Thesis for the Degree of Master of Fisheries Science

# Suggestion of the appropriate Mozambique purse seine fishing gear using numerical method

by

Monjane Teodato Arone

The World Fisheries Graduate School

Pukyong National University

February 22, 2019

# Suggestion of the appropriate Mozambique purse seine fishing gear using numerical method
# (수치해석방법을 이용한 모잠비크에 적합한 선망어구 도출)

Advisor: Prof. Chun-Woo LEE

by

Monjane Teodato Arone

A thesis submitted in partial fulfillment of the requirements
for the degree of

Master of Fisheries Science

in the World Fisheries Graduate School,
Pukyong National University

February 2019

# Suggestion of the appropriate Mozambique purse seine fishing gear using numerical method

A thesis

by


Monjane Teodato Arone


Approved by:

(Chairman) Yoo Won Lee

(Member) Mi Kyung Lee

(Member) Chun Woo Lee

February 22, 2019

# Acknowledgements

At the outset, I would like to address my special gratitude to Professor Chun-Woo Lee, as my supervisor, for his tireless strength on steering me throughout this work. To not lag behind, I express my gratitude to Dr. Mi Kyung Lee and Professor Yoo Won Lee as the thesis committee members for their comments and suggestions. I also say thank you very much to my lab mates Daeyeon Lee, Choi Cheosok, and Mr. Subong Park and Mrs. Park for their support in getting acquaint with the laboratory of Marine Production Systems and Management. Secondly, my gratitude aims to the World Fisheries University (WFU) Professors (Aminur Rahman, Christopher L. Brown, Allen Dale Marsden, Heui Chun An) for the assistance given during the lessons taught, as well as the Office staff for helping to settle down here in Pukyong National University. To all my colleagues, in special Célio Machaieie, Cesar Daviz, and Isaac Lukambagire for the friendship and family forged. From home, I would like to express my gratitude to my family and Professor António Hoguane and Dr. Anildo Naftal for the trust you have placed in me.

# Table of Contents

**Table of Figures**

**Suggestion of the appropriate Mozambique purse seine fishing gear using numerical method**

**Monjane Teodato Arone**

*The World Fisheries Graduate School,*

*Pukyong National University*

## Abstract

Mozambique currently has no tuna purse seine fleet. Here, a tuna purse seine fishing gear is proposed to fit the Mozambique fishing ground. The numerical method was applied to evaluate the tuna purse seine fishing gear's mechanical proprieties. The tuna purse seine gear layout was proposed based on the modification of the Iranian tuna purse seine fishery operating in the Indian Ocean. To do those modifications, it was compared to the Korean commercial purse seine gear which is larger and heavily rigged. The Korean gear sank at an average speed of 0.34 m/s and the Iranian with 0.28 m/s, and within 300 s both gears attained depths of 90 m and 121 m, respectively. After the simulations the Iranian gear was modified by increasing its length, depth (Design-I), to 986, 217 m, and sinker line weight 5.29kg/m (Design-II) in order to match that of the Korean tuna purse seines. The design and simulation were done using the SPurse and SimuPurse software developed by the Marine

Production Systems Management and Laboratory (MPSL), Marine Production Systems and Management Division, Pukyong National University, Busan, South Korea. The results showed that the leadline sinking depths of the two Designs (Design-I and Design-II) purse seines were 96 and 105 m, respectively and their average sinking speeds were 0.287 and 0.289 m/s. The tension on their purse lines were 5,230 and 6,216 kgf. The PA knotted netting was changed to PES knotless (Design-III) netting and showed a greater effect on the sinking performance. Comparing the sinking performance of the leadlines and considering that in the Indian Ocean, particularly in Mozambique Channel, the tuna and tuna-like species are caught near logs and FADs, the designed tuna purse seine gears fit well in this type of fishery.

**Keywords:** *Mozambique Fisheries, Purse Seine Gear, Purse Seining, Mass-Spring Model, Numerical Method.*

# 1 Introduction

A purse seine is made of long hedge webbing which is kept afloat at the water surface by means of floats strung on the line, and kept upright by sinkers (leads or chains) laced to the footrope. Another of its main features are the purse rings, through which runs a purse line.

Purse seining is an efficient fishing method, used to catch most of the world's pelagic fish species (Rounsefell & Everhart, 1962; Fridman, 1987; Kim, 2000). It mainly involves rapidly setting the netting in the water, softly encircling fish schools, and making a big bowl shape by hauling in the purse line to seal off the bottom of the gear and prevent the fish from escaping Liuxiong et al. (2015) and references therein). (Litaka, 1971), outlined that Japanese purse seiners catch fish schools such as herring, sardine, mackerel, horse mackerel, anchovy, pilchard and tuna. As well, Korea's and other countries' purse seiners target the same mixed fish schools (Lee et al. (2018) and references therein).

## 1.1 Tuna purse seine fishery in the Indian Ocean

The purse seine fishery in the Indian Ocean harvests mainly tuna and tuna-like species. Tropical tuna species in the Indian Ocean are harvested by many industrial and artisanal fisheries of coastal and distant water fishing countries. There are three main tropical tuna species, yellowfin tuna *(Thunnus albacares)*, skipjack *(Katsuwonus pelamis)*, and bigeye tuna (*Thunnus obesus*) harvested in the Indian Ocean Tuna Commission (IOTC) convention area (Floch, et al., 2017; Geehan, et al., 2018).

### 1.1.1. Catch trend by purse seine fishery

The catch trend of the three tropical tuna species in the Indian Ocean shows a fluctuation over time Geehan et al., (2018). Looking back in the 1980s, the tuna purse seine catch started to increase with the arrival of the industrial purse seiners. Later, in the 2000s piracy increased in the northwestern Indian Ocean, which decreased or displaced fishing effort and hence reduced the tuna catch Geehan et al., (2018). In that period of piracy, the catch was less than 820,000 t, but later as the threat decreased the catch increased in 2017 to more than 1,000,000 t.

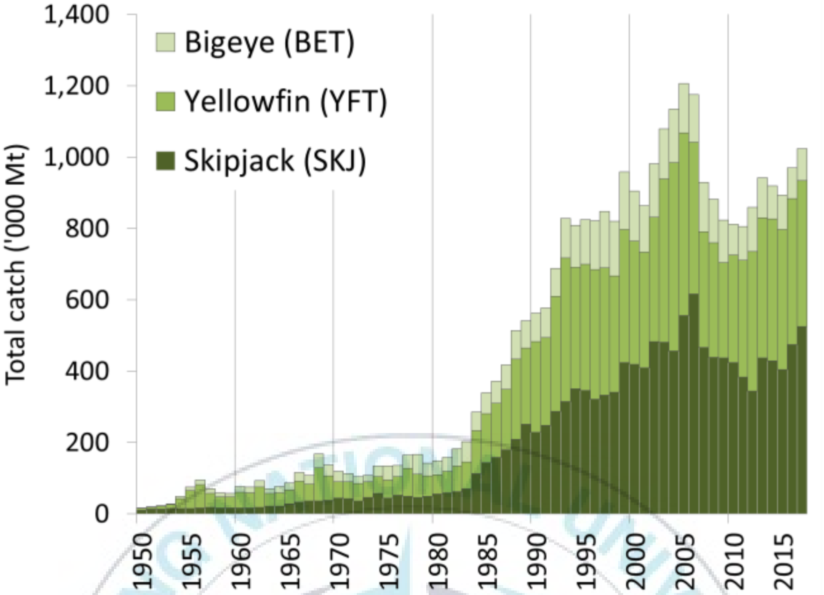



Figure 1. Catch trend of each tuna species, 1950-2016; source Geehan et al., (2018).

Major tuna production by coastal and distant waters over the period of 2013-2016, belonged to Indonesia, followed by Taiwan, all other countries, Seychelles, European Union (Spain), Japan, and European Union (France).

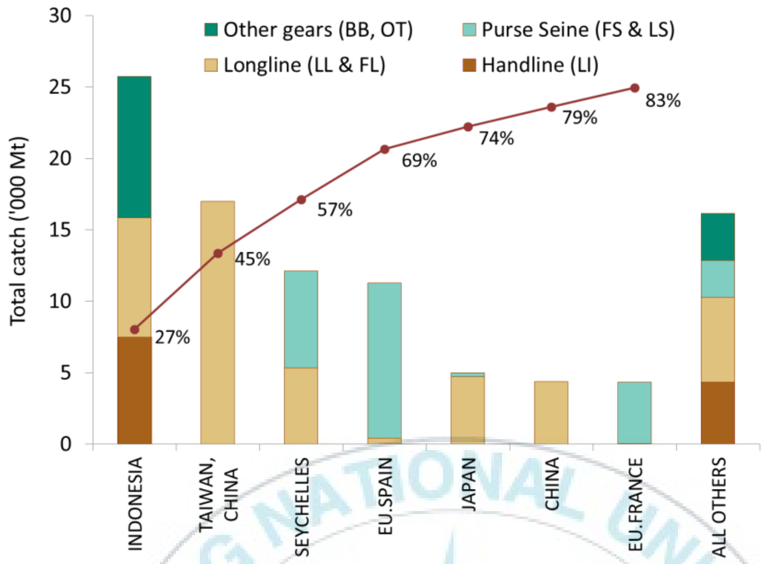



Figure 2. Bigeye tuna average catches in the Indian Ocean between 2013-2017, by nation. The line denotes the cumulative catches for those countries, over the total catch of bigeye tuna. Source: Geeham et al., (2018).

### 1.1.2. Fishing method of purse seine fishery

The purse seine fishery is conducted in two different ways, either using Fish Aggregating Devices (FADs) or fishing on free-swimming schools, and each method produces catch with a different composition Guillotreau et al., (2011) & Kaplan et al., (2014). As most pelagic fish species have shown a behavioral tendency to attach to floating objects, fishers have taken this opportunity to catch fish, Castro et al., (2002).

FADs and other floating objects have been widely used in purse seine fisheries worldwide, mainly to aggregate tropical tunas and other pelagic species in the Atlantic and Indian Oceans since 1990s, Fonteneau et al., (2000). FADs have a great benefit compared to setting on free-swimming schools as they increase efficiency in catching tunas by lessening the time to detect fish schools Guillotreau et al., (2011). FAD-related tuna purse seining is technologically advanced, with fish schools being detected through positioning systems and echo sounders Guillotreau et al., (2011) & Davies et al., (2014). Acoustic methods have been used to estimate the distance and depth of the fish school from the FADs (Josse et al., (2000); Matsumoto et al., (2014)). For instance (Josse, et al.) examined tuna aggregations by echo location and found three categories of vertical fish distributions at different distances from the FADs: (*i)* a deep distribution at 100-300 m, *(ii)* a middle distribution at 50-150 m, and *(iii)* a shallower distribution at less than 50 m. The same method was applied by Dagorn & Fréon, (2000), where they estimated the horizontal distribution of the tuna fishes in the same depth layers. Fish 100-300 m deep were found at a distance of 1500 m away from FADs, (*ii)* fish at 50-150 m depth were found at distance of 700 m away from the FADs, and (*iii)* fish at 50 m of depth were found at a distance of less than 200 m. As tuna fish swimming behavior changes daily, Matsumoto et al., (2014) showed that the swimming depth of skipjack tuna associated with FADs is less than 50 m during the night and more than 50 m during the day. Catch on FADs is much higher than that on free-swimming schools as Figure 3 depicts.

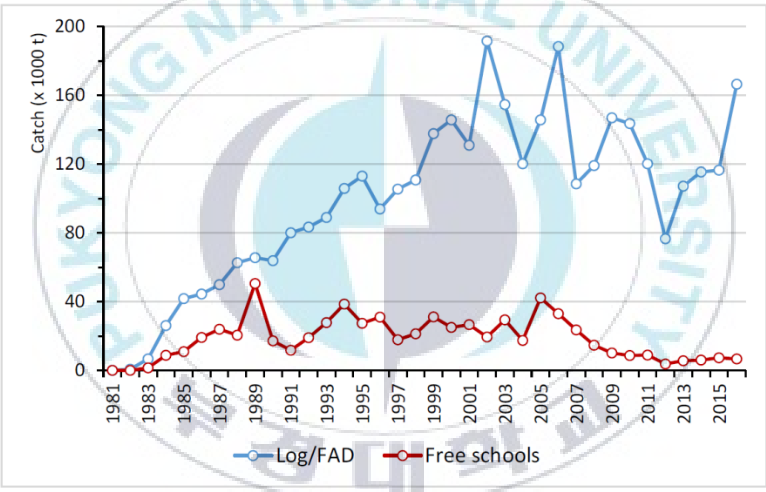



Figure 3. Skipjack tuna catch trend on Log/FADs and free-swimming schools by purse seine fleets, 1981-2016, from EU and Seychelles. (Geehan, et al., 2018)

## 1.2 Mozambique fisheries sectors

The fishery sector in Mozambique is split into small-scale, semi-industrial, and industrial. The small-scale sector has a pivotal role in the country's food security as two-thirds of the population live in coastal areas and rely on this activity. In the total annual fish catch in 2014, 91% was from the small-scale sector, 2% from the semi-industrial fishery for local consumption, and 7% from industrial fisheries, (Soto, 2014).

