_s	Seiner's setting speed

1 INTRODUCTION

1.1 Background

Mozambique extends for 2,700 km along the east coast of Africa, and covers an area of about 802,000 km^2. It is bounded by the Indian Ocean to the east, Tanzania to the north, Swaziland and South Africa to the south, Zimbabwe and Zambia to the west and Malawi to the Northwest (Figure 1). It has a population of 21,350,000 and a surface area of 799,380 km^2 (Honguane 2007). Mozambique has a tropical climate with two seasons, a wet season from October to March and a dry season from April to September. Climatic conditions, however, vary depending on altitude. Rainfall is heavy along the coast and decreases in the north and south. Annual precipitation varies from 500 to 900 mm (MoF 2009). The coast is characterized by pristine ecosystems, high biological diversity, high endemism and endangered species. Various natural resources include fisheries, coastal and marine fauna and flora that sustain about 2/3 of Mozambique population that are living in these areas (IDPPE 2007). The continental shelf is alternatively narrow and very wide, up to 90 nautical miles at the Sofala Bank. The primary productivity is relatively high due to currents and numerous rivers bringing considerable amounts of sediments and nutrients. Fresh water fisheries are important in Lake Malawi/Niassa and Cahora Bassa dam, and the numerous rivers that run through the country (SADC 2000).

Figure 1. Mozambique and it's neighbouring countries

1.2 Mozambique fisheries

The fisheries sector plays an important role in food security, nutrition and employments, and contributes 3 % to the Gross Domestic Product (IDPPE 2011). The fishing industry can be divided into artisanal, semi-industrial and industrial sector. Artisanal fishing provides livelihoods for more than 50,000 families and supplies food for a large proportion of the population. The total marine catch is around 130,000 tons/year, of which about 90% comes from artisanal fisheries (MoF 2009).

Marine and freshwater fisheries are organised in more than 1200 fishing centres, about half of them are scattered along the coast. There are around 280.000 artisanal fishers with a fleet of about 40,000 boats namely canoe, “moma”, “chuabo”, “chata”, “lancha”, fibre glass and hollowed log canoe (see Appendix 4) of which 77% are canoes and only 3% of boats are motorised. The main fishing gears used in artisanal fisheries are gillnets (41.7%), hand lines (22.8%), beach seines (17.5%), traps (3.3%), longline (2.2%) and purse seines (2%) (IDPPE 2007).

Fishing is practiced using gears with small mesh sizes (mosquito net, “chicocota” and beach seine nets). These gears catch juveniles to a great extent as the fishermen practice their activities along the coast on fish nursery grounds. In addition, their vessels are generally unsafe (not worthy sea) (MoF 2006). A guide on the fishing gear is also lacking, especially on purse seine, for the technicians at IDPPE.

Purse seining is practiced along the northern coast of Mozambique, using vessels of length from 8 to 12 m and gear dimensions of 120 to 200 m in length and 16 to 25 m deep with illegal mesh size (6mm) as opposed to the minimal 18 mm legal one (MoF 2003).

Most of the purse seines currently used by the Mozambican artisanal fishermen lack rings at the foot rope (Appendix 1), and lots of manpower is needed to pull the seine, in addition divers are needed to close the lead line during fishing. Artisanal purse seine unit has 30 fishermen (Appendix 3) and incomes are divided among fishermen (50%) and the owner of the fishing unit (50%). The catches from the unit of fishing doesn’t satisfy the fishermen’s basic needs, so there is a need to improve the conventional purse seine used and craft to reduce the number of fishermen needed to operate purse seine units and also to reduce the risk divers are subjected to while shutting the gear.

Since its establishment, the National Institute for Development of Small-Scale Fisheries (IDPPE) in partnership with fishermen has tested different fishing gear and fishing methods at various fishing centres with the main purpose to diversify fishing techniques and improve management.

In 2001, IDPPE imported an artisanal purse seine from Zanzibar (Tanzania) to be tested in Mozambique with the aim to promote open sea fishing and consequently reduce the pressure on the resource by beach seine along the coast and in such a way fish small pelagic that was less exploited. It was hoped that once purse seine tested successfully with light attraction, the gear would be adhered and a considerable number of fishermen using beach seine would shift to the purse seining. The gear was tested in Angoche (Nampula province) and gave unsatisfactory results. In December 2010, the IDPPE carried out a mission to Zanzibar with technicians and fishermen of Cabo Delgado and Nampula provinces to study purse seine and gain experience in fishing with light attraction.
However, the development of this sub-sector suffers constraints that limit production. The problem is the absence of skills on fishing gear assembly, associated with weak technical capacity of stakeholders to develop the program and disseminate information.

There are five pillars of the strategic plan of the artisanal fisheries sub-sector, to highlight:

- Added results for fisheries providing increased income to artisanal fishermen.
- Marketing of products from small-scale fisheries generating better income for fishermen.
- Improve social conditions in the communities of fishermen.
- Expand and facilitate financial services for the fishing sector.

- Strengthen and improve the performance of institutions devoted to the development and fisheries management.

1.3 Purse seine as a fishing gear

Fishing gear is a synonym for all gears used for catching, trapping or getting any aquatic organism. The purse seine belongs to the surrounding net class in which fish are surrounded not only from the side but also from below, letting them to be caught in deep waters (Fridman 1986).

Purse seine is named from the feature that along the bottom of the net are a number of rings, a rope passes through the rings, and when pulled the bottom of the seine is closed, like a purse, preventing the fish from escaping. The purse seine is a preferred technique for capturing schooling fish species, close to the surface such as sardines, mackerel and anchovies. Purse seines are classified as active gears, and are a long net with bottom edge and buoyant top. They can be divided into two general types; those in which the fish are finally contained in a bag or “bunt” at the centre of the length, and those in which the bunt is at the end.

The performance of this gear depends to a large extend on sinking speed and the speed at which it can be set. When a purse seine is set (Figure 2), the fish school may either retain its position in the centre of the net during the setting operation, or swim actively and attempt to escape from the surrounding net.

