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BOTTOM & PELAGIC SAMPLING TRAWLS IN LAKE VICTORIA (KENYA)

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ABSTRACT

Analytical studies were done on the trawl gear used for fish stock assessment in Lake Victoria, Kenya. The aim was to acquire knowledge on the trawl operations, analyse the gear components and evaluate general gear performance. Plans for bottom and pelagic nets were studied, analysed and re-drawn. Theoretical formulae and formulae derived from more reliable full-scale experiments where used to determine the resistance of gear and gear components in relation to vessel towing power, and vertical and horizontal trawl openings. The study revealed that trawls can be towed at the desired speed range 3-4 knots for the bottom trawl and 2-3 knots for the pelagic trawl. The study will help users to evaluate gear performance and to estimate vertical trawl openings of the sampling trawls.

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1 INTRODUCTION

1.1 Kenya Fisheries and trawl surveys in Lake Victoria

Kenya’s fisheries sub-sector contributes to the National economy through employment creation, foreign exchange earnings, poverty reduction and food security support. The sub-sector contributes 0.5% annually to GDP (Kenya National Bureau of Statistics, 2012). The sub-sector’s growth was estimated at 4.1% in 2005 (Planning Ministry, 2006). The sector employs about 62,000 people directly as fishermen and 67,400 as fish farmers. It supports about 1.1 million people directly and indirectly,working as fishers, traders, processors, supplies and merchants of fishing accessories (Ministry of Agriculture, Livestock & Fisheries, 2013).

In 2012 a total of 160,000 tons of fish valued at US$ 210 million were produced in the country from inland aquaculture and capture fisheries (Ministry of Agriculture, Livestock & Fisheries, 2013). Inland capture fisheries contributes 80% of Kenya’s total fish production, with the principal fishery being that of Lake Victoria. The lake accounted for 119,000 metric tonnes or 77% of the country’s total annual fish production in 2012 (Ministry of Agriculture, Livestock & Fisheries, 2013).

Commercial fish stock of Lake Victoria are routinely evaluated through fishery dependent (Catch assessment and Frame surveys) and independent observations (hydro-acoustic, bottom trawl and gillnet surveys) conducted at different periods (LVFO, 2012)

1.1.1 History of Trawling in Lake Victoria

The history of trawling is well documented (Mbuga.,et.al, 1998). The first trawl fishing on Lake Victoria was done by Graham in 1928 using a small beam trawl with main objective of evaluating trawl catch characteristics. In his findings, he recommended that commercial trawl fishing should not be permitted in the lake (Graham, 1929). Due to potential large catches of Haplochromine species, it was proposed that 200 trawlers be established to catch them to be used for manure in agricultural farms (Graham, 1929). These experimental trawl surveys were localized and not lake wide. In order to confirm findings and for the management considerations, lake wide coverage of trawl operations became necessary. In 1971, the United Nations Development Programme (UNDP) and the Lake Victoria Fisheries Research Project (LVFRP) embarked on an exploratory trawl survey covering the entire lake (Kudhongania & Cordone, 1974). From the lake-wide exploratory trawling of 1969-1971 it was observed that pelagic catches were small at only 12kg/hour, mainly consisting of Haplochromis species and that demersal trawling was more economically viable than pelagic trawling due to the fact that most fish species in Lake Victoria were more demersal (Kudhongania & Cordone, 1974). These results indicated that an ichthyomas of 700,000 tons, of which 80% was made up of haplochromine species assemblage, could be trawled. Other observations made during the lake-wide trawl surveys indicated that demersal and pelagic catches are complementary with some species moving off while others move to the bottom during the day but reverse the direction during the night.
Commercial trawling in the Kenyan waters of Lake Victoria was introduced in 1968 to harvest tilapine species for a fish processing plant in Kisumu. As the Nile perch fishing became increasingly prominent, and as the market opened up locally and internationally, the number of trawlers increased to 50 in the three countries sharing the lake. Trawling became a dominant fishing method until the early 1990s when it was banned by the Kenya Government due to its destructive nature to the environment and conflict with artisanal fishermen. Since the UNDP/LVFRP lake-wide survey, bottom trawl surveys are being are been conducted by the fisheries departments and research institutes of the riparian countries. The trawl surveys by these institutions have been restricted to their respective national water. They

have been undertaken with irregular frequency, and have been carried out for various individual needs of the institutions.
Bottom trawl surveys are being conducted annually in Lake Victoria by the Kenya Marine Research Institute. The surveys provide information on the abundance, distribution and biological characteristics of fisheries resources. During hydro-acoustic and bottom trawl surveys, the bottom and midwater (pelagic) is used to sample the benthic and pelagic fish stocks (LVFO, The Standard Operating Procedures for Catch Assessment Surveys , 2005). In 2010, the Kenya Marine and Fisheries Research Institute (KMFRI) acquired R.V Uvumbuzi a 250 Hp, 18 m stern trawler equipped with bottom and pelagic trawl nets. At present the vessel is being used for bottom trawl surveys only. This is because lack of technical knowledge to operate the pelagic trawl at the institute. For optimal performance, it might be necessary to readjust the rigging on the gear to match the vessel towing power. Bottom trawls in Lake Victoria are restricted from operating in areas with irregular bathymetry rocky and muddy substrates which might be habitants for many species. The main target fish species whose standing stocks are assessed using bottom trawl nets are Nile perch (*Lates niloticus*), Nile tilapia Victoria (*Oreochromis niloticus)* and Haplochromine cichlids. Pelagic species like the Dagaa (*Rastrineobola argentea*) are not accounted for by the bottom trawls survey and also the Nile perch which tend to occupy the vertical water column depending with age and size due to patterns of vertical migration. For adequate sampling there is a need to incorporate the pelagic trawls net in the stock assessment surveys which will overcome the aforementioned challenges of the bottom trawl (LVFO, The Standard Operating Procedures for Catch Assessment Surveys , 2005).

1.2 Justification and objectives.

Knowledge on the abundance of fish stocks in the Kenyan part of Lake Victoria is obtained primarily by analysing commercial catch data and from research vessel surveys. At present operational guidelines for the bottom and mid-water gear on the research vessel provided in the Standard Operating Procedures (SOP) are inadequate. Analysis and documentation of normal performance parameters (net width, door spread, and net height and rigging) could reduce trial and error experiments. The pelagic trawl could be incorporated into the trawl surveys, and more information on pelagic species and vertical migration could be available for the lake.

The study was designed to evaluate the current status of bottom and mid-water trawl gear and the vessel used for stock assessment in the Kenyan waters of Lake Victoria by analysing the following:

- Drawings of the current bottom and midwater sampling trawls used in Lake Victoria.
- Rigging of the trawl.
- Towing force and gear resistance.
- Vertical and horizontal opening of trawl mouth.

2 MATERIAL AND METHODS

2.1 Study area

This study focuses on research trawling operations in Lake Victoria (Figure 1). The lake occupies a wide depression near the equator between the Western and Eastern Rift Valleys. It has a maximum depth of 84 m and an average depth of 40 m. Its catchment area covers 184,000 km^2 and has a shoreline of 4,828 km with many islands. Many fishing villages are found on these islands and along the shores of the lake. The fishers mostly use gillnets, hooks and beach seines. There are over 25 fish export processing factories around the lake that have increased the demand for fish.