### *1.2.1 The small-scale sector*

About 300,000 fishers were involved in the small-scale fishery in 2016, of which 45% used gears constructed based on their knowledge, while 55% used conventional fishing gears such as beach seines, hand lines, gillnets, small purse seines, longlines, traps and spearfishing, Mutombene et al., (2016). The vessels are less than 10 m length, and mainly catch sardine (*Sardinella gibbosa*), anchovy (*Encrasicholina punctifer*), Trachurus (*Decapterus russelli*) (Laissane, 2011), tunas, tuna-like species, and narrow-barred Spanish mackerel (Mutombene et al., (2016); Chacate & Mutombene (2018)).

In 2017, the artisanal fisheries catch in the Mozambique exclusive economic zone (EEZ) managed by IOTC was 4,821 tons of tuna species, where the highest proportion is from the two northern provinces, Nampula and Cabo-Delgado (Chacate & Mutombene, 2018). In this sector in 2017, among the IOTC main species the narrow-barred Spanish mackerel comprised the largest share with 78%, followed by frigate and bullet tunas with a total output of 20%, Chacate & Mutombene.

### *1.2.2 The semi-industrial sector*

The main feature of the semi-industrial fishing vessels is that vessel size range from 10-20 m. It is divided into shallow water shrimp trawling and a line fishery, targeting demersal fishes.

### *1.2.3 The industrial sector*

Shallow water shrimp trawling and deep-water crustacean trawling which have no impact on tuna and tuna-like species mainly dominates this sector. Over the last five years, the Mozambican government has been committed to implement the Tuna Fisheries Development Plan (PEDPA), which has resulted in 12 longliners (Chacate & Mutombene, 2018). Vessels in this sector are greater than 20 m.

### *1.2.4 The Mozambique purse seining*

Mozambique purse seining is largely carried out in the nearshore waters of the northern region, Nampula and Cabo-Delgado. In these regions, purse seine gears account for over 70% of fishing gears, and are used to catch small pelagics and neritic tunas Mutombene et al (2016). Purse seining for small pelagic fish is carried out at night using light attraction with auxiliary boats of 8 to 12 m length and gear dimensions of 120 to 200 m in length and 16 to 25 m in depth with illegal mesh size (6 mm), conflicting with the minimum 18 mm legislated (MMAIP, 2003; Laissane, 2011).

## 1.3 Tuna fleet structure in the Mozambique Exclusive Economic Zone (EEZ)

Mozambique has no tuna purse seine fleet in its EEZ. Distant Water Fishing Nations (DWFN) in which longliners operate from May to November and purse seiners from February to June have caught most of the tuna and tuna-like species in the EEZ. In 2016, the catch composition of the DWFN in Mozambique EEZ was 3,445 t, dominated by yellowfin tuna with 62% of the catch, 8.8% bigeye tuna, and 6.2% albacore. At the domestic level, longliners caught 177 t in 2016, made up of swordfish with 36%, yellowfin tuna with 21%, and 15% bigeye tuna (Chacate & Mutombene, 2017).

The DWFN is comprised of Japan, Spain, France, Seychelles, South Korea, Namibia, and Mauritius (MMAIP). The amount of fishing effort of those nations in the Mozambique area has had a decreasing trend in the last 10 years. In 2007, 110 longliners and 51 purse seiners were licensed to fish in the EEZ, whereas in 2017 this was reduced to 33 longliners and four purse seiners (Figure 4) (Chacate & Mutombene, 2018). The purse seiners remaining in 2017 were from the Seychelles, while the longliners were from Japan, South Korea, Taiwan, Mauritius and South Africa, (Chacate & Mutombene, 2018). The length of licensed vessels varies from 50-110 m, and the range of vessel tonnage is 1,500-3,500 GRT, (MMAIP, 2016)

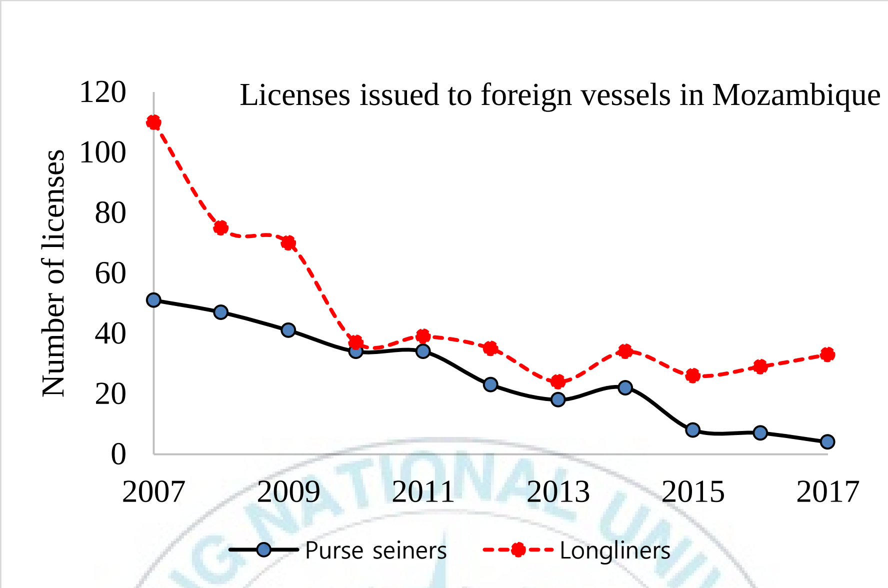



Figure 4. The trend of fishing licenses issued to foreign vessels to fish in the Mozambique fishing ground from 2007-2017. Source (Chacate & Mutombene, 2018).

### 1.4 Problems faced by Mozambique purse seining

Mozambique purse seiners used to catch pelagic fish species do so only in artisanal fisheries catching small pelagic fishes. Artisanal purse seiners are of small size and low engine power. These limitations allow them to fish only in nearshore areas and prevent them going to offshore fishing grounds which are rich in biomass (FAO, 2012). On average the length of purse seine gears used in artisanal fishery have 200 m of floatline, and the catch is shared evenly among the fishermen, so the catch amount is not enough (Laissane, 2011).

Another issue concerning the Mozambique purse seine fishery is the absence of a good quality fishing gears, as most of purse seiners use traditional gears without purse rings (Laissane, 2011; FAO, 2012). Longliners and purse seiners of foreign distant waters nations operating in the Mozambique fishing ground catch most of the tuna. The catch of those fisheries are large compared to national catches Mutombene et al (2016). Because of those issues, the Mozambique government has been committed to encouraging the implementation of the Tuna Fishery Development Plan (PEDPA) since 2012, to boost the tuna production, which until now has only focused on longline gears, (Chacate & Mutombene, 2018).

# 2 Background and Literature Review

## 2.1 The numerical method on fishing gears sinking performance

The numerical method of fishing gears systems is pivotal in understanding the mechanical proprieties of gears. For instance, in purse seines, mechanical proprieties of significance include having an insight into the relationship between force, velocity, and distance throughout fishing activity (Machii & Nose, 1992). Therefore, the estimation of those forces in fishing gear mechanics is a challenging task as the mesh size, gear shape, tension on a moving purse line, and other proprieties change during the fishing operation (Machii & Nose, 1992). Much research delving into the fishing gears behaviour has been carried out using sea-trials and experiments in a flume-tank to validate the models. However, those field survey and research are expensive and time consuming. Therefore, the numerical method was developed to overcome these difficulties. Lee et al., (2007) developed a numerical computation, which computes model outcomes with steadiness and a high degree of accuracy for purse seine gears. The model is described using the Mass-spring model, which considers the mesh bars and strings as springs with a mass point placed in between to characterize the flexibility of the string. The model regards the knots and other gear riggings as mass point elements. A similar model suggested by Suzuki et al., (2003), modeled the net as a cluster of lumped mass points strung with massless springs. The numerical calculation by Lee et al., (2011) and Lee et al., (2007), computes with high accuracy how the net shape evolves with time and the gear's diving behavior in various sea conditions, the forces acting on the net as well as on the riggings. Another gear characteristic that is underpinned by numerical simulation on the computer-aided tools is the computation of the surrounding volume of the purse seine, which is shaped by the floatline length, gear depth and fishing ground conditions throughout the fishing operation Lee et al., (2011).

## 2.2 Previous findings

Throughout the development of fishing gear systems, a series of studies have been carried out regarding the fishing gears' mechanical properties. A more recent study by Xu et al., (2017), summed up various components that shape the diving behavior of the purse seine gear. Such components are the webbing material, weight of the sinks, length-height relationship, mesh size, purse line length, shooting position and speed, currents and wind speeds. The netting material is well known because of its strong influence on the sinking performance of the fishing gears; turning back to (Litaka, 1971), the faster the net sinks the better performs. Most fishing gears in the world use nylon (PA) netting material, owing to its strong point and good sinking performance, Tang et al., (2018). According to the results of (Kim, 2004), polyester (PES) has a greater sinking depth and speed than nylon (PA) material. This faster sinking speed can be attributed to the density of the material, viz., polyester has 1.38 g/cc and nylon (PA) density of 1.14 g/cc, (FAO).

Another component that shapes the behavior of the purse seine fishing gear is the mesh size of the netting sections. Hosseini et al., (2011), demonstrated that large-meshed panels of the tuna purse seine performed better than small-meshed panels. Moreover, another factor of importance is the net geometry, which helps determine the encircled volume and deformation of the gear under strong current conditions (Xu, et al., 2015). Regarding the type of knot, knotted netting material is deemed stronger and more durable than knotless nets, but produces a larger net bulk with increased water resistance and weight, South Pacific Commission

Twenty First Technical Meeting (1989). The Japanese purse seiners favor knotless nylon netting owing to its good sinking performance and pursing speeds Tang et al., (2018) that are attainable with a given amount of hydraulic power South Pacific Commission Twenty First Technical Meeting (1989). However, the United States object to the use of knotless webbing because of its weakness to tolerate high speeds when closing the net along the rough sea conditions (Itano, 2008). Another advantage of knotless nets is that they require a smaller power block, less space, and less vessel payload, which allows small vessels to carry larger nets, South Pacific Commission Twenty First Technical Meeting (1989).

## 2.3 Objectives

- As the Mozambique government is committed in encouraging the implementation of the Tuna Fishery Development Plan (PEDPA), this study aims to recommend the appropriate tuna purse seine gear for Mozambique by using the numerical m ethod to:
  - analyzing the leadline sinking performance of the tu na purse seine fishing gear; and

- calculate the tension on the purse line and its surro unding area;

# 3 Material and methods

## 3.1 Study area and fishing ground conditions

The Mozambique Channel lies in the Southwestern Indian Ocean, between Mozambique and Madagascar. This channel is characterized by strong intermediate scale motion and is a natural site for ecological studies (Kai & Marsac, 2010). The purse seine fishing grounds in the Mozambique Channel are in the north from 12-16$^{o}$S, depicted in Figure 5. In this north region, Ullgren et al., (2016), observed current speeds of up to 0.6 m/s are observed at a depth of 850 m, while surface currents are up to 1.7 m/s, which is characteristic of a western boundary current. The Channel's bathymetry shows depths varying from 2000 to 3000 m, and lessening from 2000 to 500 m towards the coasts of Mozambique and Madagascar. It also features islands and sea mounts (Kulseng, 2010; Sete, 2010).

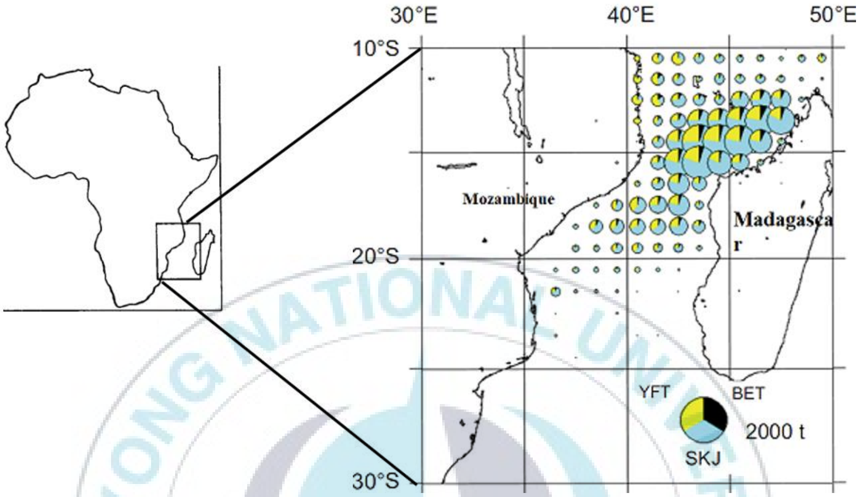



Figure 5. Map showing the purse seine fishery in the Mozambique Channel. Source: (Kai & Marsac, 2010).

### 3.2 Study material

In this study, two tuna purse seine fishing gears were selected for examination, the Iranian and Korean tuna gears designed by Korea Trading & Industries (KTI). The Iranian gear was designed in 2012, and is operated in the Indian Ocean. It is made out of nylon braided nettings, which is knotted. It has a float line length of 728 m and leadline length of 924 m. Its fully stretched depth is 168 m. Floats of ethylene vinyl acetate (EVA) are strung on the line, with 5 kg of buoyancy each, and laced onto the headrope. The mesh size in the bunt is 90 mm, and in other sections is between 105-210 mm. Rigged with a chain attached as a sinker line of 919 m length, bridles chain and steel rings providing a total sinking force of 5038.88 kg (3.64 kg/m). The layout is depicted in Figure 6, and all of its specifications are displayed in Table 3 and the Appendix.