An actively swimming school may slip out of the net before the encircling is completed, by passing between the buoy-end and vessel or under the lead line before it descends completely. Thus, a mobile school must be observed in order to surround it. The lead line must sink fast enough to prevent the school from escaping by swimming under the lead line. The buoyancy is important because surrounding net seines are operated at the surface. Their float lines should therefore be buoyant under all conditions and the buoyancy should be sufficient to resist the weight of netting, sinkers and the catch in the water. The mesh size is important in purse seine. It must be both large enough to let out juveniles and small enough not to gill the fish.

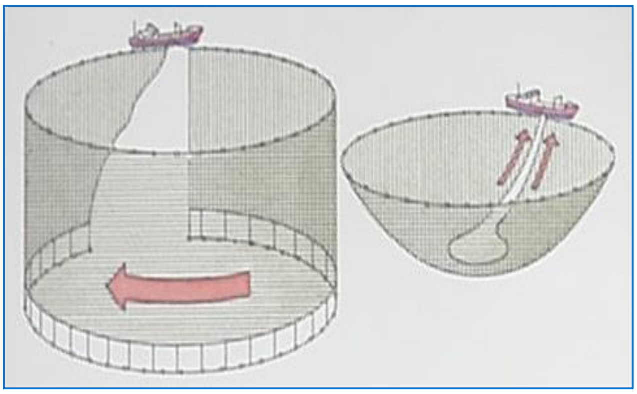

Figure 2. Purse seine in operation

1.4 Target species

Artisanal purse seines in Mozambique are mostly used to catch small pelagic fish such as sardinella, trachurus and anchovy.

1.4.1 Sardinella (sardinella gibbosa)

Sardinella is a genus of fishes in the family clupeidae (Figure 3). These fish are generally coastal, schooling fish and abundant in warmer waters. They can be found nearly anywhere in the tropical and sub-tropical oceans of the world. Many species are distinguished by their distribution around the globe but may also be distinguished according to specific body features. Sardinella can be found at both sides of the Atlantic, throughout the Mediterranean, along with the tropical and subtropical Indian and West Pacific Oceans (Peter *et al.* 1988). The spawning season for these fish ranges from April to October. There is a trend of smaller fish spawning earlier in the spawning season. Peak spawning occurs in June and July and this is followed by the older larger specimens, which tend to move into the spawning areas later in the season (Okera 1969). Three small to medium sized species live in Mozambique and may reach 12 to 17cm in adult state. The body is moderately to strongly flattened, forming a strong keel on the belly.

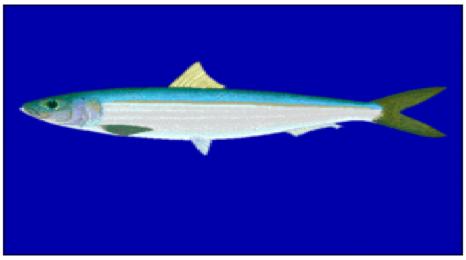

Figure 3. Sardinella gibbos

1.4.2 Trachurus (Decapterus russelli)

Decapterus is a genus of fishes in the family Carangidae (Figure 4). These fish are generally coastal schooling fish, found in waters between 30-170 m depth. There are five species in Mozambique, small to medium in size and may reach 35 cm (Smith 1986). In Mozambique, the sardines and trachurus purse seine fishing is done at night using light attraction with auxiliary boats.

Figure 4. Decapterus russelli

1.4.3 Anchovy (Encrasicholina punctifer)

Anchovies (Engraulidae) are small (can reach up to 9 cm) (FAO 1990b), green fish with blue reflections due to a silver longitudinal stripe that runs from the base of the caudal fin (Figure 5). They are found throughout the world's oceans, but are concentrated in temperate waters, but are rare or absent in cold or warm seas. They are generally tolerant of a wide range of temperature and salinity. The anchovy is a significant food source for almost every predatory fish and is also extremely important to marine mammals and birds. These fish (sardinella, trachurus and anchovy) usually form schools of same species and uniform size, swimming in a dense formation maintaining an approximately uniform course and swimming speed. There is also other accumulation of fish, such as those attracted to light. Such accumulation can be composed of several species and of fish of different sizes whose behaviour is often not uniform (FAO 1990)

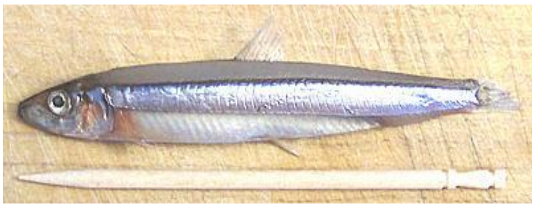

Figure 5. Encrasicholina punctifer

1.5 Objective

The objective of the present project is to design a technically upgraded artisanal purse seine for pelagic species (sardinella and trachurus) in Mozambique to be tested in June 2012. This should be a guide for the technicians of the sector and encouragement for the fishermen for increasing productivity and contributing to the strategic plan of the artisanal fisheries.

In order to reach the goal the following steps were taken:

- Analysis of a representative artisanal purse seines used in Mozambique.
- Reviewing the biology of target species relevant to purse seining.
- Designing a modified version of existing gear.

2 METHODS

In this study an artisanal purse seine used in Mozambique was analysed. Information on a particular purse seine design was collected from Mozambique artisanal fisheries through the IDPPE. The seine is currently in use for small pelagic fish (sardine, trachurus and anchovy) on 8 to 12 m long vessels.

According to Ben-Yami (1994) the main elements of a purse seine design are overall dimensions, float line to lead line ratio, hanging ratios patterns of the net ends (wings), length to the deep ratio, shape of the net, number, distribution and buoyancy of floats, number, distribution and weight of sinkers, and material used. These criteria were used for both analysing existing purse seine and for designing a modified version. The calculations and design were supported by literature review and practical assembling exercises and studies made at the Fjarðanet hf net loft in Isafjordur, Iceland.

All calculations were done using MS excel software, Design CAD 2000 computer software was used for drawing gear plans.

2.1 Overall dimensions

The overall dimension of a purse seine (length and depth) should be selected according to the following criteria: 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).

A formula illustrating the main physical criteria for seine length selection is given as follows (Fridman 1986):

L= b (a + r) *Equation 2.1*

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

The seine length coefficient b depends on speed ratio of seiner's setting speed V_s/ against the school's swimming speed V_f, m/s (Figure 6).