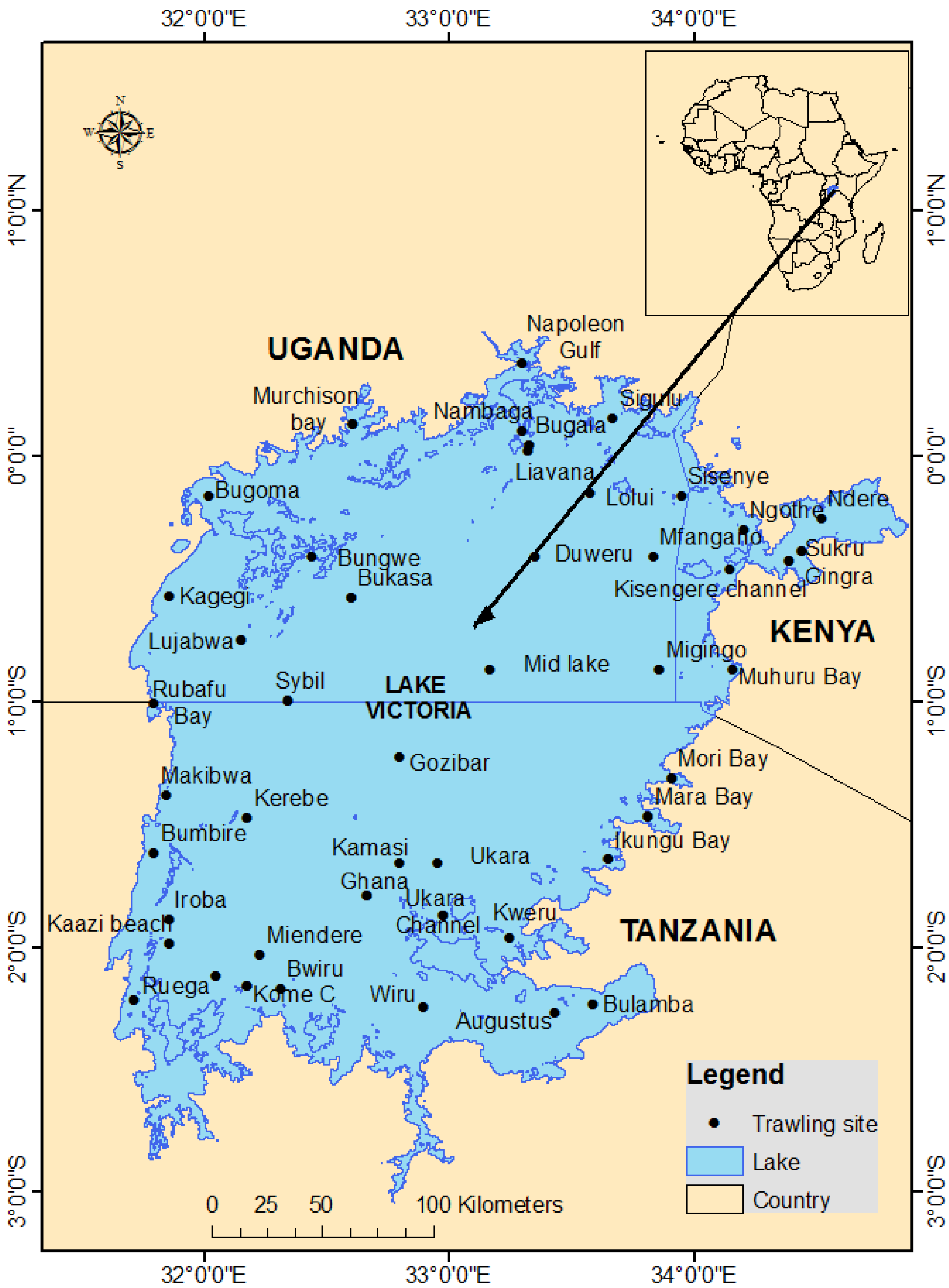


Figure 1. Map of Lake Victoria riparian countries and main trawling sites (LVFO, 2009)

2.2 Vessel specifications

The information involving the technical aspects of the current fishing gear was mainly based on reviewing documents and supplemented by specific measurements from the trawl nets (Figures 2 and 3) and research vessel (Table 1), guided by predesigned data collection forms, (Table 2 and Table 3). Calculations based on formulae by (Fridman, 1986) were used to verify cutting ratios, cutting combinations, net area, net resistance and vessel towing power.
Design CAD 3D MAX 23, computer aided drawing software was used for drawing bottom and pelagic trawls.

2.2.1 Specification of RV Uvumbuzi

Specification of the Research Vessel RV, Uvumbuzi used in Lake Victoria is shown in Table 1 below.

Table 1. RV Uvumbuzi Specification

Research Vessel ;RV Uvumbuzi	
Length overall	18.00 m
Length between perpendiculars	16.10 m
Beam width	5.20 m
Draft/depth	2.00 m
Displacement	58.000 kg
Engine Horsepower	250 hp
Endurance	15 days
Navigation equipment radar marine GPS	auto pilot,
Communication equipment	VHF radio
Fish finding equipment sounder	echo
Personnel 6 crew	6 scientists,

2.2.2 Bottom trawl net provided by the net manufacturer and Predesign gear specification form

The plan of the bottom trawl net from the manufacturer is shown in Figure 2.

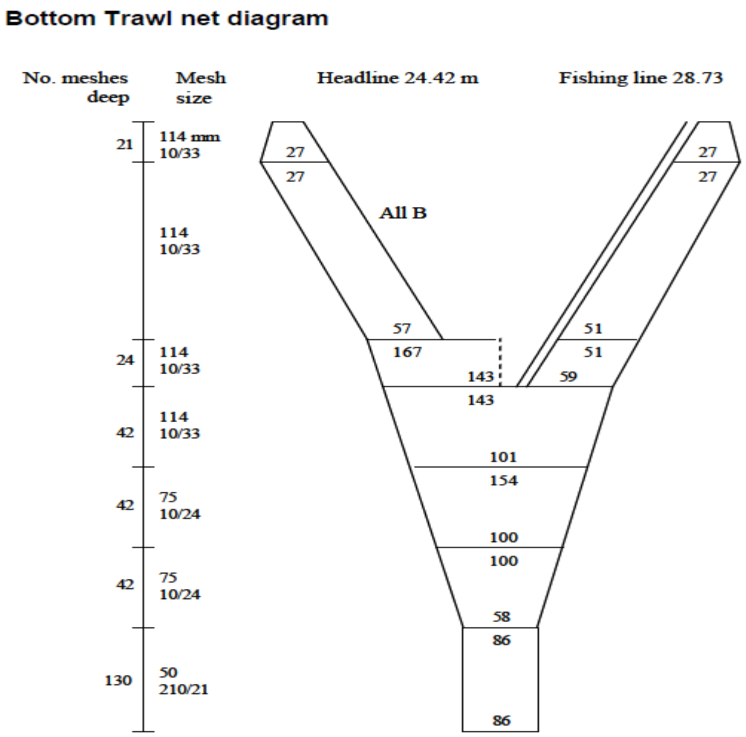


Figure 2. Existing trawl bottom net provided to vessel by the net manufacturer

The predesign gear specification form for bottom trawl net shown in Table 2.

Table 2. Predesigned gear specification form for bottom trawl

Sections	Panels	Upper net section	Lower net section	Meshes in depth	Meshes in size	Twine diameter (mm)	Stretched Length (m)
Top wing tip	2	6	27	21	114	1.13	
Top wing	2	27	57	75	114	1.13	
Square	1	167	143	24	114	1.13	
Lower wing tip	2	6	27	21	114	1.13	
Lower wing	2	27	51	75	114	1.13	
Bunt	2	51	59	24	114	1.13	
Top belly 1	2	143	101	42	114	1.13	
Top belly 2	2	154	100	42	75	0.8	
Top belly 3	2	100	58	42	75	0.85	
Cod end	2	86	86	130	50	0.8	
Ropes and Lines							
Warp						12	360
Head rope						12	12.2
Foot rope						12	12.2
sweep line & bridles						12	116
				Numbers	Area	Shape	Material
Floats				21	0.13	Spherical	Plastic
Otter boards				1 Pair	3.38	V-Shaped	Steel

2.2.3 Existing pelagic trawl net provided by manufacturer Predesign gear specification form

The plan of the pelagic trawl net provided by the manufacturer is shown in Figure 3.