The Korean tuna purse seine gear, used at commercial scale, is made out of polyester (PES) material, knotless netting at all parts and nylon at the wings (including the bunt section). It has a float line length of 1928 m and leadline length of 2074 m. Its fully stretched depth is 282 m. Floats of polyvinyl alcohol (PVA) are strung on the line, with 15 kg/m of buoyancy (total 48412 kg), and laced onto the headrope. The mesh size in the bunt ranges between 140-180 mm, and in other sections is between 200-280 mm. Rigged with a chain attached as a sinker line of 2074 m length, bridles chain and steel rings providing a total sinking force of 11342 kg (more than 5 kg/m). The layout is depicted in Figure 7, and all of its specifications are displayed in Table 3 and the Appendix.

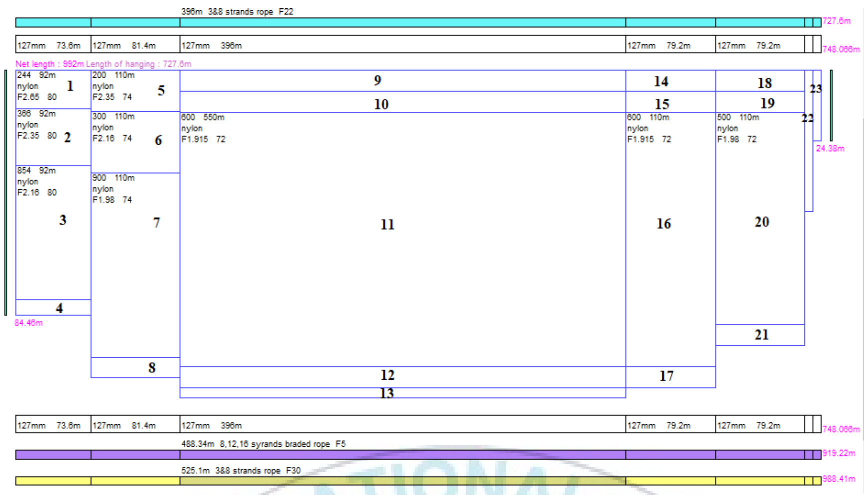



Figure 6. Layout of the Iranian tuna purse seine. Source: (Author)

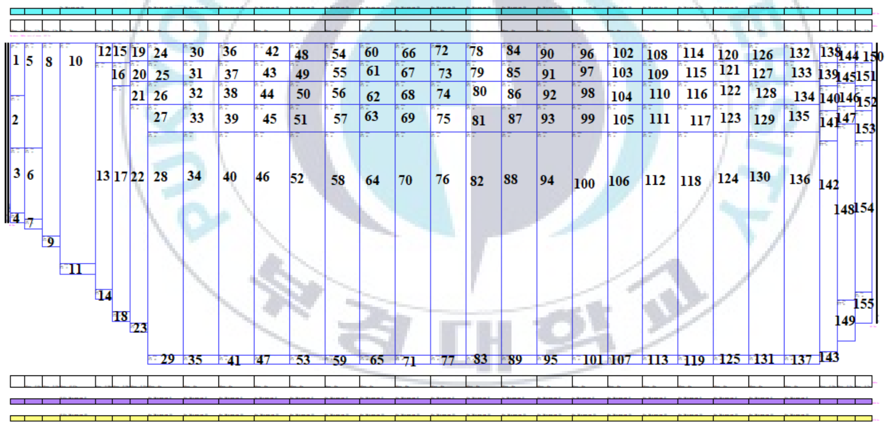


Figure 7. Layout of the Korean tuna purse seine. Source (Author).

## 3.3 Model description for purse seine simulation

### *3.3.1 The equation of motion*

To simulate the purse seine fishing gear, the Mass-spring model is adopted; for more details, see the studies of (Lee et al., 2007, and references therein). The purse seine is modelled as a set of nettings, and the model considers the knots as finite mass points and the ropes as springs, which are considered as flexible structures, i.e., which can bend without breaking. The appendages, such as floats and sinkers, are regarded mathematically as rigid bodies, Lee et al., (2007).

This study will be based on the model of purse seine fishing gear used and described by Lee et al., (2007), where the physical system is based on the mass-spring model, split into a limited number of mass points linked by springs with no resistance to bending. Physically the mass-spring model considers the external forces (drag, lift, buoyancy and sinking forces) with no effects on the mesh bar (spring) only concentrates all the external forces to the mass point.

To lessen the computational effort for a flexible structure with so many mass points, the mesh grouping method proposed by (Bessonneau & Marichal, 1998) was applied. In the mesh grouping method, several units of mesh are gathered into a made-up corresponding mesh with the equal specific mass, apparent weight and roughly the same drag resistance, as depicted in Figure 8. To characterize the flexibility of the mesh bar, one mass point is fitted in between two mass points

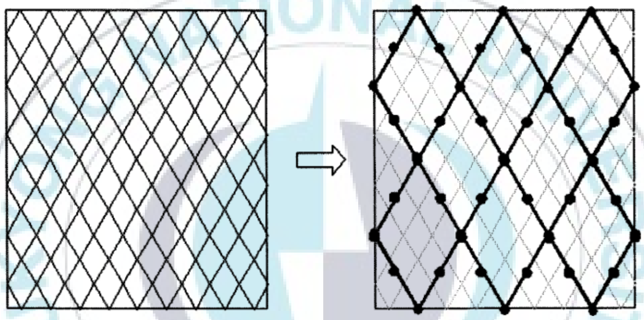


Figure 8. The mesh number approximation method.

Following Newton's second law, the basic mechanical model of the mass point is:

$$m\ddot{\boldsymbol{q}} = \sum \boldsymbol{F} \tag{1}$$

Where *m* is the mass of the mass point, $\ddot{\boldsymbol{q}}$ is the acceleration vector and

$\boldsymbol{F}$ is the sum of the internal $\boldsymbol{f_{int}}$ and external $\boldsymbol{f_{ext}}$ forces acting on the mass point,

$$\boldsymbol{F} = \boldsymbol{f}_{int+}\boldsymbol{f}_{ext} \tag{2}$$

The internal forces symbolize the forces of two consecutive mass points, acting on different types of ropes. The approximated mass points (knots) belong to the attachement and webbing of the gear. The force performed on the spring (rope) is understood as corresponding to the displacement, and the internal force is as follows:

$$\boldsymbol{f}_{int} = -k\boldsymbol{n}(|\boldsymbol{r}| - l^0) \tag{3}$$

where $k$ is the global stiffness matrix of the mesh bars and lines (ropes) of the fishing gear, $n$ is the unit vector of the spring, r is the position vector of the spring and $|\boldsymbol{r}|$ its magnitude, and $l^0$ is the original length between mass points. From algebra, the unit vector $\boldsymbol{n}$ is defined as the position vector divided by its magnitude in Eq. (8).

The external forces include drag $\boldsymbol{f}_D$, lift force $\boldsymbol{f}_{\boldsymbol{L}}$, sinking force $\boldsymbol{f}_B$ and buoyancy on the mass point:

$$\boldsymbol{f}_{ext} = \boldsymbol{f}_D + \boldsymbol{f}_{\boldsymbol{L}} + \boldsymbol{f}_B \tag{4}$$

The lift and drag forces are denoted by equations (6) and (7), and Figure 9 represents the mass spring-model, where the drag force is a quadratic function of the current velocity($\mathbf{v}^2$):

$$\boldsymbol{f}_D = -\frac{1}{2} C_L \rho_w S \boldsymbol{v} |\boldsymbol{v}| \tag{5}$$

$$\boldsymbol{f}_L = \frac{1}{2} C_D \rho_w S v^{\mathbf{2}} \boldsymbol{n}_L \tag{6}$$

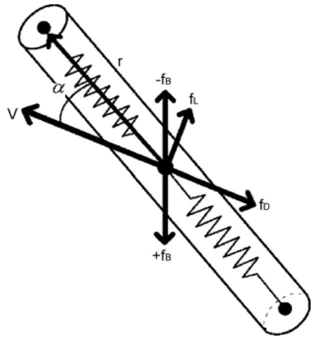



Figure 9. The mass-spring model illustrating the vector notation of the mesh bar. Source: (Lee, et al., 2007).

The symbols $C_D$ and $C_L$ represent coefficients of drag and lift forces respectively, $\rho_w$ is the density of seawater, $S$ is the estimated area of the mass point, and $\boldsymbol{v}$ is the resultant velocity, defined as:

$$\boldsymbol{v} = \boldsymbol{v_m} - \boldsymbol{v_c} \tag{7}$$

where $\boldsymbol{v_m}$ stands for the velocity vector of the mass point and $\boldsymbol{v_c}$ is the current velocity vector. In Eq. 6 $\boldsymbol{v}$ is the magnitude of the resultant vector and $\boldsymbol{n}_L$ is the unit vector of the lift force direction, which is perpendicular to the resultant velocity, as follows:

$$\boldsymbol{n}_L = \frac{(\boldsymbol{v}\mathrm{x}\boldsymbol{r})\mathrm{x}\boldsymbol{v}}{|(\boldsymbol{v}\mathrm{x}\boldsymbol{r})\mathrm{x}\boldsymbol{v}|} \tag{8}$$

The estimation of the drag and lift coefficients of the netting is complex. Throughout a range of experiments and analysis, researchers have encountered barriers, so established standard coefficients have yet to set.

The buoyancy and sinking forces are as follows:

$$\boldsymbol{f}_B = (\rho_i - \rho_w)V_N\boldsymbol{g} \tag{9}$$

where $\rho_i$ is the density of the material, $V_N$ is the volume of the material, and $\boldsymbol{g}$ is the gravitational acceleration, which is calculated following Eq. 9.

The original mass of a net is as follows:

$$m_o = \rho_i V_N \tag{10}$$

In this method, the mesh's bars are treated as cylinders and the knots as spheres, hence:

$$V_N = \frac{1}{4}\pi N_b l d^2 + 3N_k \pi d^2 \tag{11}$$

where $l$ is the bar length of the mesh, $d$ the diameter, $N_b$ the total number of bars in the web, and $N_k$ the number of knots in the web.

Seawater is physically deemed incompressible fluid, therefore, it is assumed that the added mass point is identical to the mass of seawater, displaced by the structure. For the knots for instance, the added mass is 50% of the original mass, as follows:

$$m_a = \rho_w \left(\frac{1}{4}\pi N_b l d^2 + 3N_k \pi d^2\right) \tag{12}$$

The total web mass is a result of the amount resuting from the original and added masses represented as:

$$m = m_o + m_a \tag{13}$$

### *3.3.2 Computation method*

Substituting the internal and external forces equations into Eq. 1, the equation of motion, which shapes the motion of the flexible structures, turns out to be a second-order nonlinear ordinary differential equation on time domain *t* as following:

$$\boldsymbol{m}\ddot{\boldsymbol{q}}(t) + c\dot{\boldsymbol{q}}(t) + k\boldsymbol{q} = \boldsymbol{f}(t) \tag{14}$$

where $\boldsymbol{m}$ is the mass, $c$ is the damping coefficient, $k$ is the spring stiffness, $q$(t) is the displacement of the mass point, and $\boldsymbol{f}$(t) is the sum of external forces excluding the drag and internal forces.

The Eq. (15) is the initial value problem; therefore, explicit and implicit methods are applied to solve it. In addition, is can be expressed as two first-order differential equations:

$$\dot{\boldsymbol{q}}(t) = \boldsymbol{v}(t) \tag{15}$$

$$\dot{\boldsymbol{v}}(t) = \boldsymbol{m}^{-1} + [\boldsymbol{f}(t) - c\boldsymbol{v}(t)^2 - k\boldsymbol{q}(t)] \tag{16}$$

The positions $q(t + \Delta t)$ and $\boldsymbol{v}(t + \Delta t)$, can be obtained as follows:

$$q(t + \Delta t) = q(t) + \Delta t \text{ x } \boldsymbol{v}(t + \Delta t) \tag{17}$$

$$\boldsymbol{v}(t + \Delta t) = v(t) + \Delta t \text{ x } \boldsymbol{m}^{-1}[\boldsymbol{f}(t + \Delta t) - c\boldsymbol{v}(t + \Delta t)^2 - k\boldsymbol{q}(t + \Delta t)] \tag{18}$$

The value of $\boldsymbol{v}(t + \Delta t)$ on right-hand side in Eq. (17) and (18) is calculated from an explicit Euler integration.

### *3.3.3 The surrounding volume computation*

After the setting process of the purse seine, it forms a cylinder shape. Hence, the surrounding volume ($V_p$) of the gear can be computed based on the encircling area surrounding by the floatline and the depth of the leadline.

$$V_p = \pi R^2 . h \tag{19}$$

where $R$ is the radius surrounded by the floatline after setting the net (AB), and $h$, the operating depth of the leadline, equals the distance of the floatline (B) and the leadline (C) depicted in Figure 10. In this study, the depth of the gear is measured at the middle part of the gear, at the closure. As highlighted by (Fridman, 1987), the fished schools occupy partially the surrounded volume of the gear, therefore we should not just conclude that the amount of catch rests mainly on the length and depth of the gear.