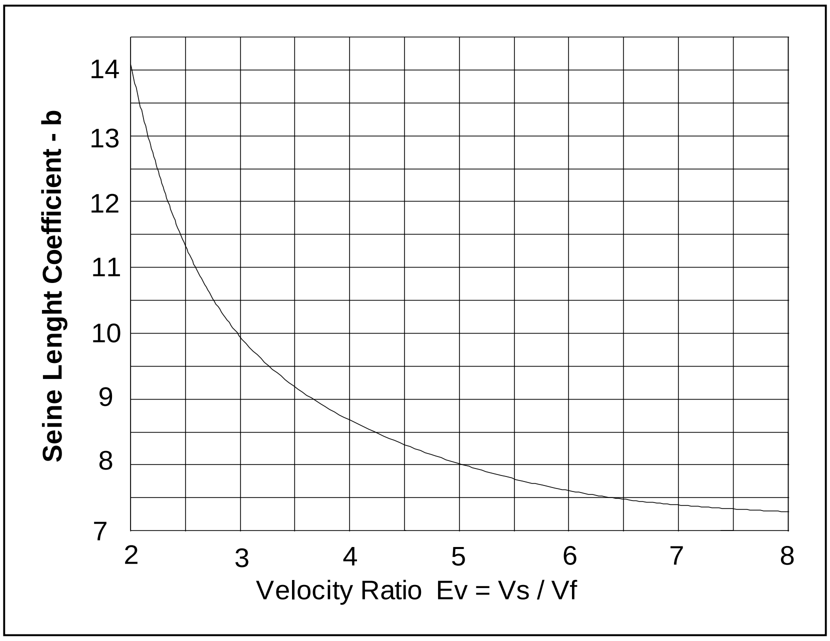

Figure 6. Seine length coefficient b as a function of seine setting speed (V_s) and school swimming speed ratio (V_f) (Fridman 1986).

The design of the seine depth takes into account the depth to which the fish are capable of descending and the speed of their descent. This determines the ratio of depth to length of the seine needed to preserve the required shape during the pursing operation.

According to experienced fishermen (Fridman 1986), the 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 for nearly circular schools and their maximum speeds, V_f by species is given in Table 1 (Fridman 1986).

Table 1. Characteristics of fish schools (Fridman 1986 pp. 194).

Species	**Diameter (m)**	**Speed V_f (m/s)**
Atlantic herring	25	1.0
Sardine	50	1.1
Mackerel	40	1.3
Belted bonita	30	1.6
Black se anchovy	60	0.8

For successful fishing, the lead line should be designed to reach to 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 the length of the seiner and the depth of the seine should be at least 10% of its length. The minimum length of the bunt should be at equal to the length of the vessel. These criteria were also taken into account.

2.2 Hanging ratio.

The proper distribution of tension, the fishing depth, and the shape of the seine in operation are all directly related to the amount of slack used in hanging the netting to the frame lines (FAO 1990). For determining the amount of netting needed (given the frame rope lengths and mesh sizes) these formulas for primary and secondary hanging were used:

The primary hanging ratio (E_1) is calculated:

$$E_1 = \frac{\text{Rope length (m)}}{\text{Stretched net length (no. of meshes X mesh size)}}$$ *Equation 2.2*

$$E_2 = \sqrt{1 - E_1^2}$$ *Equation 2.3*

Where E_1 is the primary (horizontal) hanging ratio of the netting, and E_2 the secondary hanging ratio representing the ratio of rope length and stretched net length in the vertical direction.

2.3 Determining the mesh size

The netting specification (mesh size, twine construction, fibre type etc.) is selected according to fishing conditions and fish to be caught (Fridman 1986). Enmeshing or gilling the fish should be avoided in accordance to mesh size regulations (FAO 1990a). A common procedure is to select a mesh size considerably smaller than this in the bunt where the fish crowds the netting, but a larger mesh is satisfactory in the other parts where it herds the fish while achieving faster sinking. The bunt of a purse seine has basically the same function as the codend of trawls. The mesh opening should be such that the smallest commercial fish sardinella in this case will not become entangled (Fridman 1986). Mesh sizes were calculated using equation 2.4 (Fridman 1986 pp. 200):

$m_{OB} \approx \frac{2}{3} \times m_{OG}$ *Equation 2.4*

where:
m_{OB} is the mesh opening in the seine bunt
m_{OG} is the mesh opening of a gill net designed to capture fish of the same species and size.

In this term m_{OG} may be estimated from:

$m_{OG} = L/K_m$ *Equation 2.5*

Where:
L = length of the fish body from snout to the base of the caudal fin.
K_m= empirical coefficient depending on the morphology of the fish found by experimental fishing with gill nets.

As an approximation the following values for K_m can be used:

K_m= 5 for fish that are long and narrow.
K_m= 3.5 for average shaped fish.
K_m= 2.5 for flat, deep-bodied, or wide.

The value K_m= 5 was used in this work (sardinella).

2.4 Estimation of netting weight in air

According Fridman (1986) the weight of the netting panel in grams (W_n) is given by:

$Wn = W_A \times A_f$ *Equation 2.6*
$A_f = An/(E_1 \times E_2)$ *Equation 2.7*

where:
W_n = is the weight of the netting in panel express in grams.
W_A= Weight in grams per square metre of the fictitious area, given in Appendix 3. Properties of kapron (PA) light, laid netting (Fridman 1986 pp. 230).
A_f = Factious area of the netting.
A_n = Working area of a rectangular net.

2.5 Estimation of netting weight in water

The netting weight in water was obtained using equation 2.8 from FAO (1990 pp. 4):

$P = A \ x\ (1 – DW / DM)$ *Equation 2.8*

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

2.6 Estimation of buoyancy.

The buoyancy or float line should be sufficient to resist downward pull of the weight of the netting, the sinkers and the catch in water, as well as other forces acting on the net through their downward resultant, such as the downward component of the pull in the purse line as transferred to the net through the purse rings (Ben-Yami 1994). The number of floats to be fitted to a float line can be calculated using the two following expressions (Ben-Yami 1994):

$$\text{No. of floats} = \frac{L_1 \times (S+E)}{B} \qquad \textit{Equation 2.9}$$

where:
L_1 = float line length (m).
S = sinking power of the net per 1m (netting, ballast, frame lines, purse line and rings).
B = buoyancy of one float (Kgf).
E = required extra buoyancy per metre (Kgf) (50% used here according to (FAO 1990a pp. 65).
K = flotation factor by which total floats buoyancy in water should exceed the total weight of the seine in the water. Most commonly K= 2.