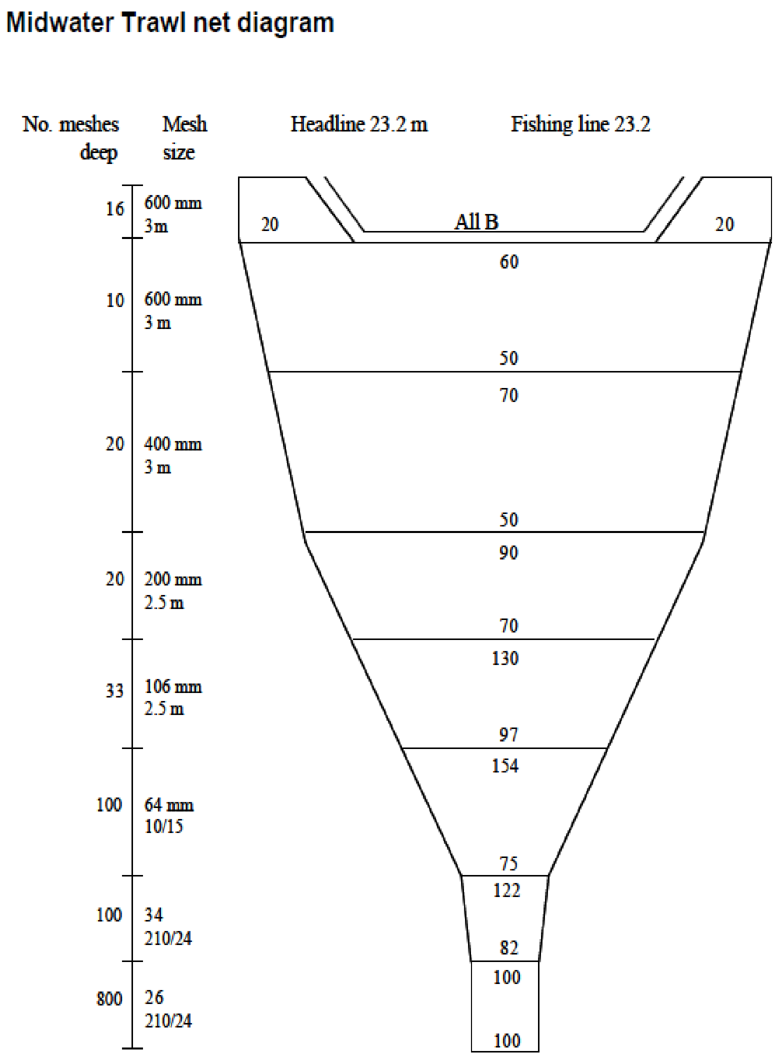


Figure 3. Existing pelagic trawl net provided to vessel by the net manufacturer

Table 3. Predesigned gear specification form pelagic trawl

Sections	Panels	Upper net section	Lower net section	Meshes in depth	Meshes in size	Twine diameter (mm)	Stretch length (m)
Wings	8	4	16	600	600	3	
Belly 1	4	60	10	600	600	3	
Belly 2	4	70	20	400	400	3	
Belly 3	4	90	20	200	200	2.5	
Belly 4	4	130	33	100	100	2.5	
Belly 5	4	154	100	60	60	0.65	
Belly 6	4	122	100	34	34	0.85	
Cod end	4	100	800	26	26	0.85	
Ropes and Lines							
Warp							250
Head rope *							46.4
sweep line & bridles							200
Floats				Numbers	S,area	Shape	Material
				40Φ;4 pcs	0.5 m^2	Spherical	Plastic
				50Φ;4 pcs	0.79 m^2	Spherical	Plastic
Otter boards				1 Pair	3.6 m^2	Superkrup	Steel

2.3 Calculations

2.3.1 Available towing power of vessel

Fridman (1986) prescribed the following formula for calculating the available towing force as:

Ft = P x (KF-0.7 x V) (eq 1)

Where,
Ft: towing pull in kgf
P: engine brake horsepower
V: towing speed in Knots

K_F is an empirical coefficient, this coefficient and ranges from 10 to 20 depending upon the type of propeller and the presence of propeller nozzle. In this work the value of 15 for K_F is used.

2.3.2 The cutting ratios

Tapering the different panels of both bottom and pelagic was determined using the formula

$\mathrm{R} = \mathrm{MT}/\mathrm{MN}$ (eq. 2)

Where:
R ; is the cutting ratio (taper ratio)
MT; is the total number of twine in meshes lost/gained
MN ; is the total number of nominal meshes in the section

2.3.3 Cutting combination

Cutting combination is a regular, repeated cycle of B-cuts and N- cuts or B- cuts and T- cuts of meshes to be cut in the netting to produce the required shape of a net web piece. Cutting combination is calculated as follow;

$\mathrm{Y} = (\mathrm{M} - \mathrm{m})/2\mathrm{m}$ (eq. 3)

Where:
M = the higher number of meshes (Ns or Ts) to be cut.
m = the lower number

2.3.4 Projected twine surface area

$A= ((N +n)/2))*H*4*a*d*10^{-6}$ (Fridman, 1986) (eq. 4)

Where,
A: twine area (m2)
N: number of meshes across the top of panel
n: number of meshes across the bottom of panel
H: number of meshes across the depth or height of the panel
4: number of bars in one mesh

a: bar length (mm)
d: diameter of twine

2.3.5 Calculation of the opening of the net

The following formulas were used to calculate the vertical mouth opening of the gear H:

$H = 0.16 \times \alpha \times V^{-0.87}$ (Koyama.,et.al, 2008) (eq. 5)

Where,

α: Maximum circumference of the widest part of the belly (m)
V: Towing velocity (m/sec)

Also:
$VO = n \times \alpha \times 0.25$ (Prado 1990) (eq. 6)

Approximate vertical opening of net mouth (m) *n*: width in number of meshes of front edge of belly
α: mesh size (m)

For horizontal mouth opening of the net S the following formula is used;
$S = HR \times 0.5(to)0.6$ (Prado 1990) (eq. 7)

Where,
S: Approximate horizontal spread between ends of wings (m)
HR: Length of head rope (m)

Approximate door spread of the design is illustrated in Figure 4.

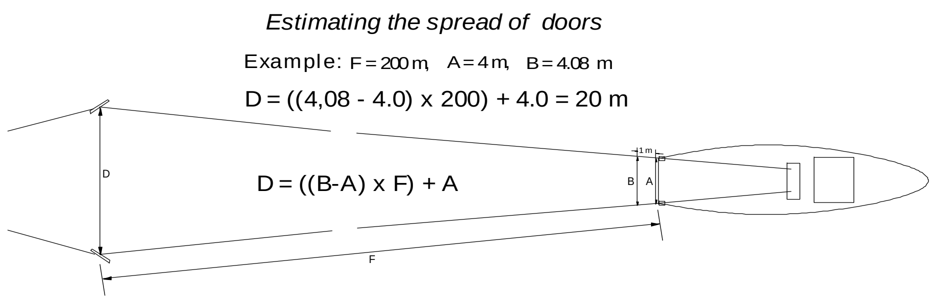


Figure 4. Approximating the door spread

2.3.6 Calculation of net drag

R^1= Cx* q * A (Fridman, 1986) (eq. 8)

Where:
R^1= is the total netting resistance
q= (ρv^2)/2 the hydrodynamic stagnation pressure
where
ρ is the density of seawater and

V is the towing speed in m/sec.
A= Projected twine surface area of the netting in the gear.

Cx= empirical coefficient depending on the netting angle of incident (Derived from Figure 3.6. page 55 in Fridman 1986)

2.3.7 Method for estimating the angle of incident for the net cone

The circumference is calculated using the no. of meshes at each end of the belly times the mesh size multiplied by the selected primary hanging coefficient E1. Lc is found by using the no. of meshes in the panels length times the mesh size multiplied by the secondary hanging coefficient E2. In this study primary hanging coefficient $E_1 = 0.5$ was used and consequently $E_2 = 0.86$. Figure 5 below illustrates the angle of incident for a netting cone.

$\tan \alpha = (D2 – D1) / (2xLc)$

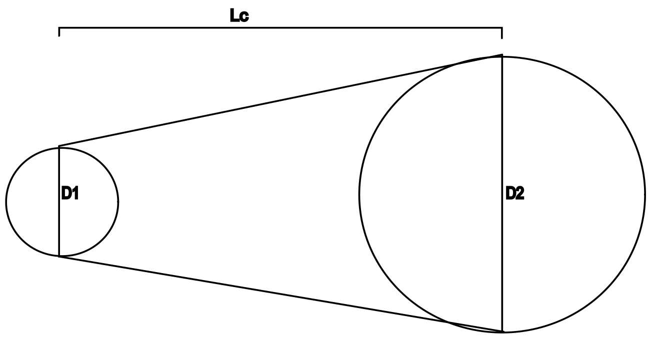


Figure 5. Angle of incident for a netting Cone

2.3.8 The drag of otter boards

Is calculated by the Fridman (1986) formula:

$$R_O = C_X \times q \times A \qquad \text{(eq. 9)}$$

Where
R_O: Otter board drag
C_X: Angle of attack
A: Area of the otter board

q: Hydrodynamic stagnation pressure which is calculated by formula
$q = (p \times V^{2}) \div 2$
P: water density
V: velocity

2.3.9 Calculation of the drag of floats.

The basic hydrodynamic formula was used for estimating the drag due to floats or

$$R_f = N \times C_X \times A \quad \text{(Fridman 1986).} \qquad \text{(eq. 10)}$$

Where:

R_f: resistance due to floats and sinkers (kgf)
N: Number of floats (and sinkers)
q: hydrodynamic stagnation pressure (kgf/m2) =$pV^2/2$

A: area of the sphere (m^2)
C_x: drag coefficient

2.3.10 Drag induced by lines and ropes.

Calculation of the drag of ropes and lines i.e., head line, foot rope, sweep line and bridals was made according to the formula given by Fridman (1986). The *Cx* value and length and diameter will change according to the lines and ropes and their angles.

The sweep line angle of incidence is important for determining individual warp drag coefficient.

It was assumed that:
(i) The distance between the trawl doors is approximately the same as sweep line length
(ii) The distance between the wing ends is half the length of the headline.

The sweep line and headline were then drawn to scale (Figure 6) using 3DMAX CAD program, and angle of incidence λ (RST) is determined.