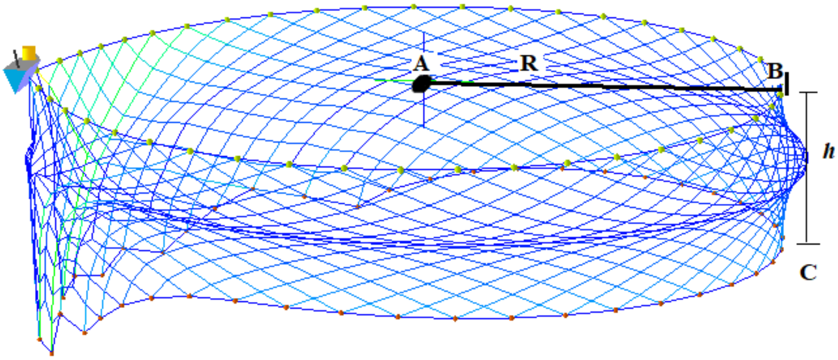



Figure 10: Schematic diagram for computation of surrounding volume of the purse seine gear. Source (Author).

### *3.3.4 The dynamic simulation*

For the dynamic simulation, the mass-spring model was coded in the software SimPurse, which simulates the behaviour of the purse seine fishing gear in various operation conditions. The Department of Marine Production Systems and Management, at Pukyong National University, Busan, South Korea, developed it,

- Design tool

The parameters of the three purse seine fishing gears were collected from current layouts and then sorted and fitted to the design software.

- Simulation tool

After the fishing gear is designed, the file is converted into a simulation file, where the simulation of the purse seine behavior in different environmental condition is done. The simulation is done in static (no currents) conditions, where the diving behavior of the purse seine is checked.

# 4 Results and Discussion

## 4.1 Simulation results

### *4.1.1 Sinking performance of the leadline with no current*

Data on sinking depth and speed of Iranian and Korean tuna purse seines are described below and throughout the study, collected at the main body (middle section) of the gears' leadlines. The leadlines sinking depth of Iranian and Korean gears were 90 and 121 m, respectively in 300 s (Figure 11). The sinking speeds of the same leadlines on averages were 0.28 and 0.34 m/s, of Iranian and Korean gears (Figure 12).

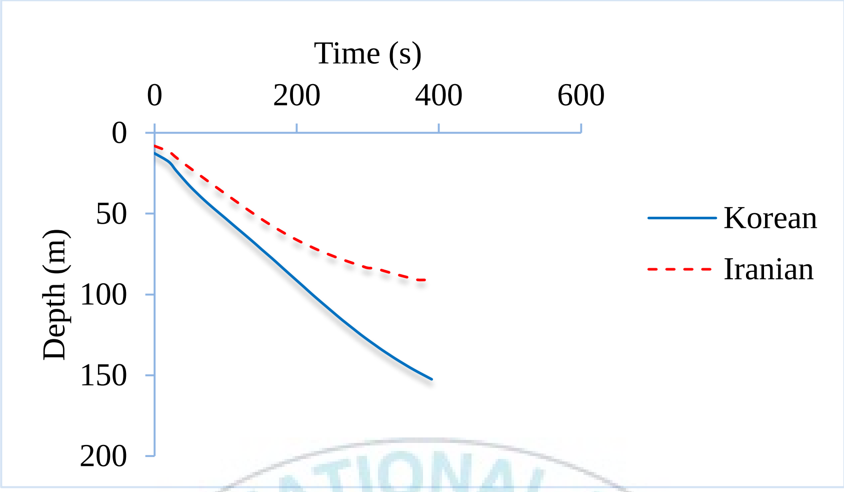



Figure 11. Sinking depths of the leadlines of tuna purse seine gears.

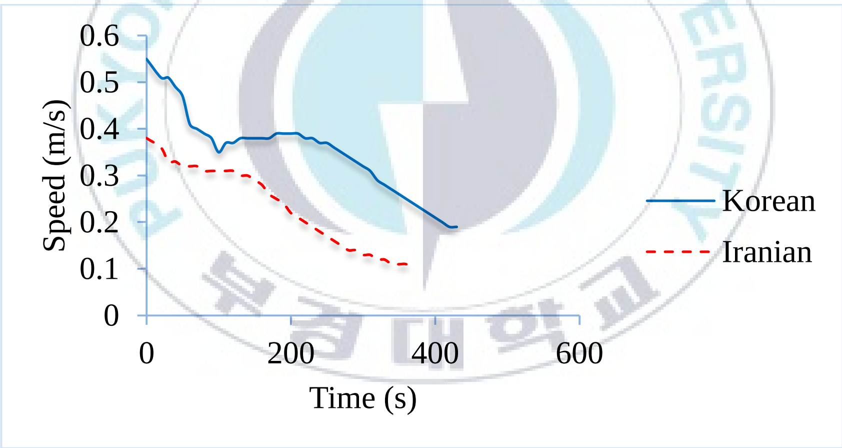



Figure 12. Sinking speeds of the leadlines of tuna purse seine gears.

### *4.1.2 Tension on the purse line*

The maximum tension on the purse lines throughout pursing, under the pursing speed of 3 m/s, of Iranian and Korean gears were 3,600 and

10,600 kgf respectively (Figure 13).

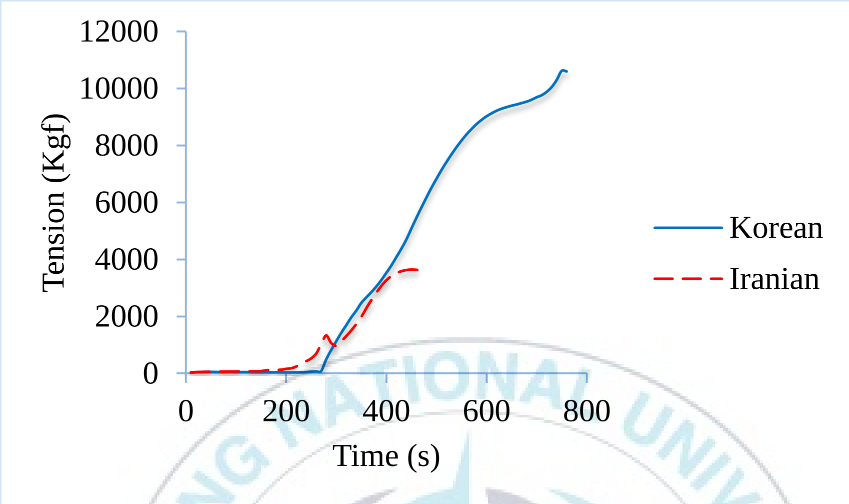



Figure 13. Tension on the ring lines of the tuna purse seine with no current.

#### *4.1.3 Surrounding area and shape of the simulated gear*

The surrounding areas of the gears were computed automatically by the SimPurse software immediately after finished setting the net, so the floatlines surrounding areas displayed were the case throughout the pursing process. The maximum floatlines surrounding areas of the Iranian and Korean gears were 21,000 and 124,200 $m^2$, and then shrunk as the purse lines were hauled in (Figure 14). The shapes of the gear which describe the sinking behaviour in static conditions from shooting to pursing processes are illustrated in Figure 15, only one gear presented as the simulations conditions were the same.

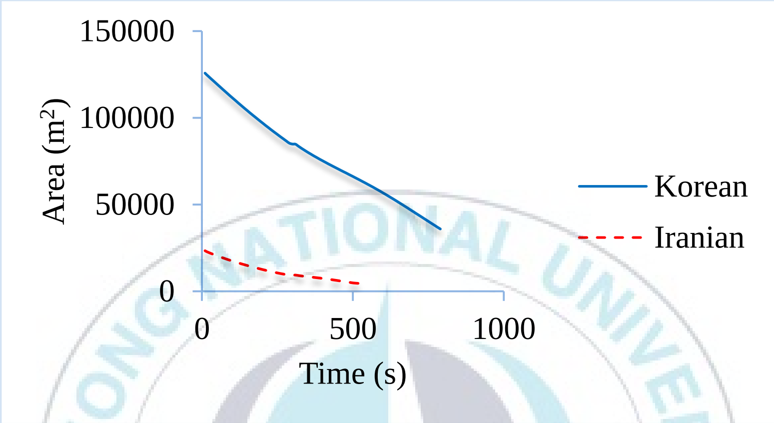
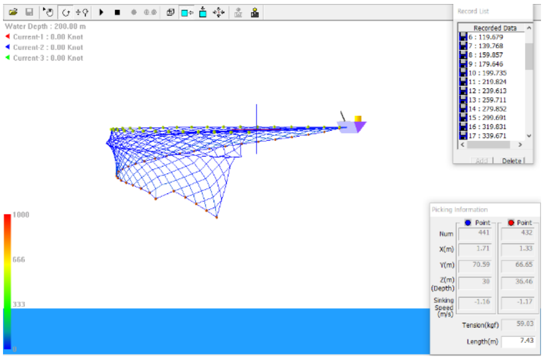
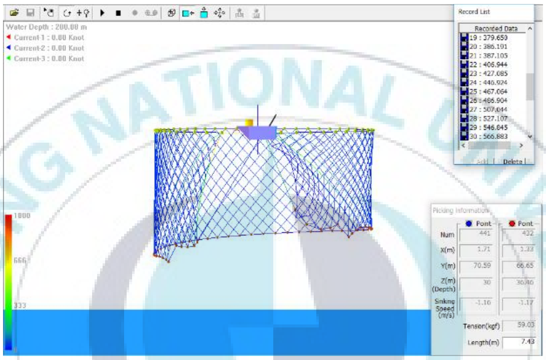
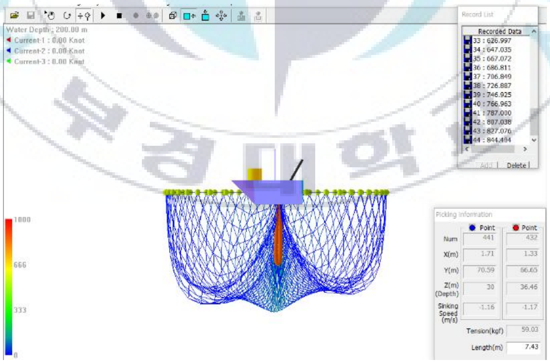



Figure 14. Surrounding area of the floatline of the gears with no current.


Water Depth : 200.00 m
Current-1 : 0.00 Knot
Current-2 : 0.00 Knot
Current-3 : 0.00 Knot
Record List
Recorded Data
Delete
Picking Information
Point
Point
Num
441
432
X(m)
Y(m)
Z(m) (Depth)
Sinking Speed (m/s)
Tension(kgf)
Length(m)
1000
666
333


Water Depth : 200.00 m
Current-1 : 0.00 Knot
Current-2 : 0.00 Knot
Current-3 : 0.00 Knot
Record List
Recorded Data
Delete
Picking Information
Point
Point
Num
X(m)
Y(m)
Z(m) (Depth)
Sinking Speed (m/s)
Tension(kgf)
Length(m)
1000
666
333


Water Depth : 200.00 m
Current-1 : 0.00 Knot
Current-2 : 0.00 Knot
Current-3 : 0.00 Knot
Record List
Recorded Data
Delete
Picking Information
Point
Point
Num
441
432
X(m)
Y(m)
Z(m) (Depth)
Sinking Speed (m/s)
Tension(kgf)
Length(m)
1000
666
333
0

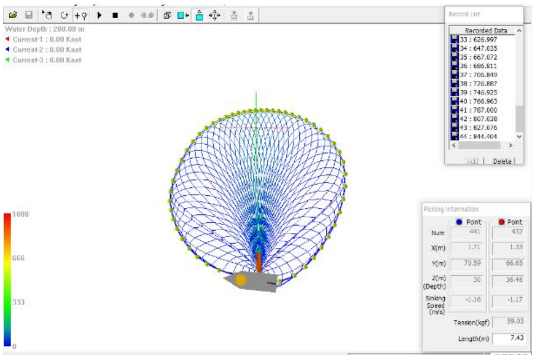


Figure 15. Shapes of the tuna purse seine with no current from shooting to hauling in process.

### *4.1.4 The modification of the Iranian tuna purse seine gear to suggest to Mozambique*

#### *4.1.4.1 Comparison between the Iranian tuna purse seine to Korean large tuna purse seine to modify the gear*

To design a Design tuna purse seine gear to propose to Mozambique, were compared the Iranian and Korean commercial tuna purse seine gear. Table 1 shows the dimensions of the two gears used here, in order to design one with good performance to fit to Mozambique. Korean large purse seine gears are rigged with chain leadline, chain bridles and steel rings, so they have a sinking force of greater than 5 kg/m Hosseini et al, (2011). As Korean tuna purse seine gear is heavily rigged, therefore has a good sinking performance. So, to make the Iranian tuna purse seine gear wider, it was enlarged and deepened (Figure 16), hereinafter referred as Design-I but keeping the same sinker line weight of the present Iranian gear of 3.53 kg/m and the results are displayed in Table 2.