For the artisanal purse seines float length (L) range from 100 to 400 mm, diameter (Ø) 75 to 300 mm for buoyancy from 300 to 22,000 gf (Figure 7). Equation 2.10 was used to calculate the buoyancy of a single float (FAO 1990a).

Buoyancy of one float (Kgf) was:

$$B = 0.5 \times L_1(cm) \times Ø^2(cm) \qquad \textit{Equation 2.10}$$

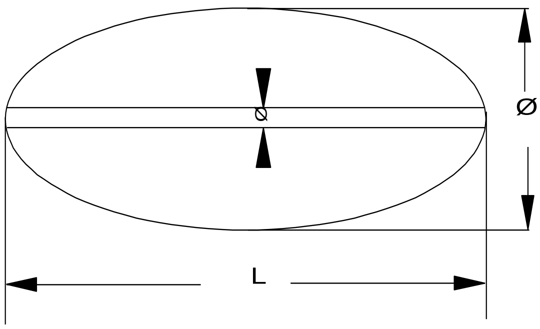

Figure 7. Floats dimension (FAO 1990).

2.7 Estimation of sinking speed

Sinking speed was determined using equation 2.11 from Baranov (1969) expressing the relation between the ballast and the sinking speed:

$$T = 0{,}9 \times H \times \sqrt{H / Fs} \qquad \textit{Equation 2.11}$$

where:
H = fishing depth of the lead line (m).
T = the time (in seconds) for the lead line to sink to the depth H.
Fs = weight in water of the lead line, purse line, purse rings, etc. per 1 linear metre of the lead line (Kg/m) and can be estimated using formula.

$$Fs = \frac{W(Kgf)}{l(m)}$$ *Equation 2.12*

where:
W = is the total ballast of the purse seine.
l = is the total length of the lead line.

3 RESULTS

3.1 Analysis of a representative artisanal purse seine.

3.1.1 Seine length, seine depth and hanging ratio

The conventional artisanal purse seines used in Mozambique are 186 m long and 20 m deep. They are symmetric, with central bunt, having 6.4 mm mesh size and hanging ratio of 0.6 in all the length of the gear (Table 2).

Table 2. Number of meshes on length and depth and hanging ratio on each part of the gear.

Mozambique Artisanal Purse Seine- 186 m							
Sections	E_1 Horiz. Hanging	E_2 Vertical Hanging	Lenght (m)	Depth (m)	Mesh size (mm)	No. of meshes horizontal	No. of meshes vertical
Wing	0,6	0,8	36	20	12,7	4.724	1.969
Shoulder	0,6	0,8	42	20	12,7	5.512	1.969
Bunt	0,6	0,8	30	20	6,35	7.874	3.937
Shoulder	0,6	0,8	42	20	12,7	5.512	1.969
Wing	0,6	0,8	36	20	12,7	4.724	1.969

3.1.2 Buoyancy

The floats used in Mozambique artisanal purse seines are PVC material SH-20 (90 mm of length, 50 mm Ø and 20 mm Ø of hole (Figure 7) with 190 grf buoyancy and arranged at a distance ranging from 100 mm to 190mm. The total buoyancy of each gear is about 236 kgf (Table 3).

Table 3. Buoyancy and number of floats in different part of the gear.

Buoyancy of Mozambique Artisanal Purse Seine- 186 m					
Section	L(m)	Distance between floats (mm)	Bouyancy (gf)	Nr of floats	Buoyancy (Kgf)
Wings	36	150	190	240	46
Shoulder	42	150	190	280	53
Bunt	30	150	190	200	38
Shoulder	42	150	190	280	53
Wings	36	150	190	240	46
Total	186			1240	236

3.1.3 Net weight in air and in sea water

The total net weight in air is about 143 kgf. When inserted in seawater the weight reduces to about one-tenth with the material used in Mozambique (Polyamide-PA) (Table 4). The calculations were made using the material coefficients density in seawater (0.1) (FAO 1990a).

Table 4. Net weight in air and water.

Netting weight of Mozambique Artisanal Purse Seine- 186 m								
Sections	Length (m)	Depth (m)	E_1 (Horiz)	E_2 (Vert)	Mesh size (mm)	A_f (m^2)	W_n (kg)	Weight in sea water (kg)
Wing	36	20	0,6	0,8	12,7	1500	27,75	2,78
Shoulder	42	20	0,6	0,8	12,7	1750	32,38	3,24
Bunt	30	20	0,6	0,8	6,35	1250	23,13	2,31
Shoulder	42	20	0,6	0,8	12,7	1750	32,38	3,24
Wing	36	20	0,6	0,8	12,7	1500	27,75	2,78
Total	186					7750	143,38	14,34

3.1.4 Ballast

The length of the lead line was measured, distance between sinkers measured and number of sinkers checked. The weight of lead sinkers in water was calculated as 91% of the weight in air (FAO 1990a). Ballast here is used as a term for the total sinking force (48.2 kgf) acting on the gear that is the sinking force of the netting (14.3 kgf) plus the sinking force of the lead sinkers (33.9 kgf) or 48.2 kgf, see Table 5.

Table 5. The ballast of current Mozambique purse seine.