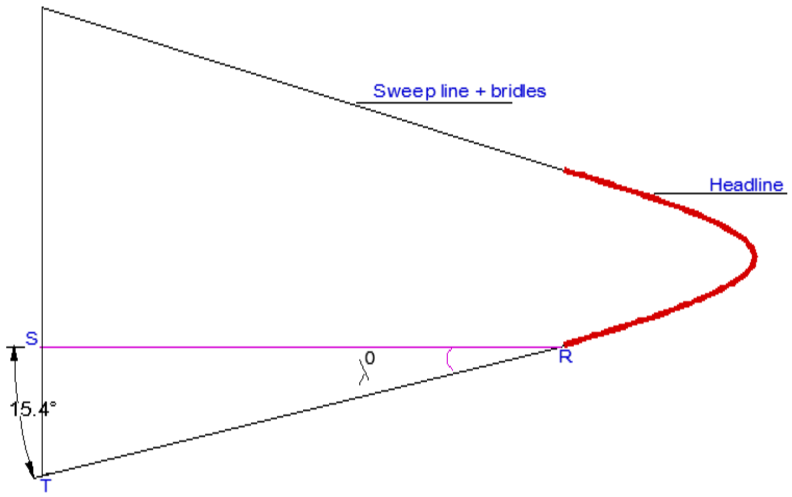


Figure 6. Determination of angle of incidence for sweeplines

$$R_X = C_X \times L \times D \times q \qquad \text{(eq. 11)}$$

Where,
L: length of rope (m)
D: diameter of rope (m)
C_x: drag coefficient (Fridman 1986 page no. 64 and 65)
q: hydrodynamic stagnation pressure (kgf/m^2) = $pV^2/2$

2.3.11 Other formulae that were used to calculate and verify the drag resistance

According to Zhou *et al.* (1982) the total drag of the netting in two panel demersal trawls can be predicted using the following formula**:**

$$D = R\ 24.9V^2 / (1 + 0.0516V) \qquad \text{(eq. 12)}$$

Where:

D= Total Netting resistance

R= Total twine area

V= towing speed in knots

Reid (1977) defines a relationship between net drag, net speed and net twine area which is independent of parameters derived from the net geometry using the following equation for four panel pelagic trawls

$$D = (V^2 \times R) \div (54.72 \times 115.2) \qquad \text{(eq. 13)}$$

Where,
D: Drag in tonnes
R: Total twine area (m^2)
V: Speed in knots

3 RESULTS

3.1 New Net drawings

3.1.1 Bottom trawl net re-drawn in scale

The re-drawn bottom trawl net is shown in Figure 7. The plan shows both the upper and lower panels drawn side by side. The cutting combinations, mesh sizes and number, and material the trawl net is made of in each panel are included. In addition, it gives the details of the framing ropes.

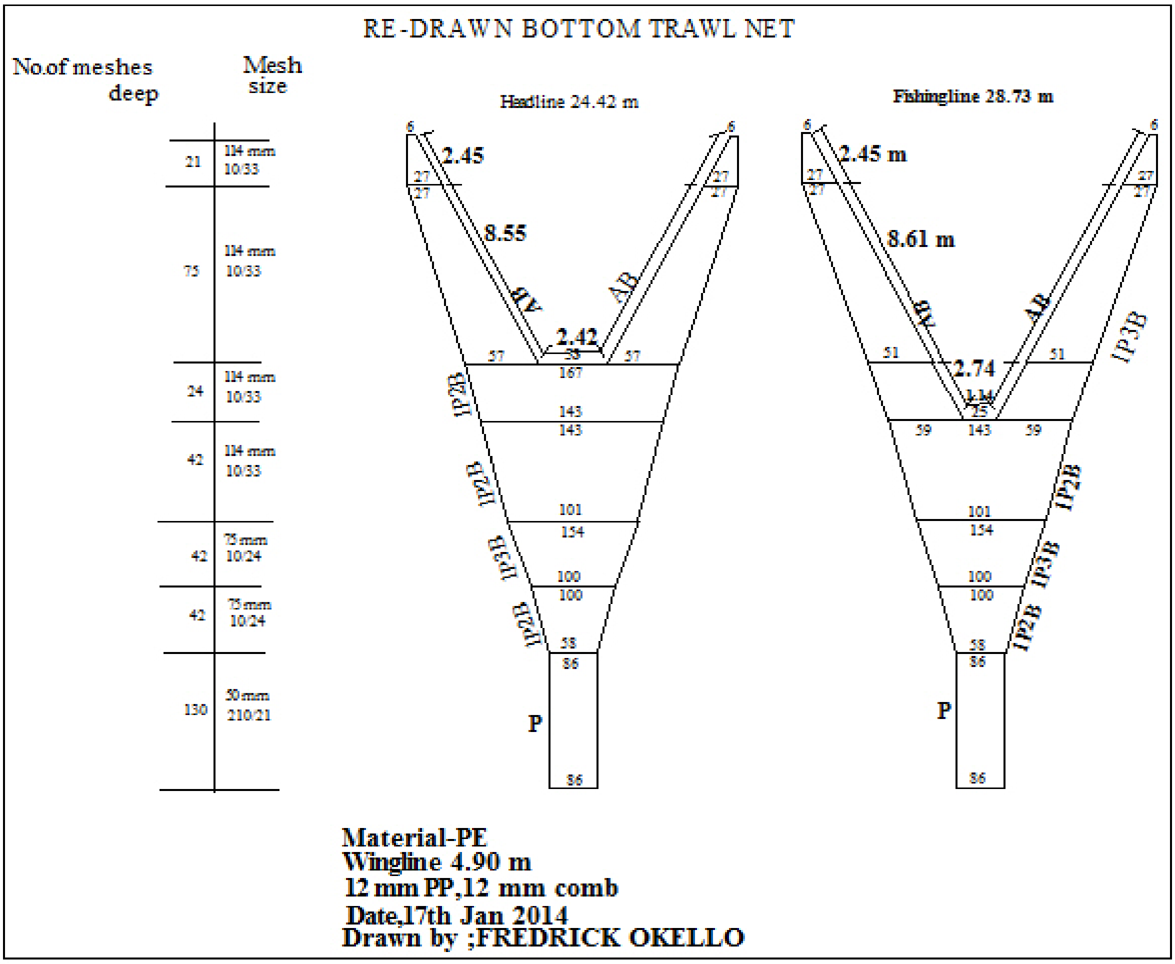


Figure 7. Bottom trawl re-drawn to scale

3.1.2 Rigging arrangement for the bottom trawl gear and drawing in 3 dimensions

All the gear components and the rigging arrangement were re-drawn to scale as shown in Figures 8 and 9 and the general structure of the trawl net is drawn in 3 D as shown in Figure 10.