Table 1. Comparison between the Iranian and Korean tuna purse seine gears.

| | ***Floatline*** | ***Stretched depth*** | ***Buoyancy*** | ***Sinking force*** |
|---|---|---|---|---|
| ***Korean purse seine*** | 1928 m | 282 m | 15 kg/m | 5.22 kg/m |
| ***Iranian purse seine*** | 728 m | 168 m | 22.19 kg/m | 3.53 kg/m |

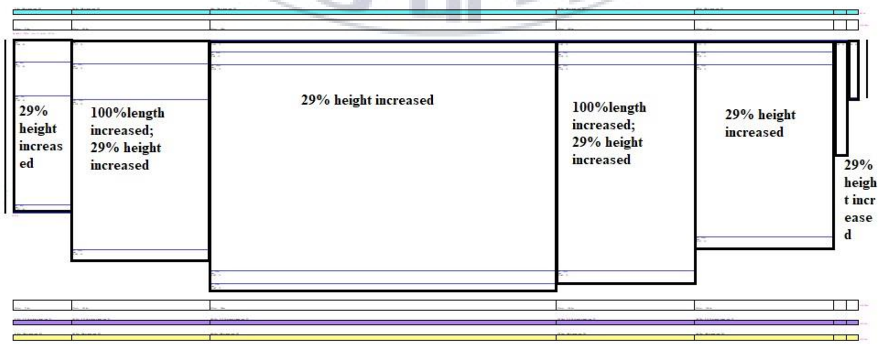



Figure 16. Design-I of tuna purse seine gear. Source: (Author)

Table 2. Dimensions and riggings of the Design-I.

| ***Dimensions*** | ***Design-I*** |
|---|---|
| ***Floatline*** | 986 m |
| ***Stretched depth*** | 217 m |
| ***Leadline*** | 1218 m |
| ***Buoyancy*** | 21749 kg |
| ***Total sinking force weight*** | 6796.56 kg |
| ***Ring number*** | 128 EA |
| ***Purse line*** | 1310 m |

*4.1.4.2 The volume of the improved tuna purse seine*

As the gear was increased in length and depth, this resulted in an increase in its volume. After shooting the gear, the computed volume was around 5 million cubic meters. This means that the amount of space enclosed by the improved purse seine is greater.

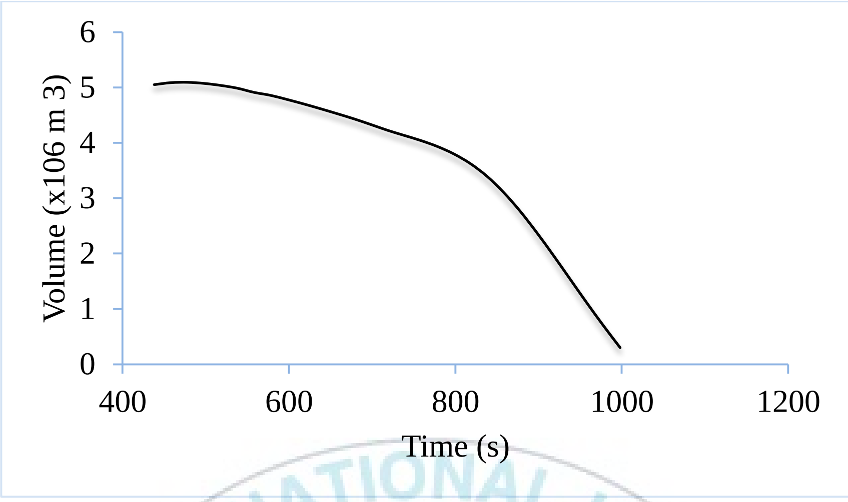



Figure 17. Enclosed volume of the Design-I purse seine gear.

#### *4.1.4.3 Performance of the sinker line weight to attain the Korean sinker weight*

To attain the sinker weight of Korean tuna purse seine gear, another simulation was done, where the Design-I sinker line weight was rigged with more 50% of its weight (5.295 kg/m), (Design-II). As the Design-II was heavily rigged with the same weigh as the Korean gear, hence has a good performance than the Design-I, as can be seen in Figure 18 and Figure 19 as well as its sinking speed by depth of the two Design gears Figure 20.

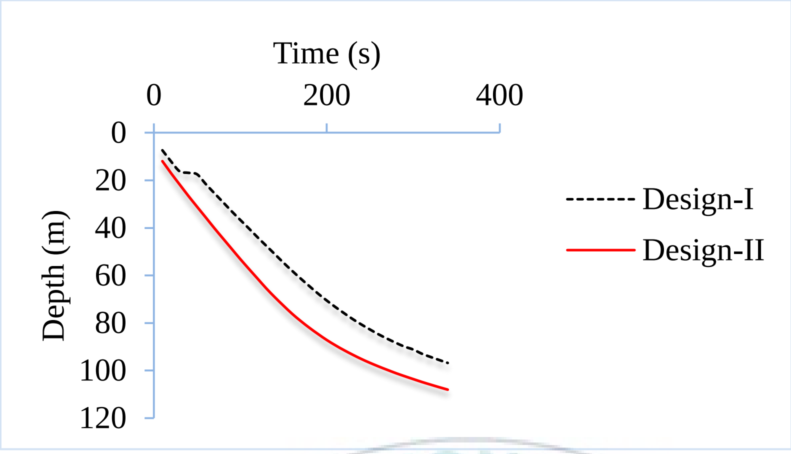



Figure 18. Sinking depth of the leadlines Design-I enlarged and deepened, and Design-II rigged with same weight as the Korean.

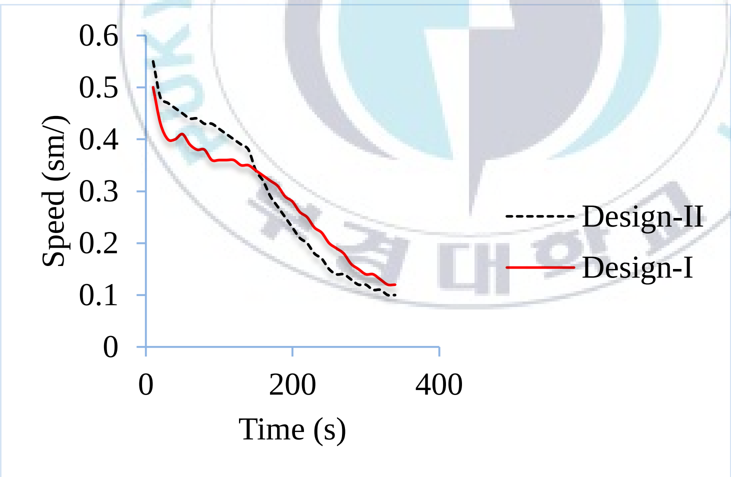



Figure 19.Sinker line sinking speed rigged with same weight as the Korean gear.

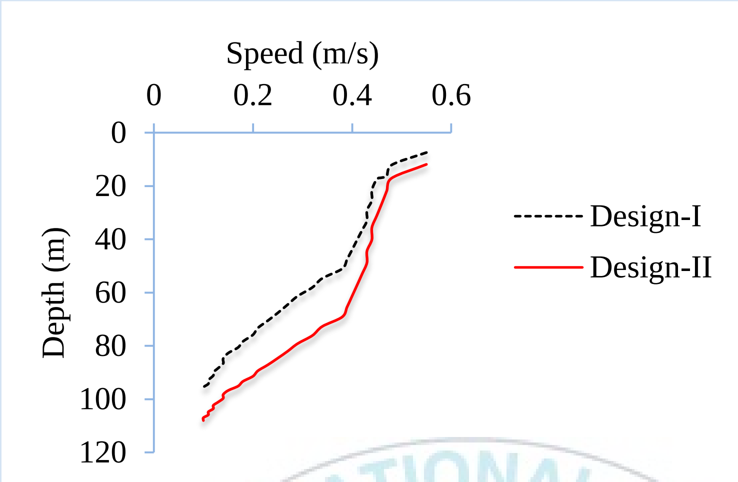



Figure 20. Sinker line weight speed by depth of the two Design gears.

*4.1.4.4 Comparison of the Tension between the two Designed gears.*

The Design-II had a tension of 6,200 kgf, which is higher compared to the tension of the Design-I which is 5,230 kg, as a result of the increased sinker weight line's weight.

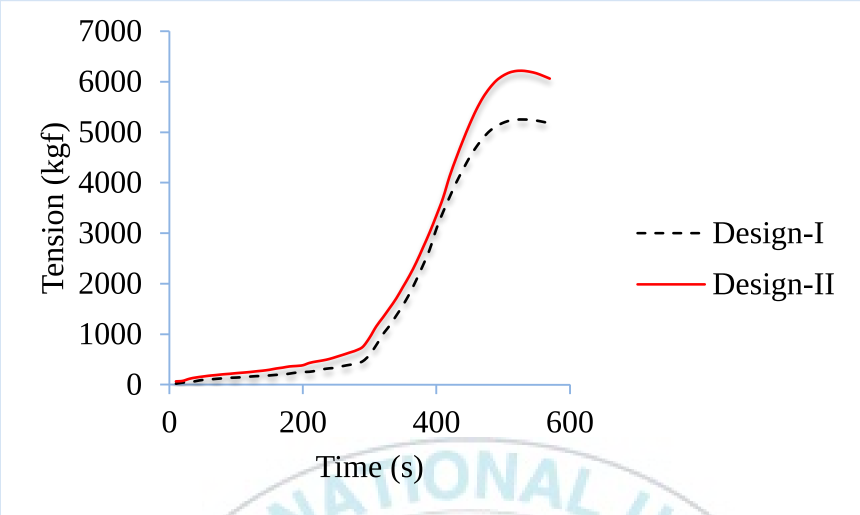



Figure 21. Tension on the purse line of the two Design gears.

#### *4.1.5 Simulation of the gears designed-II gear with different netting materials.*

The Design-II, originally had PA knotted netting in the whole sections, then it was changed the netting material to PES knotless netting (Design-III), in all sections except at the bunt.

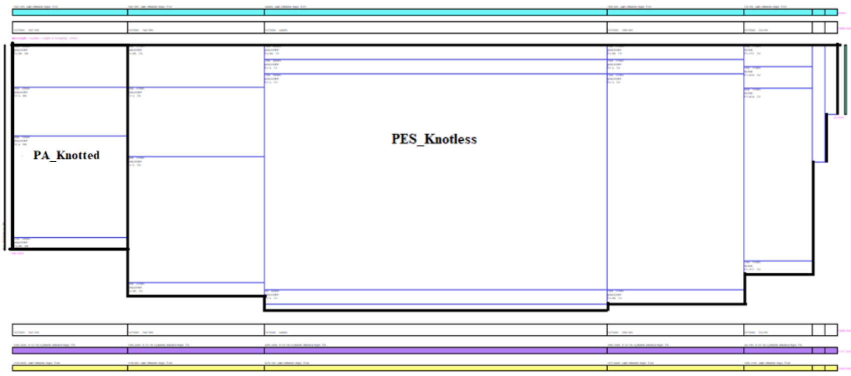



Figure 22. Design-III of tuna purse seine gear. Source: (Author).

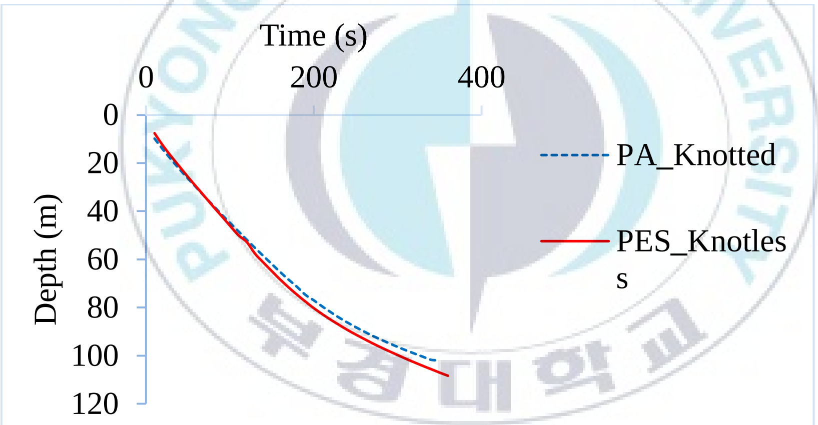



Figure 23. Sinking depth performance of the modified netting material (Design-III).

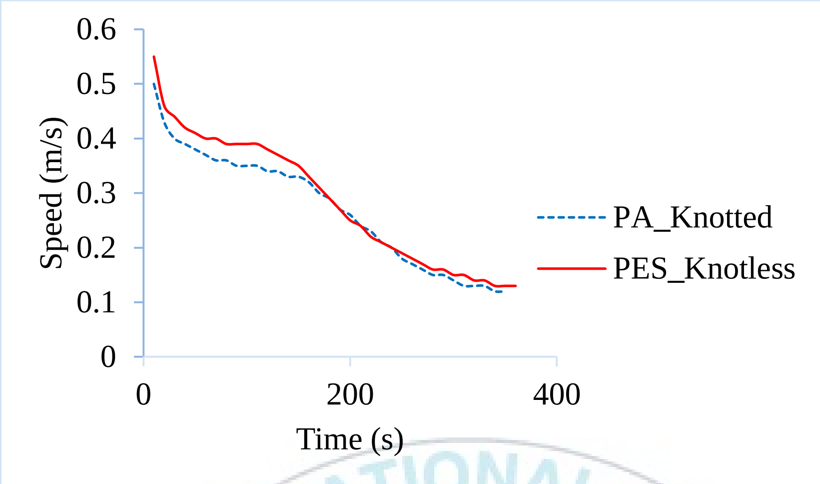



Figure 24. Sinking speed performance of the modified netting material (Design-III).