Ballast (total sinking force)of Mozambique Artisanal Purse Seine- 186 m						
Sections	L(m)	Buoyancy (Kgf)	Weight of netting in sea water (Kg)	Buoynacy - Weight of netting (Kg)	Weight of lead in water (Kgf)	Total ballast
Wing	36	46	2,78	42,83	6,6	9,3
Shoulder	42	53	3,24	49,96	7,6	10,9
Bunt	30	38	2,31	35,69	5,5	7,8
Shoulder	42	53	3,24	49,96	7,6	10,9
Wing	36	46	2,78	42,83	6,6	9,3
Total	186	236	14,3	221,3	33,9	**48,2**

3.1.5 Sinking speed of current Mozambique purse seine

The sinking force per unit of length of the lead line was calculated according to equation 2.12:

$Fs = W(kgf)/ l\ (m) = 33.85 kgf/ 186\ m = 0.18\ kgf/ m$

The sinking time (t) is calculated according to equation 2.11:

$T = 0{,}9 \times H \times \sqrt{H} / Fs = 0{,}9 \times 20\ m \times \sqrt{20\ m/0.18\ kgf/m} = 254.5\ sec = 4\ min.\ and\ 14\ sec.$

3.2 Biology of targeted species and criteria for new purse seine design.

a) Depth of schools

The target species (sardine and trachurus) generally swim at about 30 m depth according to (FAO 1990b). The conventional artisanal purse seine is 20 m depth and can therefore be said to be too shallow for this type of fishery. Designing a purse seine 20% deeper than the swimming depth of the targeted species would give us the depth of 36 m (Fridman 1986) i.e. approximately twice the existing depth. Taking into account the size and type of the existing vessels it is considered wiser to take smaller steps and aim a new design to sink to 30 m max.

b) The size of school and swimming speed

The length of the conventional net (186 m) is rather low in relation to estimated fish swimming speed of 1.1m/s. The common size of fishing school in Mozambique being approximately 15 m, according to fishermen's experience, verbal information and personal experience. The swimming speed of the targeted species is considered to be in the vicinity of 1.1 m/sec (Fridman 1986 pp. 194).

c) Mesh size

The current mesh sizes is 6.4 mm. Taking into account the size of the main targeted species (sardinella and turchurus) 145 mm and using equations 2.4 and 2.5 the mesh size should be 19 mm. Further, the minimum regulated mesh size is 18 mm for purse seines in Mozambique.

d) Handling
The purse seine should be closed as quickly as possible and with minimum manpower, so the new gear should have a purse line and a purse rings system. To haul the gear after encircling the school and close the purse ring system calls for mechanization through the introduction of winches.

3.3 New design of modified purse seine

The parameters taken into account for the new modified purse seine were: mesh size, length, buoyancy, weights and hanging ratio. The new design has to fit the existing vessels and introduction of mechanical winches is needed.

3.3.1 Determining the mesh size

The average length of sardinella was selected as 14.5cm according to FAO (1990b).

Using equation 2.4 and 2.5:

m_{oG} = 145/5 = 29 mm; m_{oC} = 2/3 x 29 mm = 19,3 mm =3/4" in the bunt section.

It was decided to use 1 inch and 1 ¼ inch (25.4 and 31.75 mm) for the shoulder and wing sections respectively. Both these mesh sizes are commonly used and available in Mozambique.

3.3.2 Seine length

Minimum rope length

The total length of new design was calculated according the size of common fishing schools in Mozambique being 15 m, the fish swimming speed 1.1m/s (sardinella), see Table 1, and the minimum reaction distance (a) estimated by the author to be 15 m.

Using Equation 2.1 to determine the seine length:

L= b (a + r)= 9.5 x (15 + 7.5) = 212m (b taken from Figure 6, see also Table 5).

It was therefore decided to design a 200 m long purse seine.

Table 6. Seine length according to the analyses of seine velocity, school fish size and distance that the fish react to the gear.

Seine length calculations								
Specie	**School Diamter(m)**	**Vf school velocity**	**Vs setting velocity**	**Velocty ratio: Ev=Vs/Vf**	**b**	**a**	**r**	**L**
Sardinella	15	1,1	3,60	3,27	9,5	15	7,5	213,75

b = seine length coefficient (Figure 6), which in turn depends on a speed ratio (seiner's setting speed V_s/school's swimming speed V_f, m/s).
a = the distance at which the fish react to the net (m).
r = the radius of the school (m).
l = minimum length of purse seine (m).

Netting length to fit rope length

The number of meshes of length and depth was calculated in different parts of the gear using different hanging ratio in different mesh size (Table 7) (see also Appendix 2).

Table 7. Number of meshes on length and depth and their respective hanging ratios.

Panel sizes of a improved Artisanal Purse Seine							
Sections	**E_1**	**E_2**	**Length (m)**	**Depth (m)**	**Mesh size mm**	**No. Meshes wide**	**No. Of meshes deep**
Wings	0,4	0,92	37,5	30	31,75	2953	1031
Shoulder	0,6	0,80	45	30	25,40	2953	1476
Bunt	0,6	0,80	35	30	19,05	3062	1969
Shoulder	0,6	0,80	45	30	25,40	2953	1476
Wings	0,4	0,92	37,5	30	31,75	2953	1031

3.3.3 Buoyancy

It was decided to use available floats made of PVC material, type Y-30 (70*110*20 mm) with 270 grf buoyancy and arranged at a distance 80 mm in the bunt and 110 mm in shoulder and wings. The total buoyancy of gear is about 252kgf (Table 8).

Table 8. Buoyancy of Mozambique new modified purse seine.

Buoyancy on improved Artisanal Purse Seine					
Sections	**L(m)**	**Distance between floats (mm)**	**Nr of floats**	**Flotation each (gf)**	**Buoyancy (Kgf)**
Wing	37.5	220	170	270	46
Shouder	45	220	205	270	55
Bunt	35	190	184	270	50
Shoulder	45	220	205	270	55
Wing	37.5	220	170	270	46
Total	200		934		252

3.3.4 Weight of netting in air and in seawater

The total weight of the netting in air and seawater was calculated according to Equations 2.6, 2.7 and 2.8 and is presented in Table 9.

3.3.5 Ballast

A total number of 400 leads of 300 g each are evenly distributed along a 200 m long lead line giving 0.6 kg/m. A total of 90 purse rings are distributed evenly along the lead line and breast lines each weighing 0.3 kg. In Table 10 values of buoyancy and sinking force is given for each section.

Table 9. Net weight calculation in the air and water.