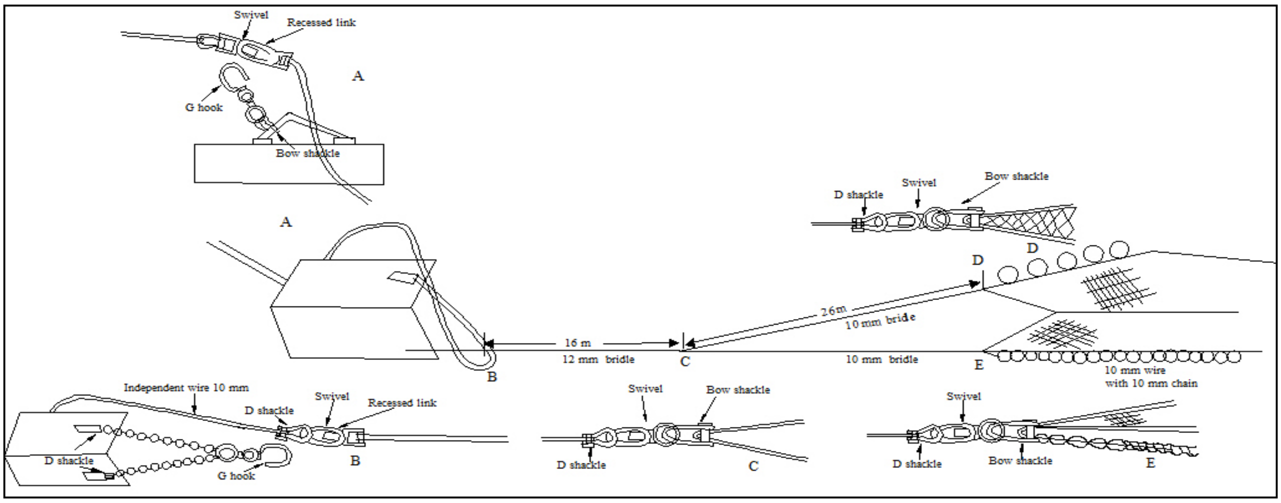


Figure 8. Rigging plan for bottom trawl gear

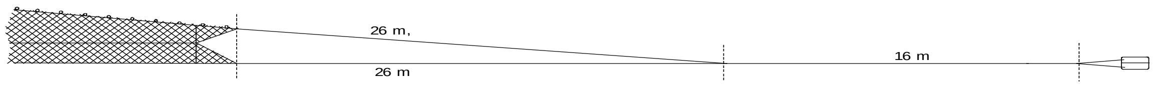


Figure 9. Rigging plan for bottom trawl drawn to scale

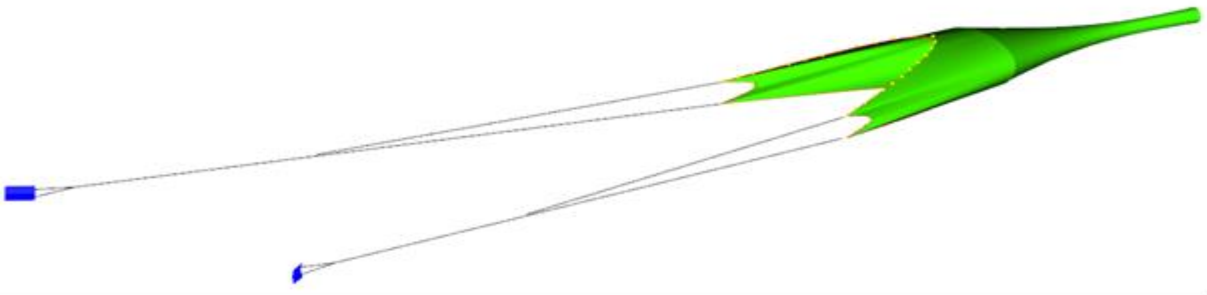


Figure 10. 3D Illustration (in scale) of the bottom trawl and rigging

3.1.3 Pelagic trawl net re-drawn in scale.

The re-drawn pelagic trawl net is shown in Figure 11. It is re-drawn to scale and represents the actual net. Each panel is clearly marked, and the twin diameter from the wing tip to cod end are accurately shown.

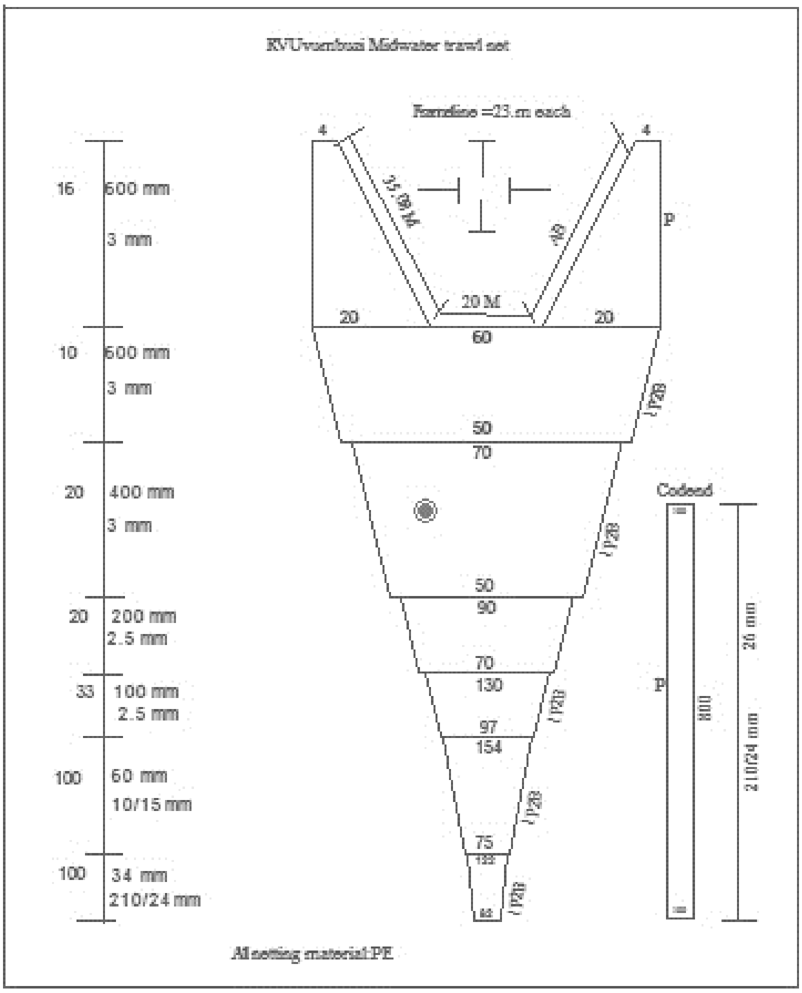


Figure 11. Uvumbuzi pelagic trawl net re-drawn to scale

3.1.4 Rigging arrangement for the pelagic trawl gear and drawing in 3 dimensions

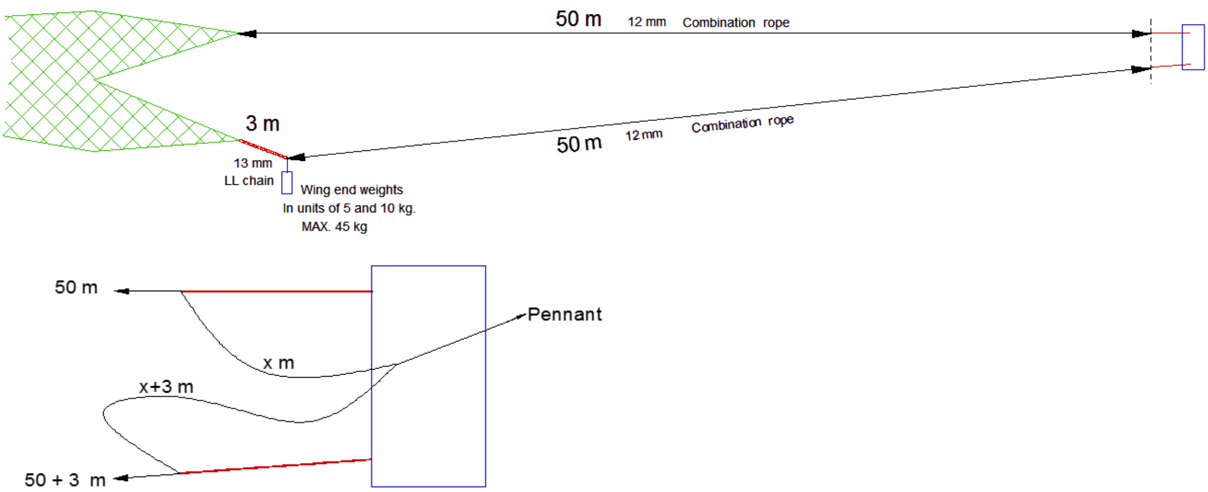


Figure 12. Rigging plan for pelagic trawl drawn to scale

The rigging plan for the pelagic trawl gear and the attachment of the otter board was calculated and re-drawn to scale as shown in Figure 12. The general structure of the trawl net drawn in 3 D is shown in Figure 13.

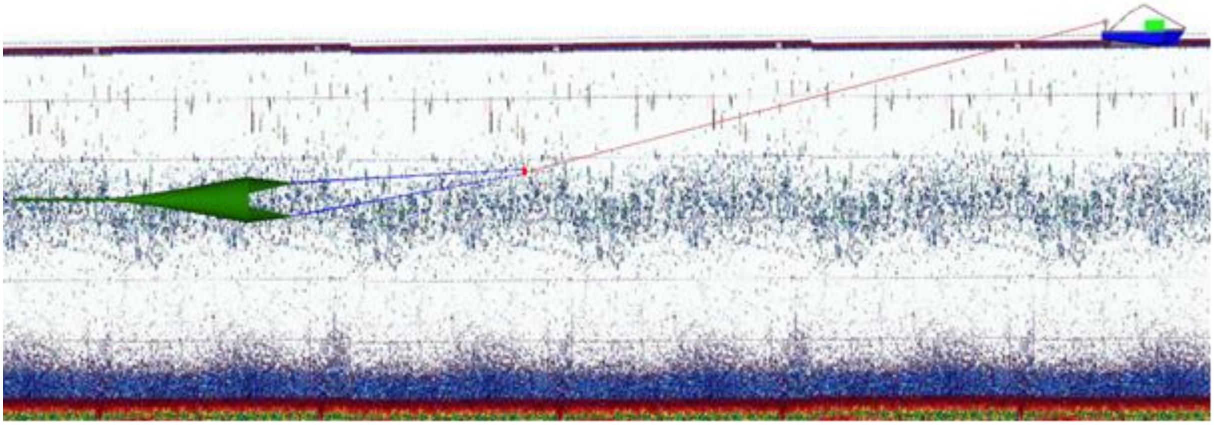


Figure 13. Illustration (not scale) of the pelagic trawl position in water column as shown by sonar

3.2 Net twines surface area.

3.2.1 Twine surface area for bottom trawl net

The twine surface area both for bottom and pelagic trawl nets were calculated using formula 3.4 Fridman (1986) for each section of the net and then summed up. The netting area of the bottom trawl net is given in Table 4.