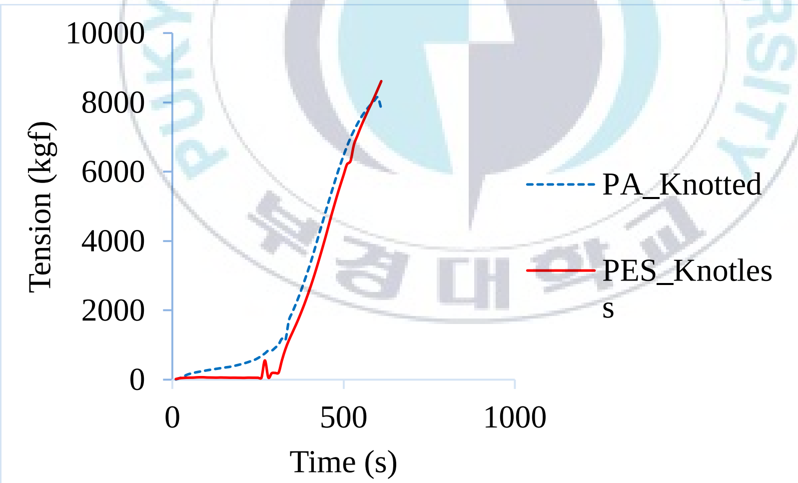



Figure 25. Tension on the ring line of the modified netting material (Design-III).

## 4.2 Discussion

### *4.2.1 Design of the appropriate Mozambique purse seine fishing gear*

The design of the appropriate Mozambique tuna purse seine fishing gear has to take into account the fishing ground physical features and the type of purse seine fishing method. The fishing ground features comprise its bathymetry, which determines the working depth of the fishing gear leadline. Knowledge regarding the target species is of pivotal importance as well. The fishers experience in operating a certain type of purse seine must also be considered (Widagdo, et al., 2014). This study has examined a purse seine gear which targets tuna fishes and is larger than the ones used to catch small pelagic fishes.

The improved tuna gear has a new length of 986 m, which culminated in a 50,000 $m^2$ surrounding area. This surrounding area will permit the fish school movement throughout the process from shooting to hauling in. As the Iranian gear was increased its dimensions, its total sinking performance also improved. Nets with greater depth and sinking speed reduce the likelihood of fish escaping under the leadline when the shooting and hauling are underway, South Pacific Commission Twenty First Technical Meeting Twenty First Technical Meeting, (1989). When the purse seine gears are rigged with a heavy steel chain leadline, chain bridles and steel purse rings, their performance is reasonable.

In all fishing gears, when the leadline's weight is increased, it contributes to their sinking performance. Widagdo et al. (2014) highlighted that the total sinking force is the major contributor to the sinking performance of the fishing gears amongst the contributorsas the gear reached greater working depths and did so at greater sinking speeds. Tang et al., (2018), found that the purse seine gear has a good sinking performance, as its leadline approaches a greater depth in a small amount of time. The greater sinking performance of the purse seine leadlines contribute to the gear's efficiency to catch fish Hosseini et al., (2011).

As outlined in the South Pacific Commission Twenty First Technical Meeting Twenty First Technical Meeting, (1989), when designing a tuna purse seine gear, the target species as well as its environment should be considered. The length and depth of the purse seine gear is determined according to the fishing ground conditions and purse seine method. In the Indian Ocean, for instance, tuna species such as a skipjack tuna with associated log/FADs during the night time swims to depths less than 50 m, and more than 50 m when it is off FADs during the day time, Matsumoto et al., (2014). According to (Josse, et al.), swimming depth of yellowfin tuna around Comoros varies throughout the day between 70-110 m, and at night varies around 40-70 m. Therefore, considering the working depths of the leadlines of the Design purse seine gears, they can catch those species at those depths. As the water depth within the Mozambique Channel decreases from 2000 m to 500 m towards the coast, with thermocline found at depth between 80-100 m (Sete, 2010), so a characteristic of purse seine suitable for these areas may range from 900 to 1000m in length and 80 to 140 m depth (South Pacific Commission Twenty First Technical Meeting Twenty First Technical Meeting, (1989). Hence, the Designed purse seine gear has 986 m length and 217 m of designed depth, and therefore falls in that range, making it suitable for catching species like tuna in this area.

# 5 Conclusion

The numerical method is appropriate for analyzing fishing gears' sinking performance for large gears such as purse seines;

It was possible to design new purse seine gears larger than the present gear with the sinker line weight which matches of the Korean tuna purse seine, as well as check how it behaves, from the shooting to hauling-in processes;

The improved tuna purse seine gear had higher sinking performance compared to the present gear as its weight and depth were increased, and culminated in increased total sinking force;

The tension on the purse line increased along with the total sinking force;

A purse seine gear was designed considering the fishing ground conditions and the purse seining mode in Indian Ocean (FADs) using a numerical.

## 6 Bibliography

Bessonneau, J. S. & Marichal, D., 1998. study of the dynamics of submerged supple nets (applications to trawls. *Ocean Engng, Elsevier,* Volume 25, p. 563–583.

Castro, J. A., Santiago, J. J. & Santana-Ortega, A. T., 2002. A general theory on fish aggregation to floating objects: An alternative to the meeting point hypothesis. *Reviews in Fish Biology and Fisheries,* Volume 11, p. 255–277.

Chacate , O. E. & Mutombene, R., 2017. *Mozambique National Report to the Scientific Commitee of the Indian Ocean Tuna Commission,* Maputo: FAO-IOTC.

Chacate, O. E. & Mutombene, R., 2018. *Mozambique National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2018,* Maputo: IOTC.

Commission, S. P., 1989. *Technical Asoects of Tuna Purse Seine Opeerations,* Noumea, New Caledonia: South PacificCommission.

Dagorn, L. & Fréon, . P., 2000. TLopical tuna associated with floating objects: a simulation study of the meeting peint hypothesis. *Canadian Journal of Fisheries and Aquatic Sciences* , Volume 56, pp. 984-993.

Davies , T. K., Mees, C. C. & Milner-Gulland, E. J., 2014. The present and future use of drifting fish aggregating devices (FADs) in the Indian Ocean. *Marine Policy,* Volume 45, pp. 163-170.

Drinkwater, K. & Arístegui, J., 2014. The Mozambique Channel: From physics to upper trophic levels. *Deep-Sea Research II,* Volume 100, p. 19.

FAO, 2012. *Programa da FAO em Mocambique-No ambito das Nacoes Unidas "Delivering as One"*, 2013: FAO.

Floch, L., Damiano, A., Billet, N. & Bach, P., 2017. *Statistics of the French pursen seine fishing fleet targeting tropical tunas in the Indian Ocean (1981-2016),* Victoria, Seychelles: Indian Ocean Tuna Commission.

Fonteneau, A. et al., 2000. Observed changes in the species composition of tuna schools in the Gulf of Guinea between 1981 and 1999, in relation with the Fish Aggregating Device fishery. *Aquat. Living Resour.*, Volume 13, p. 253–257.

Fonteneau, A., 2010. *Atlas of Tropical Tuna Fisheries-World catches and environment,* Paris: ORSTOM.

Fridman, A. L., 1986. *Calculations for Fishing Gear Design.* USA: FAO-Fishing Manuals.

Fridman, A. L., 1987. *Calculations for Fishing Gear Designs.* edited and enlarged by P.J.G. Carrothers. ed. s.l.:FAO Fishing Manuals.

Geehan, J., Fiorellato, F. & Pierre, L., 2018. *REVIEW OF THE STATISTICAL DATA AND FISHERY TRENDS FOR TROPICAL TUNAS,* s.l.: Indian Ocean Tuna Commission.

Guillotreau, P., Salladarré, . F., Dewals, P. & Dagorn, . L., 2011. Fishing tuna arund Fish Aggregating Devices (FADs) vs free swimming schools: Skipper decision and other determining factores. *Fisheries Research,* Volume 109, pp. 234-242.

Hosseini, S. A. et al., 2011. The sinking performance of the tuna purse seine gear with large-meshed panels using numerical method. *Fish Sci,* Volume 77, p. 503–520.

Hung, D. X., LEE, C. W. & PARK, S., 2016. Dynamic analysis and improvement of the sinking performance of the Vietnamese tuna purse seine using numerical methods. *J Korean Soc Fish Technol,* Volume 52(1), p. 1 - 8.

Itano, D. G., 2008. *Notes on the improvement of of fishing power and efficiency in the western tropical Pacific tuna purse seine fishery* , s.l.: s.n.

Josse, E., Dagorn, L. & Bertrand, A., 2000. Typology and behaviour of tuna aggregations around fish aggregating devices from acoustic surveys in French Polynesia. *Aquat. Living Resorces,* Volume 13, pp. 183-192.

Kai, E. T. & Marsac, F., 2010. Influence of mesoscale eddies on spatial structuring of top predators' communities in the Mozambique Channel. *Progress in Oceanography,* Volume 86, p. 214–223.

Kai, E. T. & Marsac, F., 2010. Influence of mesoscale eddies on spatial structuring of top predators' communities in the Mozambique Channel. *Progress in Oceanography,* Volume 86 , p. 214–223.

Kaplan, D. M. et al., 2014. Spatial management of Indian Ocean tropical tuna fisheries: potential and perspectives. *ICES Journal of Marine Science* , Volume 71(7), p. 1728–1749.

Kim, S.-. J., 2004. An analysis on the Sinking Resistence of Purse Seine-In the Case of the Model Purse Seine with Different Netting Material and Sinkers. *Bull. Korean Soc. Fish. Tech,* Volume 40(1), p. 8.

Kim, Y. -H., 2000. Geometry of the Model Purse Seine in Relation to Enclosed Volume During Hauling Operation. *Fisheries Science and Technology-The Korean Fisheries Society*, pp. 3(2)156-162.

Kulseng, R. . K., 2010. *100-year waves in the Mozambique Channel-Master thesis in Physical Oceanography,* Norway: UNIVERSITY OF BERGEN-Geophysical Institute.

Laissane, R. F. J., 2011. *ARTISANAL PURSE SEINE DESIGN IMPROVEMENTS SUGGESTED FOR MOZAMBIQUE FISHERIES,* Reykjavik, Iceland: United Nations University-Training Programme.

Lee, -W.C. et al., 2007. Dynamic simulation of the behavior of purse seine gear and sea-trial verification. *Fisheries Research,* Volume 88, p. 109–119.

Lee, C. -W., Lee, J., Choe, M. -Y. & Lee, G. -H., 2011. Applying Fishing-gear Simulation Software to Better Estimate Fished Space as Fishing Effort. *Fish Aquat Sci,* Volume 14(2), pp. 138-147.

Lee, C. -W., Lee, J., Choe, M. Y. & Lee, G. H., 2010. Design and Simulation Tools for Moored Underwater Flexible Structures. *Korean J Fish Aquat Sci,* Volume 43(2), pp. 159-168.

Lee, C. -W., Lee, J. & Park, S., 2018. Prediction of shooting trajectory of tuna purse seine fishing. *Fisheries Research-ELSEVIER,* pp. 189-201.

Litaka, Y., 1971. Purse Seine Design and Construction in Relation to Fish Behavior and Fishing Conditions. In: *Morde Fishing Gear of The World: 3.* Grat Britain: FAO-UN, pp. 253-279.

Liuxiong, X., Cheng, Z., Xinfeng, Z. & Xuchang, Y., 2015. Application of Numerical Simulation for Analysis of Sinking Characteristics of Purse Seine. *J. Ocean Univ. China (Oceanic and Coastal Sea Research),* pp. (1): 135-142.

Machii, T. & Nose, Y., 1992. Mechanical propriety of a rectangular purse seine in ideal conditions. *Fisheries Research,* Volume 14, pp. 261-271.

Marsac, F. et al., 2017. *Data-derived fishery and stocks status indicators for skipjack tuna in the Indian Ocean*, s.l.: IOTC.

Matsumoto, T., Satoh, K. & Toyonaga, M., 2014. Behavior of skipjack tuna (Katsuwonus pelamis) associated with a drifting FAD monitored with ultrasonic transmitters in the equatorial central Pacific Ocean. *Fisheries Research* , Volume 157, p. 78–85.

MMAIP, M. o. S. I. W. a. F., 2016. *Tuna Fishery,* s.l.: s.n.

Muthombene, R., Chauca, I. & Chacate, O., 2016. *ASSESSMENT OF THE STATUS OF DATA COLLECTION AND REPORTING OF ARTISANAL FISHERIES IN MOZAMBIQUE-Case study of two coastal provinces, Cabo Delgado and Nampula,* Maputo,: National Institute of Fisheries Research (IIP).

Mutombene, R., Chauca, I. & Chacate, O., 2016. *ASSESSMENT OF THE STATUS OF DATA COLLECTION AND REPORTING OF ARTISANAL FISHERIES IN MOZAMBIQUE-Case study of two coastal provinces, Cabo Delgado and Nampula,* Maputo,: National Institute of Fisheries Research (IIP).

Rounsefell, G. A. & Everhart, W. H., 1962. *FISHERY SCIENCE_Its Methods and Applications.* New York : John Wiley &Sons .

Sæ tre, R., Silva & Paula, R. d., 1979. *Reports on survey with the R/V Dr Fridtjof Nansen.,* Maputo : Serviço de Investigações Pesqueiras, nstitute of marine Research, Bergen.