Netting weight of improved Artisanal Purse Seine in air and in water								
Sections	**L(m)**	**Deep (m)**	**E_1**	**E_2**	**Mesh size**	**Af (m^2)**	**Weight in air Wn (kg)**	**Weight in sea(kg) P**
Wing	37.5	30	0.9	0.4	31.75	3125.00	57.81	5.78
Shoulder	45	30	0.8	0.6	25.4	2812.50	52.03	5.20
Bunt	35	30	0.71	0.7	19.05	2112.68	39.08	3.91
Shoulder	45	30	0.8	0.6	25.4	2812.50	52.03	5.20
Wing	37.5	30	0.9	0.4	31.75	3125.00	57.81	5.78
Total	200						258.77	25.88

Table 10. The ballast of new purse seine in air and water.

Ballast (total sinking force) of improved Mozambique Artisanal Purse Seine - 200 m								
Sections	L(m)	Buoyancy (Kgf)	Weight of netting in sea water (Kg)	Buoyancy - Weight of netting (Kg)	Weight of lead in water (Kgf)	No of rings	Weight of rings in water (Kgf)	Total ballast (Kgf)
Wing	37.5	46	5.78	40.24	20.48	17	4.40	30.66
Shoulder	45	55	5.20	50.02	24.57	20	5.29	35.06
Bunt	35	50	3.91	45.83	19.11	16	4.11	27.13
Shoulder	45	55	5.20	50.02	24.57	20	5.29	35.06
Wing	37.5	46	5.78	40.24	20.48	17	4.40	30.66
Total	**200**	**252**	**26**	**226**	**109**	**90**	**23**	**159**

3.3.6 The sinking time

The lead line of the seine sinks at a gradually decreasing rate until it stops (Fridman 1986). Despite that the approximate time it takes for the lead line to a given depth can be estimated from using Equations 2.11 and 2.12:

$Fs = W(kgf) / l\ (m) = (159)\ Kgf / 200\ m = 0{,}795\ kgf/\ m.$

$T = 0{,}9 \times H \times \sqrt{H} / Fs = 0{,}9 \times 30m \times \sqrt{30}\ m / 0{,}795 kgf/m = 165{,}85\ sec = 2\ min.$ and 35 sec.

3.3.7 Gear construction

Purse seine is made by assembling the three main sections, namely bunt, shoulder and wings (see Appendix 2). Joining the different sheets of netting along their length and depths does this. Netting wedges for reinforcement are laced all around the main body of the gear. The netting is then completed and is ready for hanging onto the frame lines. Care must be taken that the desired hanging ratio is according to design. Floats are tied to an extra floatline, which is then attached to the top mainline. At the bunt more floats per rope length unit is required. The lead sinkers are threaded up on an extra lead line, which is then attached to the main lower line. The purse ring bridles are fastened to the combined leadline and mainline. The purse line of approximately twice the length of the purse seine is threaded through the rings.

3.3.8 Operating methods

The fishing operation consists of surrounding or encircling sighted schools or aggregations of fish attracted to the light. This operation results in the formation of a rough circle. First, the bunt end of the net and the purse line are fastened to the buoy. Then the purse seiner moves in encircle, paying out the net, to reach back to the buoy attached to the first end of the net set. Once the encircling is completed, the purse line is drawn with the help of a double capstan or other type of line hauler. On completion of the pursing operation, the leadline is bunched on the surface, closing the net and preventing the fish from escaping. Then the net is hauled on board, starting from the wings end so as to gradually drive the fish into the bunt, of which the floatline has already been lifted and kept away from the side of the boat. The brailing of the catch is done with large scoopnets, often hand operated (Figure 2).

Artisanal fishermen have shown that a small boat can be used for purse seining. To reduce manpower on each purse seine fishing unit, however winches should be added on the vessel to haul the net on board.

"The hauler consists of one vertically-mounted ***warping head (1) (****Figure 8). Used for hauling ropes, it has the advantage that it can take ropes coming from any horizontal direction without the need for guiding blocks and other rope leading systems, provided that the rope is perpendicular to the capstan shaft and approximately on the same horizontal plane as the warping head.A capstan can be made out of an old truck rear axle"* (FAO 2012).

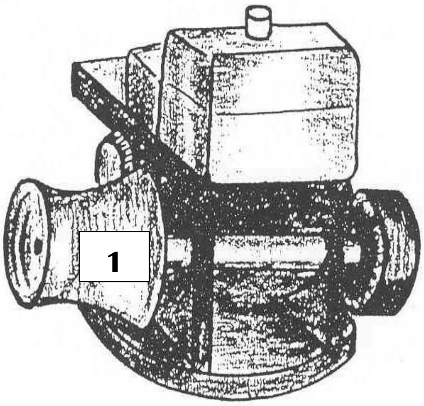

Figure 8. A small winches powered by small petrol engine (FAO 1987).

The boat in Figure 9 is a 10 m vessel (the size of Mozambique artisanal purse seine). Can be introduced the winch with two drums (2) for hauling the purse line. The new purse seines can be worked from port side or starboard. They can be pursed from either side or the bow.

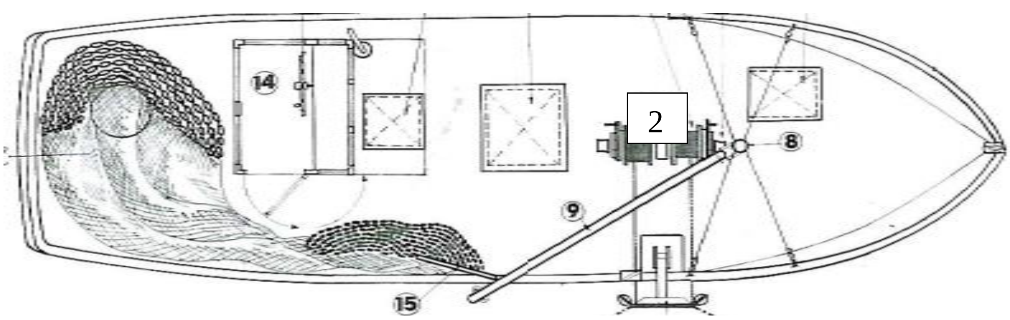

Figure 9. Arrangements for winches in the artisanal boat (FAO 1987).

4 DISCUSSION AND CONCLUSIONS

The essence of designing a purse seine is to produce a gear variant that matches the vessel used and behaviour of the target species. For this purpose, information regarding existing fishing gear and methods as well as fish behaviour was collected and analysed.