Table 4. Twine surface area for bottom trawl net

SECTIONS	PANELS	UPPER (M)	LOWER (n)	M+n/2	M. DEP (H)	MESHES SIZE	B.LENGTH (a)	TWINE Ø	AREA	k	AREA (m^2)
TOP WING TIPS	2	6	27	16.5	21	114	57	1.13	0.18	1.1	0.20
TOP WING	2	27	57	42	75	114	57	1.13	1.62	1.1	1.79
SQUARE	1	167	143	155	24	114	57	1.13	0.96	1.1	1.05
LOWER W. TIPS	2	6	27	16.5	21	114	57	1.13	0.18	1.1	0.20
LOWER WING	2	27	51	39	75	114	57	1.13	1.51	1.1	1.66
BUNT	2	51	59	55	24	114	57	1.13	0.68	1.1	0.75
Top belly 1	2	143	101	122	42	114	57	1.13	2.64	1.1	2.90
Top belly 2	2	154	100	127	42	75	37.5	0.85	1.36	1.1	1.50
Top belly 3	2	100	58	79	42	75	37.5	0.85	0.85	1.1	0.93
COD END	2	86	86	86	130	50	25	0.8	1.79	1.1	1.97
								AREA	11.76		12.94

3.2.2 Twine surface area for pelagic trawl net

The calculated twine surface area for the pelagic trawl net is given in Table 5.

Table 5. Twine surface area for pelagic trawl net

SECTIONS	PANELS	UPPER (M)	LOWER (n)	M+n/2	M. DEP (H)	MESHES SIZE	B.LENGTH (a)	TWINE Ø	CONST	TWINE (mm^2)	K/10^6	AREA (m^2)
WINGS	8	4	20	12	16	600	300	3	4	5529600	1.1	6.08
BELLY 1	4	60	50	55	10	600	300	3	4	7920000	1.1	8.71
BELLY 2	4	70	50	60	20	400	200	3	4	11520000	1.1	12.67
BELLY 3	4	90	70	80	20	200	100	2.5	4	6400000	1.1	7.04
BELLY 4	4	130	97	113.5	33	100	50	2.5	4	7491000	1.1	8.24
BELLY 5	4	154	75	114.5	100	60	30	0.65	4	3572400	1.1	3.93
BELLY 6	4	122	82	102	100	34	17	0.85	4	2358240	1.1	2.59
COD END	4	100	100	100	800	26	13	0.85	4	14144000	1.1	15.56
									AREA	58935240		64.83

3.3 Gear resistance and vessel towing force

Both the bottom and mid-water trawl gear resistance was computed by determining the resistance of various gear components such as netting panels, lines and ropes (i.e. warp, sweep lines, head rope, footrope and side ropes), floats, sinkers and otter boards. The towing pull for the vessel MRV Uvumbuzi was calculated using formula 3.1 Fridman (1986).

3.3.1 Towing resistance: Bottom trawl components and total drag

The values of the resistance of individual gear component for the bottom trawl and their combined resistance is plotted in Figure 14.The vessel towing power is also computed against the vessel towing speed. The calculated maximum towing speed lies around 4.4 knots.

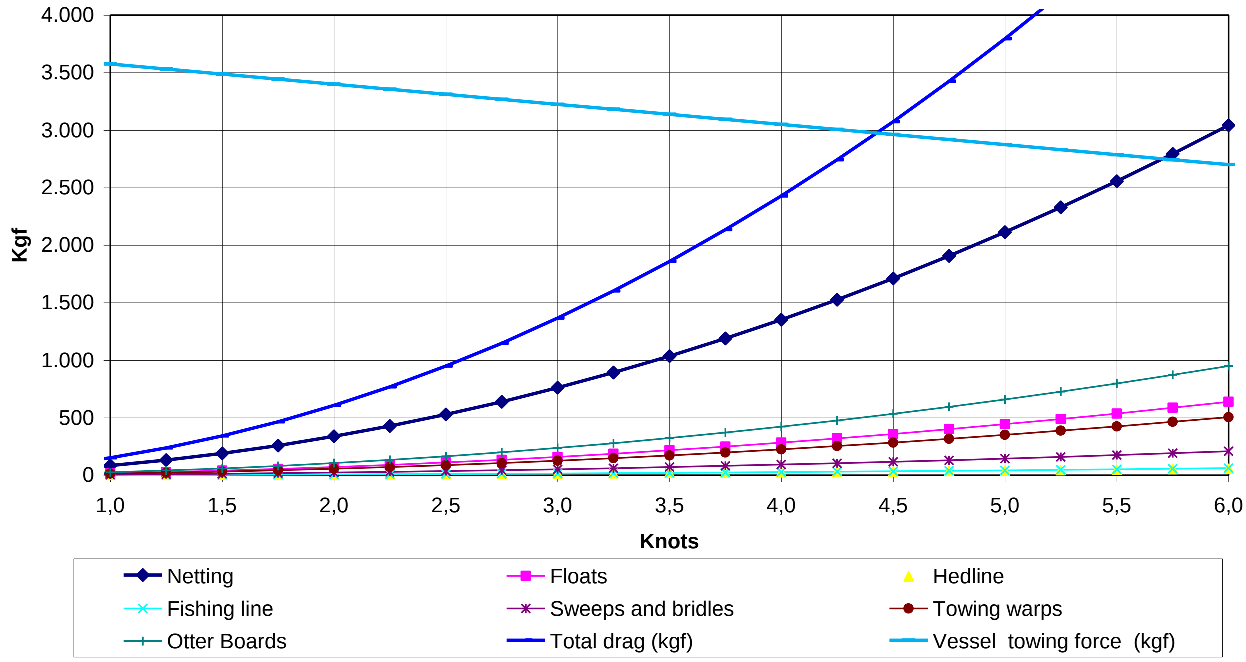


Figure 14. Gear resistance and vessel towing force against towing speed for the bottom trawl gear

3.3.2 Towing resistance: Pelagic trawl components and total drag

The values of the resistance of individual gear component for the pelagic trawl and their combined resistance is plotted in the graph shown in Figure 15.The vessel towing power is also computed against the vessel towing speed. The calculated maximum towing speed is around 2.9 knots.

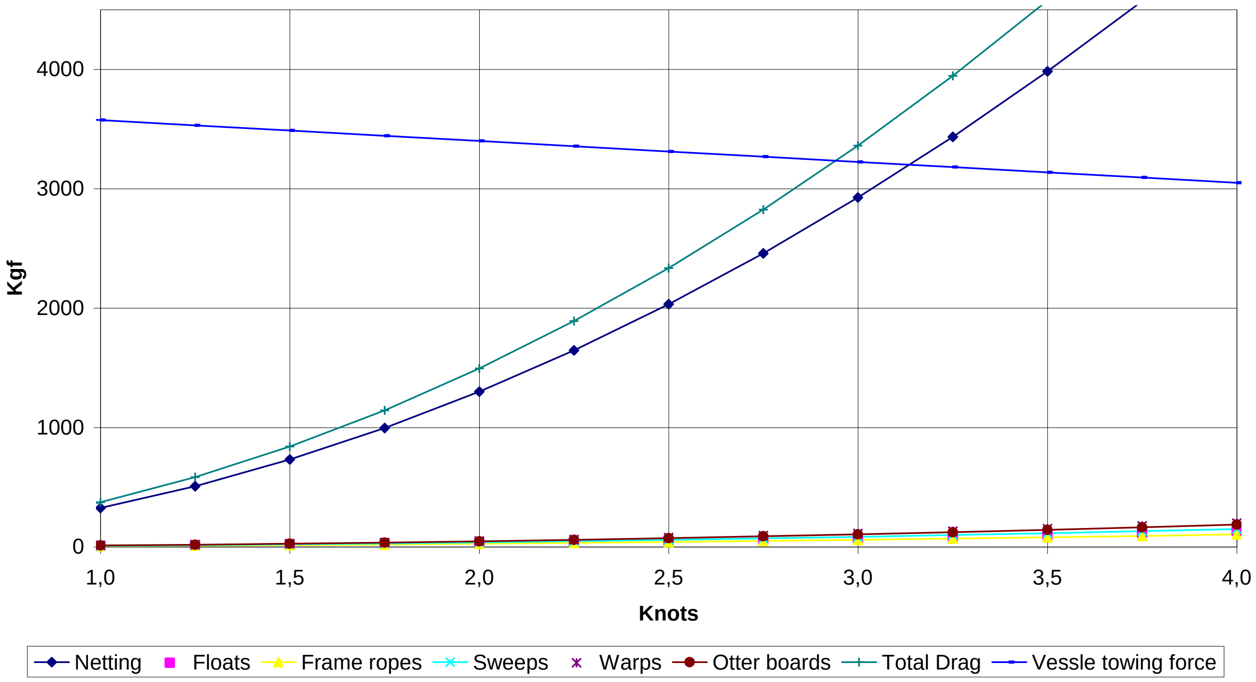


Figure 15. Gear resistance and vessel towing force against towing speed for the pelagic trawl gear

3.4 Fridman Zhou and Reid formulae for comparing resistance

The three formulae were applied to see the variations in the calculated netting drag. Fridman (1986) showed the generalised relationship between the drag of a panel of netting and its angle of incidence to the flow. The Zhou formula is based on engineering trials for two panel bottom trawls and the Reid (1977) formula expresses the relationship between net drag, net speed and net twine area which are independent of parameters derived from the net geometry for pelagic trawls.