Sete, C. I., 2010. *TIDAL STRUCTURES AND MIXING ALONG THE MOZAMBIQUE COAST,* University of Bergen - Norway: NOMA Joint Master in Applied Marine Sciences.

Soto, M., 2014. *Artisanal Fisheries and Climate Change Project (FishCC)"*-, Maputo, Mozambique: Instituto Nacional de Desenvolvimento da Pesca de Pequena Escala.

Suzuki, K. et al., 2003. Takagi T, Suzuki K and Hiraishi T. 2002. Modeling of net configurations of fishing nets. *Japanese Society of Fisheries Science,* Volume 69(4), pp. 695-705.

Tang, H., Xu, L. & Hu, F., 2018. Hydrodynamic characteristics of knotted and knotless purse seine netting panels as determined in a flume tank. *Plos One.*

Tenningen, M. M., 2014. *Uncouted mortality in purse seine Fisheries,* Norway: Dissertation for the degree philosophiae doctor (PhD) at the University of Bergen.

Ullgren, J. E., André, . E., Gammelsrød, T. & Hoguane, A. M., 2016. Observations of strong ocean current events offshore Pemba, Northern Mozambique. *JOURNAL OF OPERATIONAL OCEANOGRAPHY*, Volume 9, pp. 55-66.

Widagdo, A., Lee, C. -W. & Lee, J., 2014. *Improving the Sinking Performance of the Indonesian Small Purse Seine Gears,* Southn Korea: s.n.

Xu, L. et al., 2017. The effects of environmental variables variables, gear design and operational parameters on sinking performance of tuna purse seine setting on free swimming schools. *Fisheries Research_ELSEVIER,* Volume 196, pp. 151-159.

Xu, L., Zhou, C., Tang, H. & Wang, X., 2015. In-situ dynamics of tuna purse seine deployment in various operations and currents. *Fish Sci,* Volume 81, p. 1003–1011.

# 7 Appendices

Table 3:Specification of the Tuna purse seine gear

<Net> Total length: 728 m

| no | mesh size | hanging ratio | length (m) | V.M.N (L) | V.M.N (R) | Material | D (mm) | Type |
|---|---|---|---|---|---|---|---|---|
| **1** | 90 | 80 | 92 | 244 | 244 | nylon | 1.448 | knot |
| **2** | 90 | 80 | 92 | 366 | 366 | nylon | 1.277 | knot |
| **3** | 90 | 80 | 92 | 854 | 854 | nylon | 1.182 | knot |
| **4** | 90 | 80 | 92 | 100 | 100 | nylon | 1.277 | knot |
| **5** | 105 | 74 | 110 | 200 | 200 | nylon | 1.277 | knot |
| **6** | 105 | 74 | 110 | 300 | 300 | nylon | 1.182 | knot |
| **7** | 105 | 74 | 110 | 900 | 900 | nylon | 1.079 | knot |
| **8** | 105 | 74 | 110 | 100 | 100 | nylon | 1.182 | knot |
| **9** | 105 | 72 | 550 | 100 | 100 | nylon | 1.182 | knot |
| **10** | 105 | 72 | 550 | 100 | 100 | nylon | 1.182 | knot |
| **11** | 210 | 72 | 550 | 600 | 600 | nylon | 1.024 | knot |
| **12** | 210 | 72 | 550 | 50 | 50 | nylon | 1.182 | knot |
| **13** | 105 | 72 | 550 | 50 | 50 | nylon | 1.182 | knot |
| **14** | 105 | 72 | 110 | 100 | 100 | nylon | 1.182 | knot |
| **15** | 105 | 72 | 110 | 100 | 100 | nylon | 1.079 | knot |
| **16** | 210 | 72 | 110 | 600 | 600 | nylon | 1.024 | knot |
| **17** | 210 | 72 | 110 | 100 | 100 | nylon | 1.182 | knot |
| **18** | 105 | 72 | 110 | 100 | 100 | nylon | 1.277 | knot |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **19** | 105 | 72 | 110 | 100 | 100 | nylon | 1.079 | knot |
| **20** | 210 | 72 | 110 | 100 | 100 | nylon | 1.079 | knot |
| **21** | 105 | 72 | 110 | 600 | 600 | nylon | 1.277 | knot |
| **22** | 210 | 72 | 110 | 50 | 50 | nylon | 1.365 | knot |
| **23** | 210 | 72 | 110 | 50 | 50 | nylon | 1.365 | knot |

<Selvedge> Total length: 728 m

| no | mesh size | hanging ratio | length (m) | Material | D (mm) | Type |
|---|---|---|---|---|---|---|
| **1-1** | 127 | 72 | 73.6 | nylon | 1.806 | knot |
| **1-2** | 127 | 72 | 81.4 | nylon | 1.806 | knot |
| **1-3** | 127 | 72 | 396 | nylon | 1.806 | knot |
| **1-4** | 127 | 72 | 79.2 | nylon | 1.806 | knot |
| **1-5** | 127 | 72 | 79.2 | nylon | 1.806 | knot |
| **1-6** | 127 | 72 | 9.1 | nylon | 1.806 | knot |
| **1-7** | 105 | 72 | 9.1 | nylon | 1.806 | knot |
| **2-1** | 127 | 72 | 73.6 | nylon | 1.806 | knot |
| **2-2** | 127 | 72 | 81.4 | nylon | 1.806 | knot |
| **2-3** | 127 | 72 | 392 | nylon | 1.806 | knot |
| **2-4** | 127 | 72 | 79.2 | nylon | 1.806 | knot |
| **2-5** | 127 | 72 | 79.2 | nylon | 1.806 | knot |
| **2-6** | 127 | 72 | 9.1 | nylon | 1.806 | knot |
| **2-7** | 105 | 72 | 9.1 | nylon | 1.806 | knot |

<Floatline> Total length: 728 m

| No | Length | Kind | Material | Diameter |
|---|---|---|---|---|
| **1** | 73.6 | 3&8strands rope | polyethylene | 22 |
| **2** | 81.4 | 3&8strands rope | polyethylene | 22 |
| **3** | 79.2 | 3&8strands rope | polyethylene | 22 |
| **4** | 79.2 | 3&8strands rope | polyethylene | 22 |
| **5** | 79.2 | 3&8strands rope | polyethylene | 22 |
| **6** | 79.2 | 3&8strands rope | polyethylene | 22 |
| **7** | 79.2 | 3&8strands rope | polyethylene | 22 |

<Float> Total Buoyancy: 16147 kg

| No | Kind | Buoyancy | Quantity | Total | Link type |
|---|---|---|---|---|---|
| **1** | Hole type (E.V.A) | 5 | 4.4385 | 1633.368 | Two rope |
| **2** | Hole type (E.V.A) | 5 | 4.4385 | 1806.469 | Two rope |
| **3** | Hole type (E.V.A) | 5 | 4.4385 | 8788.229 | Two rope |
| **4** | Hole type (E.V.A) | 5 | 4.4385 | 1753.646 | Two rope |
| **5** | Hole type (E.V.A) | 5 | 4.4385 | 1753.646 | Two rope |
| **6** | Hole type (E.V.A) | 5 | 4.4385 | 201.9518 | Two rope |
| **7** | Hole type (E.V.A) | 5 | 4.4385 | 201.9518 | Two rope |

<Leadline> Total Length: 919 m

| No | Length | Kind | Material | Diameter |
|---|---|---|---|---|
| **1** | 97.6686 | 8, 12, 16 strands braided rope | polyester | 5 |
| **2** | 97.6686 | 8, 12, 16 strands braided rope | polyester | 5 |
| **3** | 488.343 | 8, 12, 16 strands braided rope | polyester | 5 |
| **4** | 103.0719 | 8, 12, 16 strands braided rope | polyester | 5 |
| **5** | 93.1953 | 8, 12, 16 strands braided rope | polyester | 5 |
| **6** | 19.63881 | 8, 12, 16 strands braided rope | polyester | 5 |
| **7** | 19.63881 | 8, 12, 16 strands braided rope | polyester | 5 |

<Sinker> Total Sinking Force: 3345 kg

| No | kind | weight (kgf) | S-force | Quantity | Total | Link type |
|---|---|---|---|---|---|---|
| **1** | Chain leadline | 3 | 0.274 | 13.28 | 355.3887 | Chain leadline |
| **2** | Chain leadline | 3 | 0.274 | 13.28 | 355.3887 | Chain leadline |
| **3** | Chain leadline | 3 | 0.274 | 13.28 | 1776.943 | Chain leadline |
| **4** | Chain leadline | 3 | 0.274 | 13.28 | 375.0498 | Chain leadline |
| **5** | Chain leadline | 3 | 0.274 | 13.28 | 339.1116 | Chain leadline |
| **6** | Chain leadline | 3 | 0.274 | 13.28 | 71.46012 | Chain leadline |
| **7** | Chain leadline | 3 | 0.274 | 13.28 | 71.46012 | Chain leadline |

<Purse line> Total length: 988 m

| No | Length | Kind | Material | Diameter |
|---|---|---|---|---|
| 1 | 105.02 | 3&8strands rope | polyester | 30 |
| 2 | 105.02 | 3&8strands rope | polyester | 30 |
| 3 | 105.02 | 3&8strands rope | polyester | 30 |
| 4 | 105.02 | 3&8strands rope | polyester | 30 |
| 5 | 105.02 | 3&8strands rope | polyester | 30 |
| 6 | 105.02 | 3&8strands rope | polyester | 30 |
| 7 | 105.02 | 3&8strands rope | polyester | 30 |

<Link Ring> Total number: 96 EA

| No | Kind | Weight | Quantity | Total | Link type |
|---|---|---|---|---|---|
| 1 | ring | 4.6 | 0.0975 | 47.10147 | V-Type |
| 2 | ring | 4.6 | 0.0975 | 47.10147 | V-Type |
| 3 | ring | 4.6 | 0.0975 | 235.5073 | V-Type |
| 4 | ring | 4.6 | 0.0975 | 49.70725 | V-Type |
| 5 | ring | 4.6 | 0.0975 | 44.94418 | V-Type |
| 6 | ring | 4.6 | 0.0975 | 9.470974 | V-Type |
| 7 | ring | 4.6 | 0.0975 | 9.470974 | V-Type |