The appropriate mesh size of netting in the bunt to catch sardine and trachurus was calculated to be 19.05 mm according to Fridman (1986). That mesh size should prevent fish from gilling. Existing artisanal purse seines in Mozambique are using small meshes (6.35 mm) in the bunts, which is illegal (MoF 2003). The minimal mesh size is 18 mm, which is close to the optimal mesh size calculated. There is therefore no obvious need to change the mesh sizes in the regulation, but the regulation should be enforced.

The current Mozambique purse seine depth (20 m) is shallower than the expected maximum depth for sardines and mackerel (30 m) according to FAO (1990b). This may be one of the reasons for the poor performance of the currently used gears. For successful fishing, the lead line should be designed to reach a depth that is 20 to 30% deeper than the swimming depth of the schools 36-39 m (Fridman 1986). That depth, however, implies increased sinking speed and thereby more weights on the leadline and would be too heavy and bulky for the artisanal vessels. As a compromise, the new purse seine was designed to be 30 m deep.

The success of the fishing operation depends on the relation between the sizes of the fish school, the size of the net and on the distance at which the fish can detect the vessel. The swimming speed and direction of the fish related to the seine (Ben-Yami 1994).

According to Fridman (1986), the depth of the seine should be greater than 10% of the length, but it is usually less than 20% of the length. The new modified purse depth ratio on this range (30 m) is 15% of its length (Appendix 2). The depth of conventional artisanal purse seines used in Mozambique is about 10% of its length (186 m, Appendix 1). According to that criterion, the depth is within limits but close to the minimum and fast fish could escape under the lead line. This type of gear can work for slow-swimming species or when fishing with attraction lights at night, which brings the fish closer to the surface. Another factor that is necessary to take into account is the relative dimensions of the vessel. According to FAO (1990a) the minimum length of the purse seine should be 15 times the length of the seiner and the minimum depth 10% of the seiner's length. These considerations were taken into account when deciding the final size of the new design.

The rigging of floats on the new purse seine must be taken into account. The buoyancy needs to be 50% more than the weight of the gear in water to compensate for rough sea conditions and other factors related to handling. The buoyancy should be greater in the area of the bunt (FAO 1990a). For that reason distance between the floats in the bunt are 80 mm and 110 mm in the shoulders and wings (Table 8). This is because the pulling force is greatest on the bunt. On the artisanal purse seines used in Mozambique, the floats are equally distributed throughout the length of the gear (Table 3).

The sinking speed of the new purse seine is twice that of the purse seines currently used in Mozambique. This is due to the increased weight of lead line and the additional weight of the purse rings. The dependence of the sinking speed on the ballasting of the seines is not directly proportional but curvilinear (Ben-Yami 1994). Nevertheless, increased ballast will result in faster sinking speed decreasing the likelihood of fish escape. Suitable rings for the new artisanal purse seine would be steel rings, with bar diameter of 12 mm, and 100 mm in diameter (FAO 1987).

This study has revealed that simple modifications of the purse seines currently used by artisanal fishermen's in Mozambique can lead to increased efficiency. Implementing existing knowhow found in simple handbooks and other literature is also of great importance. Mechanisation of the vessels is an issue that should be seriously addressed in future work on developing the artisanal fishery in Mozambique.