3.4.1 Fridman and Zhou for calculation of resistance of bottom trawl net.

Fridman (1986) and Zhou *et al*. (1982) formulae were applied to calculate the resistance of bottom trawl net (Figure 16).

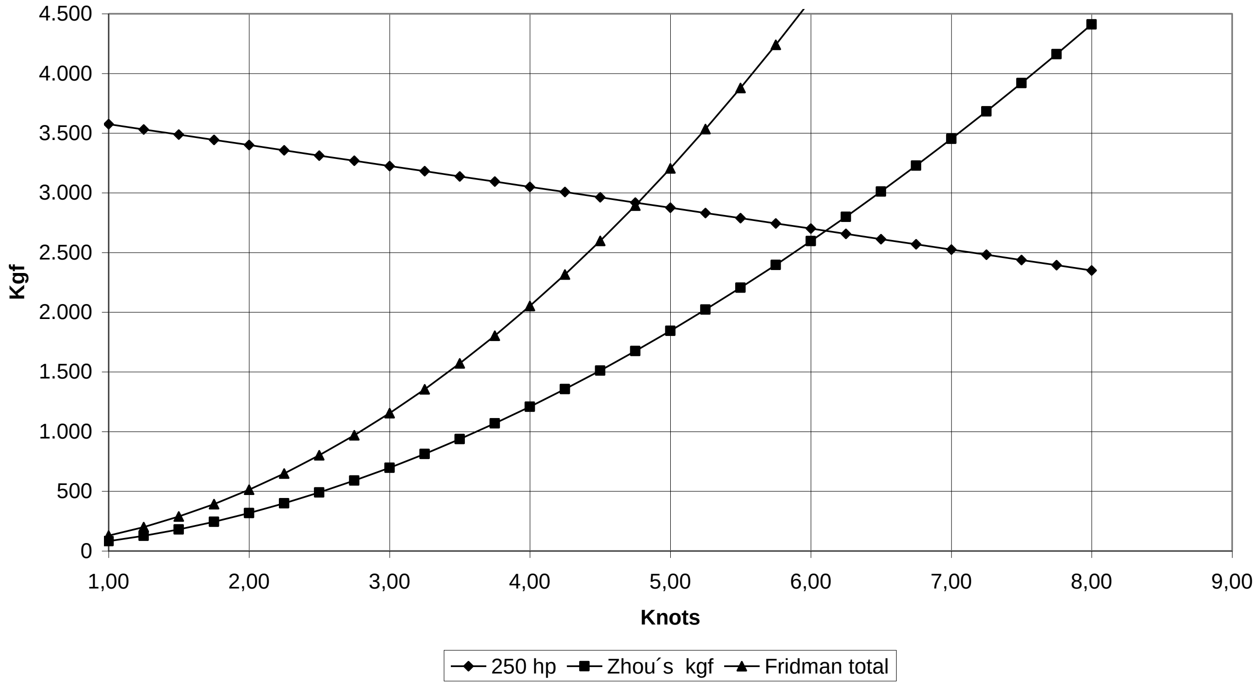


Figure 16. Computing drag for bottom trawl using Fridman and Zhou formulae

3.4.2 Fridman and Reid formulae for calculation of resistance of pelagic trawl net

Fridman (1986) and Reid (1977) formula were applied to calculate the resistance of pelagic trawl net (Figure 17).

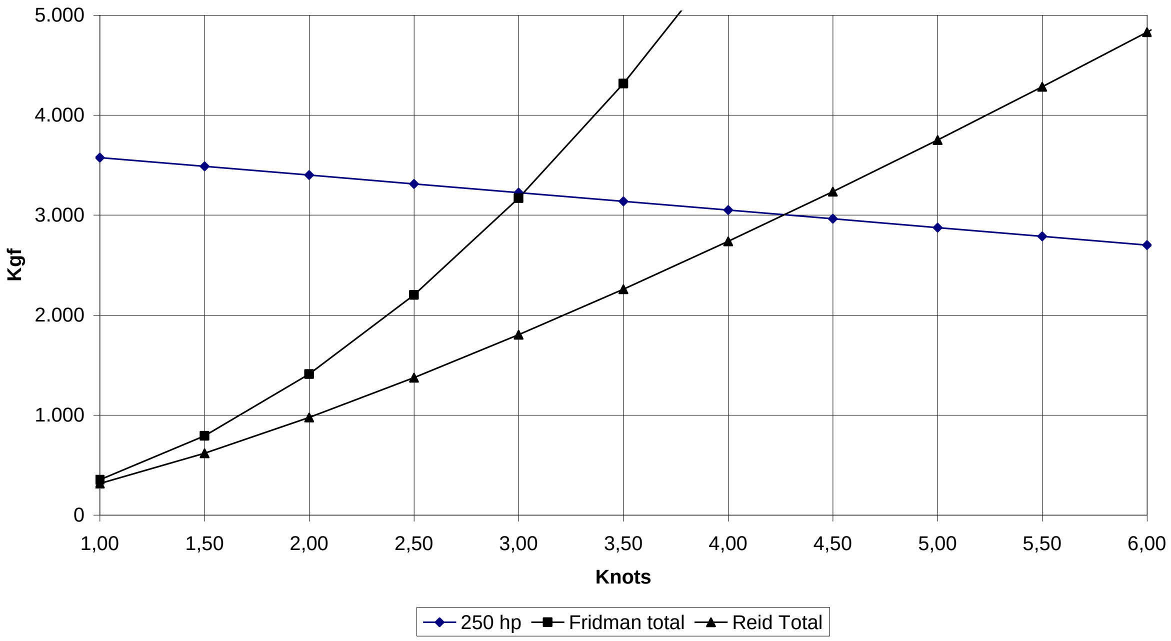


Figure 17. Computing drag for pelagic trawl using Fridman and Reid formulae

3.5 Vertical mouth opening of the net

The Koyama *et al.* (2008) formula was used to calculate vertical opening (formula 3.5). Vertical mouth opening of the net is important, since it determine the amount of water filtered in the fishing operation.

3.5.1 Vertical mouth opening in relation to hanging ratio for bottom trawl net

The vertical mouth opening is inversely related to the towing speed as shown in Figure 18. Hanging ratio also directly affects the vertical mouth opening. The figure below show the hanging ratio of 0.5 and how the mouth opening responds to towing speed.

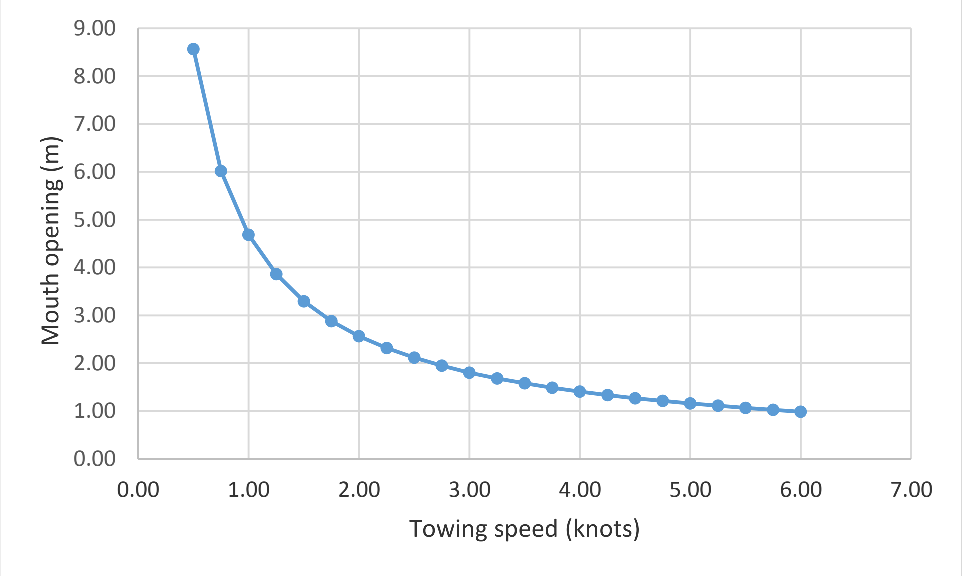


Figure 18. Vertical mouth opening for bottom trawl net at hanging ratio of 0.5

3.5.2 Vertical mouth opening in relation to hanging ratio for pelagic trawl net

Again the vertical mouth opening is inversely proportion to the towing speed as shown in Figure 19) for the pelagic trawl net. Hanging ratio of 0.5 gives the net more opening of 7 m at the towing speed of 3 knots.