Table 4. Korean tuna purse seine specifications

<Net> total length 1928

| No | Mesh size (mm) | Hanging ratio | Length | V.M.N (L) | V.M.N (R) | Material | D (mm) | Type |
|---|---|---|---|---|---|---|---|---|
| **1** | 140 | 75 | 40 | 300 | 300 | Nylon | 5 | Knotless |
| **2** | 140 | 75 | 40 | 300 | 300 | Nylon | 4.1 | Knot |
| **3** | 140 | 75 | 40 | 366 | 366 | Nylon | 3.6 | Knotless |
| **4** | 160 | 75 | 40 | 50 | 80 | Polyester | 3.05 | Knotless |
| **5** | 140 | 75 | 50 | 600 | 600 | Nylon | 4.1 | Knotless |
| **6** | 140 | 75 | 50 | 400 | 400 | Nylon | 3.6 | Knotless |
| **7** | 160 | 75 | 50 | 50 | 138 | Nylon | 2.9 | Knotless |
| **8** | 140 | 75 | 50 | 1100 | 1100 | Nylon | 3.6 | Knotless |
| **9** | 160 | 75 | 50 | 50 | 188 | Nylon | 2.9 | Knotless |
| **10** | 160 | 75 | 100 | 1100 | 1100 | Nylon | 3.4 | Knotless |
| **11** | 160 | 75 | 100 | 50 | 175 | Nylon | 2.9 | Knotless |
| **12** | 160 | 75 | 50 | 100 | 100 | Nylon | 2.9 | Knotless |
| **13** | 180 | 75 | 50 | 1000 | 1000 | Nylon | 2.9 | Knotless |
| **14** | 160 | 75 | 50 | 50 | 162 | Nylon | 3.4 | Knotless |
| **15** | 160 | 75 | 50 | 100 | 100 | Nylon | 2.9 | Knotless |
| **16** | 180 | 75 | 50 | 100 | 100 | Nylon | 2.4 | Knotless |
| **17** | 200 | 75 | 50 | 900 | 900 | Nylon | 2.9 | Knotless |
| **18** | 160 | 80 | 50 | 50 | 250 | Nylon | 3.4 | Knotless |
| **19** | 160 | 80 | 50 | 100 | 100 | Nylon | 2.9 | Knotless |
| **20** | 180 | 80 | 50 | 100 | 100 | Nylon | 3.4 | Knotless |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **21** | 200 | 80 | 50 | 100 | 100 | Nylon | 2.4 | Knotless |
| **22** | 240 | 80 | 50 | 800 | 800 | Nylon | 2.4 | Knotless |
| **23** | 160 | 80 | 50 | 50 | 225 | Nylon | 2.9 | Knotless |
| **24** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.4 | Knotless |
| **25** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.9 | Knotless |
| **26** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **27** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **28** | 280 | 80 | 100 | 700 | 700 | Nylon | 2.4 | Knotless |
| **29** | 160 | 80 | 100 | 50 | 50 | Nylon | 2.9 | Knotless |
| **30** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.4 | Knotless |
| **31** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.9 | Knotless |
| **32** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **33** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **34** | 280 | 80 | 100 | 700 | 700 | Nylon | 2.4 | Knotless |
| **35** | 160 | 80 | 100 | 50 | 50 | Nylon | 2.9 | Knotless |
| **36** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.4 | Knotless |
| **37** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.9 | Knotless |
| **38** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **39** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **40** | 280 | 80 | 100 | 700 | 700 | Nylon | 2.4 | Knotless |
| **41** | 160 | 80 | 100 | 50 | 50 | Nylon | 2.9 | Knotless |
| **42** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.4 | Knotless |
| **43** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.9 | Knotless |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **44** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **45** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **46** | 280 | 80 | 100 | 700 | 700 | Nylon | 2.4 | Knotless |
| **47** | 160 | 80 | 100 | 50 | 50 | Nylon | 2.9 | Knotless |
| **48** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.4 | Knotless |
| **49** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.9 | Knotless |
| **50** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **51** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **52** | 280 | 80 | 100 | 700 | 700 | Nylon | 2.4 | Knotless |
| **53** | 160 | 80 | 100 | 50 | 50 | Nylon | 2.9 | Knotless |
| **54** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.4 | Knotless |
| **55** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.9 | Knotless |
| **56** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **57** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **58** | 280 | 80 | 100 | 700 | 700 | Nylon | 2.4 | Knotless |
| **59** | 160 | 80 | 100 | 50 | 50 | Nylon | 2.9 | Knotless |
| **60** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.4 | Knotless |
| **61** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.9 | Knotless |
| **62** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **63** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **64** | 280 | 80 | 100 | 700 | 700 | Nylon | 2.4 | Knotless |
| **65** | 160 | 80 | 100 | 50 | 50 | Nylon | 2.9 | Knotless |
| **66** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.4 | Knotless |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **67** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.9 | Knotless |
| **68** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.4 | Knotless |
| **69** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **70** | 280 | 80 | 100 | 700 | 700 | Polyester | 3.05 | Knotless |
| **71** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.25 | Knotless |
| **72** | 160 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **73** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **74** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **75** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **76** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **77** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |
| **78** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **79** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **80** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **81** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **82** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **83** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |
| **84** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **85** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **86** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **87** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **88** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **89** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **90** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **91** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **92** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **93** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **94** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **95** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |
| **96** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **97** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **98** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **99** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **100** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **101** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |
| **102** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **103** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **104** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **105** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **106** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **107** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |
| **108** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **109** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **110** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **111** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **112** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **113** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |
| **114** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **115** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **116** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **117** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **118** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **119** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |
| **120** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **121** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **122** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **123** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **124** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **125** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |
| **126** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **127** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **128** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **129** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |
| **130** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **131** | 160 | 80 | 100 | 50 | 50 | Polyester | 3.05 | Knotless |
| **132** | 160 | 80 | 100 | 100 | 100 | Nylon | 3.25 | Knotless |
| **133** | 180 | 80 | 100 | 100 | 100 | Nylon | 2.8 | Knotless |
| **134** | 200 | 80 | 100 | 100 | 100 | Nylon | 2.5 | Knotless |
| **135** | 240 | 80 | 100 | 100 | 100 | Nylon | 2.3 | Knotless |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **136** | 280 | 80 | 100 | 700 | 700 | Polyester | 2.3 | Knotless |
| **137** | 160 | 80 | 50 | 50 | 50 | Polyester | 3.05 | Knotless |
| **138** | 160 | 75 | 50 | 100 | 100 | Nylon | 3.25 | Knotless |
| **139** | 180 | 75 | 50 | 100 | 100 | Nylon | 2.8 | Knotless |
| **140** | 200 | 75 | 50 | 100 | 100 | Nylon | 2.5 | Knotless |
| **141** | 240 | 75 | 50 | 100 | 100 | Nylon | 2.3 | Knotless |
| **142** | 280 | 75 | 50 | 600 | 600 | Polyester | 2.3 | Knotless |
| **143** | 160 | 80 | 50 | 225 | 50 | Polyester | 3.05 | Knotless |
| **144** | 160 | 75 | 50 | 100 | 100 | Nylon | 3.25 | Knotless |
| **145** | 180 | 75 | 50 | 100 | 100 | Nylon | 2.8 | Knotless |
| **146** | 200 | 75 | 50 | 100 | 100 | Nylon | 2.5 | Knotless |
| **147** | 240 | 75 | 50 | 100 | 100 | Nylon | 2.3 | Knotless |
| **148** | 280 | 75 | 50 | 500 | 500 | Polyester | 2.3 | Knotless |
| **149** | 160 | 80 | 50 | 225 | 50 | Polyester | 3.05 | Knotless |
| **150** | 160 | 75 | 50 | 100 | 100 | Nylon | 3.25 | Knotless |
| **151** | 180 | 75 | 50 | 100 | 100 | Nylon | 2.8 | Knotless |
| **152** | 200 | 75 | 50 | 100 | 100 | Nylon | 2.5 | Knotless |
| **153** | 240 | 75 | 50 | 100 | 100 | Nylon | 2.3 | Knotless |
| **154** | 240 | 75 | 50 | 500 | 500 | Polyester | 2.3 | Knotless |
| **155** | 160 | 80 | 50 | 170 | 170 | Polyester | 3.05 | Knotless |

<Floatline> Total length: 1928 m

| no | length(m) | kind | material | Diameter (mm) |
|---|---|---|---|---|
| **1** | 30 | Double braided rope | Ppm | 40 |
| **2** | 37.5 | Double braided rope | Ppm | 40 |
| **3** | 37.5 | Double braided rope | Polyester | 40 |
| **4** | 75 | 3&8 strands rope | Polyester | 26 |
| **5** | 37.5 | 3&8 strands rope | Polyester | 26 |
| **6** | 37.5 | 3&8 strands rope | Polyester | 26 |
| **7** | 40 | 3&8 strands rope | Polyester | 26 |
| **8** | 80 | 3&8 strands rope | Polyester | 26 |
| **9** | 80 | 3&8 strands rope | Polyester | 26 |
| **10** | 80 | 3&8 strands rope | Polyester | 26 |
| **11** | 80 | 3&8 strands rope | Polyester | 26 |
| **12** | 80 | 3&8 strands rope | Polyester | 26 |
| **13** | 80 | 3&8 strands rope | Polyester | 26 |
| **14** | 80 | 3&8 strands rope | Polyester | 26 |
| **15** | 80 | 3&8 strands rope | Polyester | 26 |
| **16** | 80 | 3&8 strands rope | Polyester | 26 |
| **17** | 80 | 3&8 strands rope | Polyester | 26 |
| **18** | 80 | 3&8 strands rope | Polyester | 26 |
| **19** | 80 | 3&8 strands rope | Polyester | 26 |

| | | | | |
|---|---|---|---|---|
| **20** | 80 | 3&8 strands rope | Polyester | 26 |
| **21** | 80 | 3&8 strands rope | Polyester | 26 |
| **22** | 80 | 3&8 strands rope | Polyester | 26 |
| **23** | 80 | 3&8 strands rope | Polyester | 26 |
| **24** | 80 | 3&8 strands rope | Polyester | 26 |
| **25** | 80 | 3&8 strands rope | Polyester | 26 |
| **26** | 80 | 3&8 strands rope | Polyester | 26 |
| **27** | 37.5 | 3&8 strands rope | Polyester | 26 |
| **28** | 37.5 | 3&8 strands rope | Ppm | 40 |
| **29** | 37.5 | 3&8 strands rope | Ppm | 40 |

<Float> Total Buoyancy: 48712 kg

| **no** | **Kind** | **Size** | **Buoyancy** | **Quantity** | **Link type** |
|---|---|---|---|---|---|
| **1** | Hole type | 202 | 4 | 50 | Two-rope |
| **2** | Hole type | 202 | 4 | 50 | Two-rope |
| **3** | Hole type | 202 | 4 | 50 | Two-rope |
| **4** | Hole type | 183 | 3 | 5 | Loose hanging |
| **5** | Hole type | 183 | 3 | 5 | Loose hanging |
| **6** | Hole type | 183 | 3 | 5 | Loose hanging |
| **7** | Hole type | 183 | 3 | 5 | Loose hanging |
| **8** | Hole type | 183 | 3 | 5 | Loose hanging |
| **9** | Hole type | 183 | 3 | 5 | Loose hanging |
| **10** | Hole type | 183 | 3 | 5 | Loose hanging |

| | | | | | |
|---|---|---|---|---|---|
| **11** | Hole type | 183 | 3 | 5 | Loose hanging |
| **12** | Hole type | 183 | 3 | 5 | Loose hanging |
| **13** | Hole type | 183 | 3 | 5 | Loose hanging |
| **14** | Hole type | 183 | 3 | 5 | Loose hanging |
| **15** | Hole type | 183 | 3 | 5 | Loose hanging |
| **16** | Hole type | 183 | 3 | 5 | Loose hanging |
| **17** | Hole type | 183 | 3 | 5 | Loose hanging |
| **18** | Hole type | 183 | 3 | 5 | Loose hanging |
| **19** | Hole type | 183 | 3 | 5 | Loose hanging |
| **20** | Hole type | 183 | 3 | 5 | Loose hanging |
| **21** | Hole type | 183 | 3 | 5 | Loose hanging |
| **22** | Hole type | 183 | 3 | 5 | Loose hanging |
| **23** | Hole type | 183 | 3 | 5 | Loose hanging |
| **24** | Hole type | 183 | 3 | 5 | Loose hanging |
| **25** | Hole type | 183 | 3 | 5 | Loose hanging |
| **26** | Hole type | 183 | 3 | 5 | Loose hanging |
| **27** | Hole type | 183 | 3 | 5 | Loose hanging |
| **28** | Hole type | 202 | 4 | 5 | Two-rope |
| **29** | Hole type | 202 | 4 | 5 | Two-rope |

<Leadline> Total length: 2074 m

| no | length (m) | kind | material | Diameter (mm) |
|---|---|---|---|---|
| 1 | 41.058 | 3&8 strands rope | Ppm | 5 |
| 2 | 50.58 | 3&8 strands rope | Ppm | 5 |
| 3 | 52.074 | 3&8 strands rope | Polyester | 5 |
| 4 | 100.871 | 3&8 strands rope | Polyester | 5 |
| 5 | 51.398 | 3&8 strands rope | Polyester | 5 |
| 6 | 50.308 | 3&8 strands rope | Polyester | 5 |
| 7 | 52.747 | 3&8 strands rope | Polyester | 5 |
| 8 | 80 | 3&8 strands rope | Polyester | 5 |
| 9 | 80 | 3&8 strands rope | Polyester | 5 |
| 10 | 80 | 3&8 strands rope | Polyester | 5 |
| 11 | 80 | 3&8 strands rope | Polyester | 5 |
| 12 | 80 | 3&8 strands rope | Polyester | 5 |
| 13 | 80 | 3&8 strands rope | Polyester | 5 |
| 14 | 80 | 3&8 strands rope | Polyester | 5 |
| 15 | 80 | 3&8 strands rope | Polyester | 5 |
| 16 | 80 | 3&8 strands rope | Polyester | 5 |
| 17 | 80 | 3&8 strands rope | Polyester | 5 |
| 18 | 80 | 3&8 strands rope | Polyester | 5 |
| 19 | 80 | 3&8 strands rope | Polyester | 5 |
| 20 | 80 | 3&8 strands rope | Polyester | 5 |
| 21 | 80 | 3&8 strands rope | Polyester | 5 |
| 22 | 80 | 3&8 strands rope | Polyester | 5 |
| 23 | 80 | 3&8 strands rope | Polyester | 5 |
| 24 | 80 | 3&8 strands rope | Polyester | 5 |
| 25 | 80 | 3&8 strands rope | Polyester | 5 |

| | | | | |
|---|---|---|---|---|
| **26** | 80 | 3&8 strands rope | Polyester | 5 |
| **27** | 50.028 | 3&8 strands rope | Polyester | 5 |
| **28** | 53.32 | 3&8 strands rope | Ppm | 5 |
| **29** | 51.72 | 3&8 strands rope | Ppm | 5 |

<Sinker> Total Sinking force: 11342 kg

| no | kind | weight | S-force | Quantity | Total | Link type |
|---|---|---|---|---|---|---|
| **1** | steel chain | 3 | 2.61 | 3 | 321.4841 | Chain leadline |
| **2** | steel chain | 3 | 2.61 | 3 | 398.1555 | Chain leadline |
| **3** | steel chain | 3 | 2.61 | 2 | 271.8263 | Chain leadline |
| **4** | steel chain | 3 | 2.61 | 2 | 526.5466 | Chain leadline |
| **5** | steel chain | 3 | 2.61 | 2 | 268.2975 | Chain leadline |
| **6** | steel chain | 3 | 2.61 | 2 | 262.6078 | Chain leadline |
| **7** | steel chain | 3 | 2.61 | 2 | 275.3393 | Chain leadline |
| **8** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **9** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **10** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **11** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **12** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **13** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |

| | | | | | | |
|---|---|---|---|---|---|---|
| **14** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **15** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **16** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **17** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **18** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **19** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **20** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **21** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **22** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **23** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **24** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **25** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **26** | steel chain | 3 | 2.61 | 2 | 417.6 | Chain leadline |
| **27** | steel chain | 3 | 2.61 | 2 | 261.1461 | Chain leadline |
| **28** | steel chain | 3 | 2.61 | 3 | 417.4956 | Chain leadline |
| **29** | steel chain | 3 | 2.61 | 3 | 404.9696 | Chain leadline |