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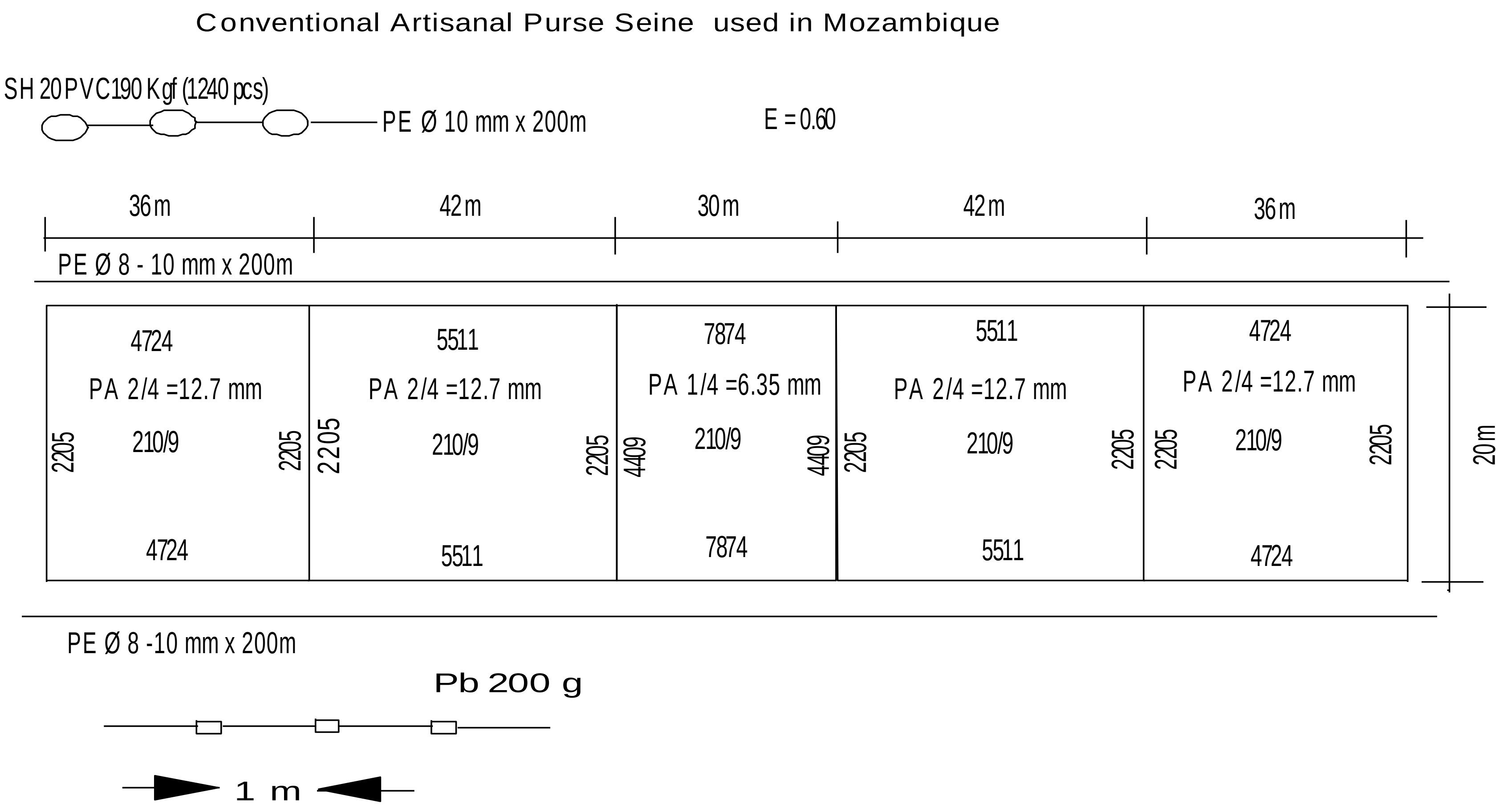
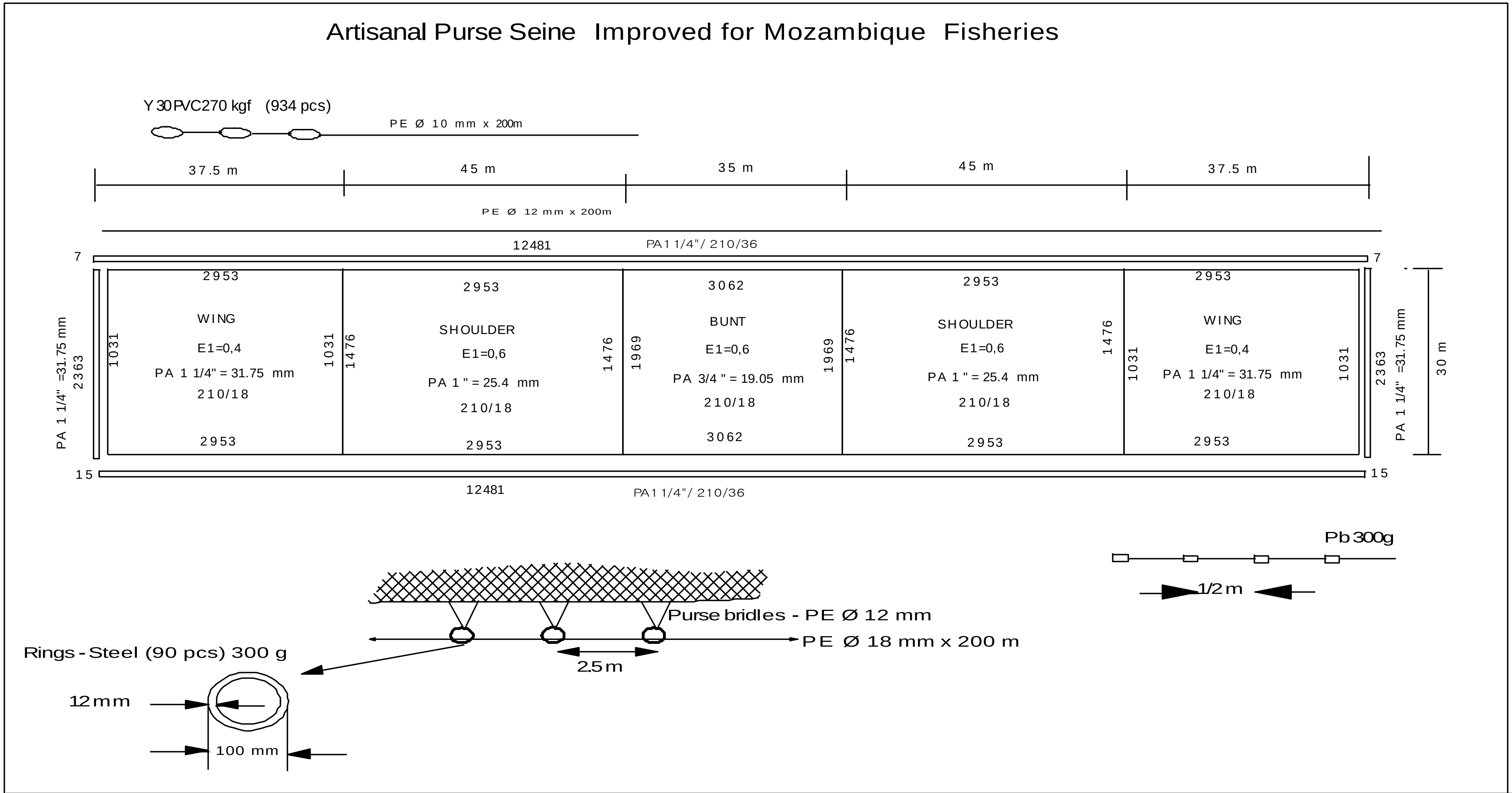
APPENDIX 1 THE CONVENTIONAL ARTISANAL PURSE SEINE USED IN MOZAMBIQUE



UNU FTP Research Project
IDPPE
Maputo - Mozambique

Vessel: Lenght 10-12 m; GT- 2-4 t; hp- 40-60
Drawn by: Rosario Fernandes Jorge Laissane, 2012
Drawn number:
Checked by: Einar Hreinsson
Approved:

APPENDIX 2 THE ARTISANAL PURSE SEINE IMPROVED FOR MOZAMBIQUE FISHERIES



UNU FTP Research Project IDPPE Maputo - Mozambique	Vessel: Lenght 10-12 m; GT- 2-4 t; hp- 40-60	
	Drawn by: Rosario Fernandes Jorge Laissane, 2012	Drawn number:
	Checked by: Einar Hreinsson	Approved

APPENDIX 3 ARTISANAL PURSE SEINE FISHING IN MOZAMBIQUE (PHOTO: BERNARD ADRIEN)

APPENDIX 4 MOZAMBIQUE ARTISANAL VESSELS
" Moma canoe"

"Chuabo canoe"

Hollowed log canoe

"Chata canoe"

“Lancha" fibres glass

"Dhaw canoe"