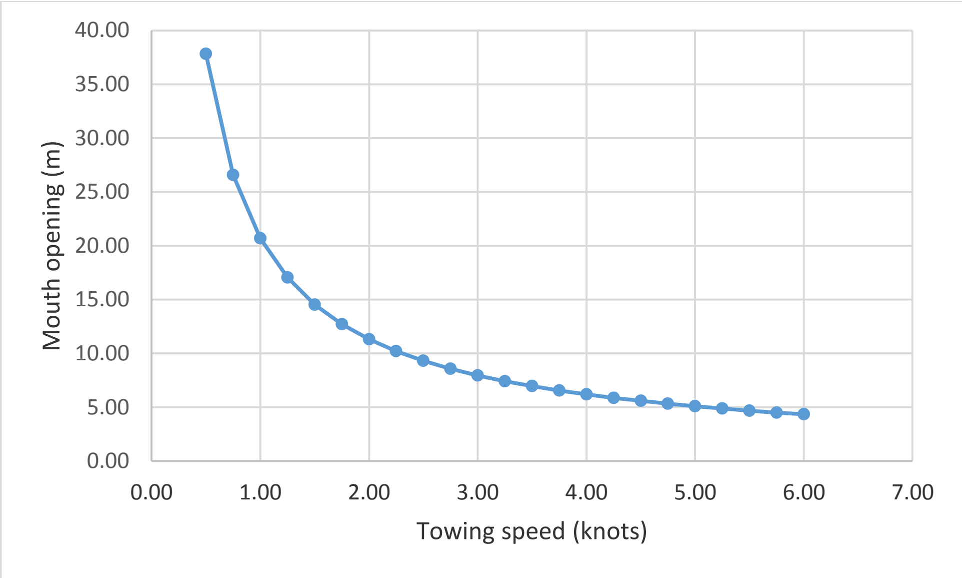


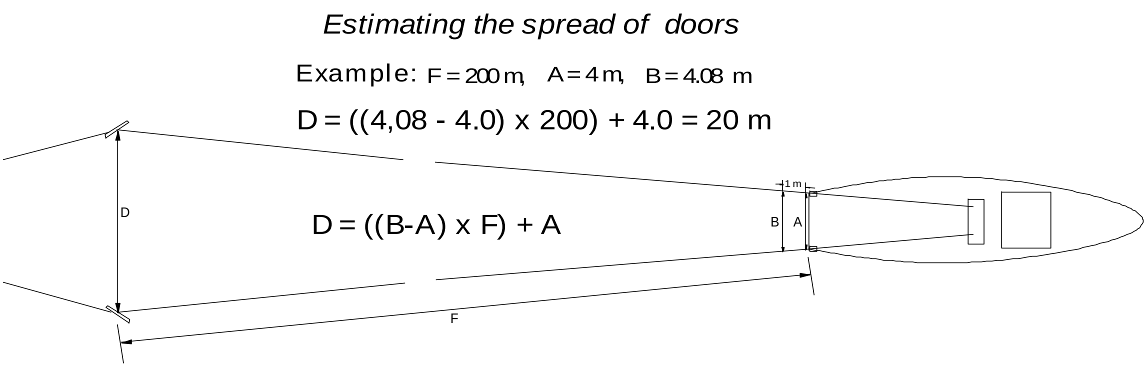
Figure 19. Vertical mouth opening for pelagic trawl net at a hanging ratio of 0.5

3.6 Horizontal mouth opening of the net

The Prado (1990) formula was used to calculate the horizontal mouth opening for the bottom and pelagic gear (Formula 3.7). Horizontal mouth opening of the net is important, since it determine the area sweep by the net.

3.6.1 Horizontal mouth opening for bottom trawl

Using the illustrations from below the spread of the door which is equivalent to horizontal mouth opening was derived.



Where
D: Door opening (m)
F: Length of towing warps
A: Beam width of the vessel
D= (5.28-5.2)*120+5.2
D=14.8 m
To confirm the accuracy we use the formula 3.7 Prado (1990)
S=HR*0.6
S=24.42*0.6

S=14.62

4 DISCUSSION AND CONCLUDING REMARKS.

The plan of the bottom trawl net provided by the manufacturer is shown in Figure 2. It lacks cutting ratio, and cutting combinations, it was not drawn to scale and number of meshes along the wing tip and top wings are missing. Labelling of denier number is wrong from the top wing to cod end hence wrong interpretation of twine diameter. Sections lengths of the framelines is also missing. The top and bottom panels are fused together and makes it difficult for interpretation and the drawings lacks identification
The plan of the pelagic trawl net provided by the manufacturer (Figure 3) was not drawn to scale, lack cutting ratio, and cutting combinations. Labelling of denier number was wrong from the tip wing to belly 6 and identification key was missing.

Calculated values for towing speed are satisfactory but they are higher than the actual speed of the vessel while towing. This calls for experimental trials at the lake by making the adjustment to various gear component to check if the calculated values can be achieved. This study recommends the installation of trawl sonde and gear sensors in trawl net .The sensors will measure trawl depth, door spread, headline height, sea temperature, speed through the water and relative amount of catch in the bag.

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To God be the Glory

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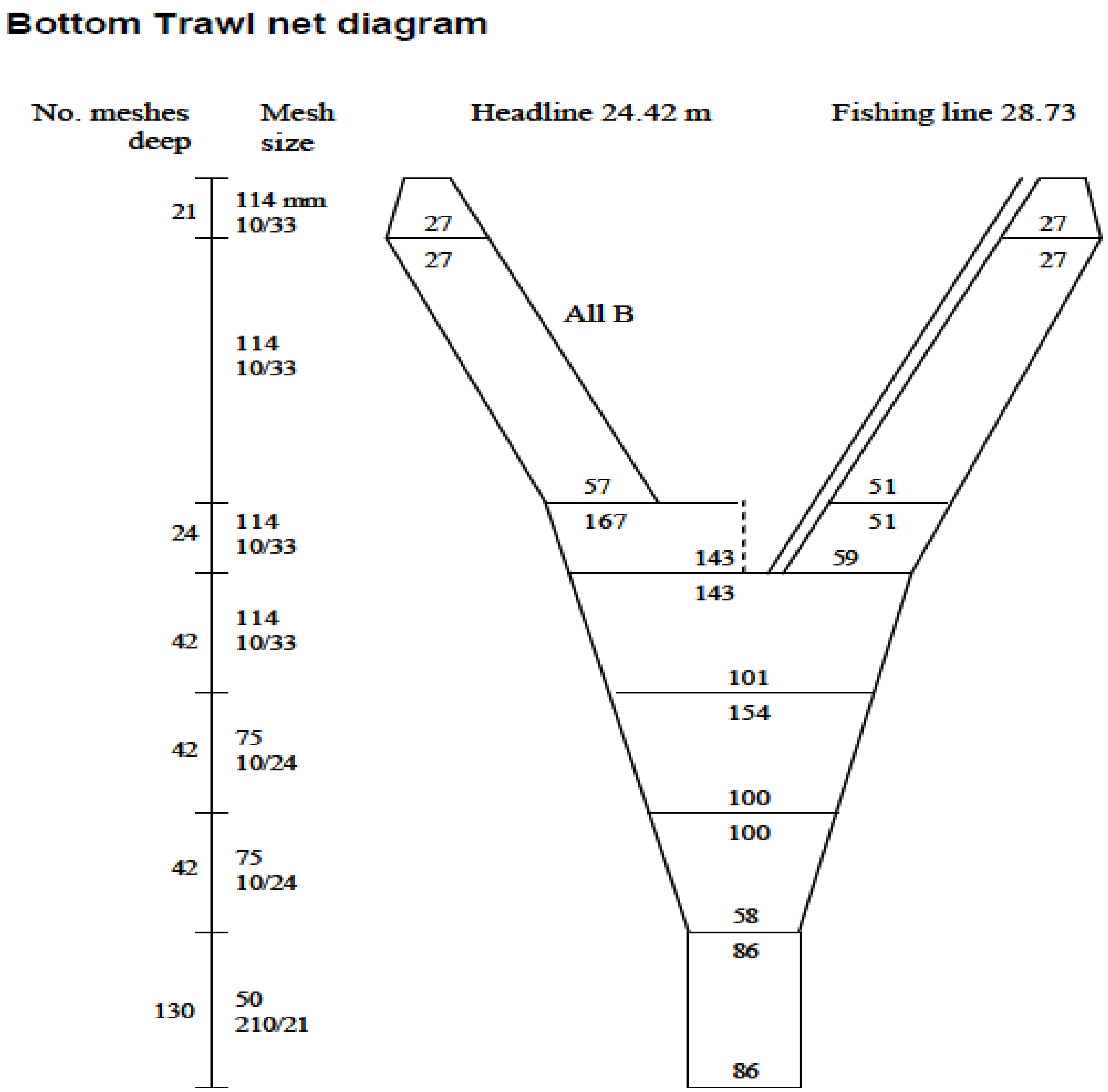
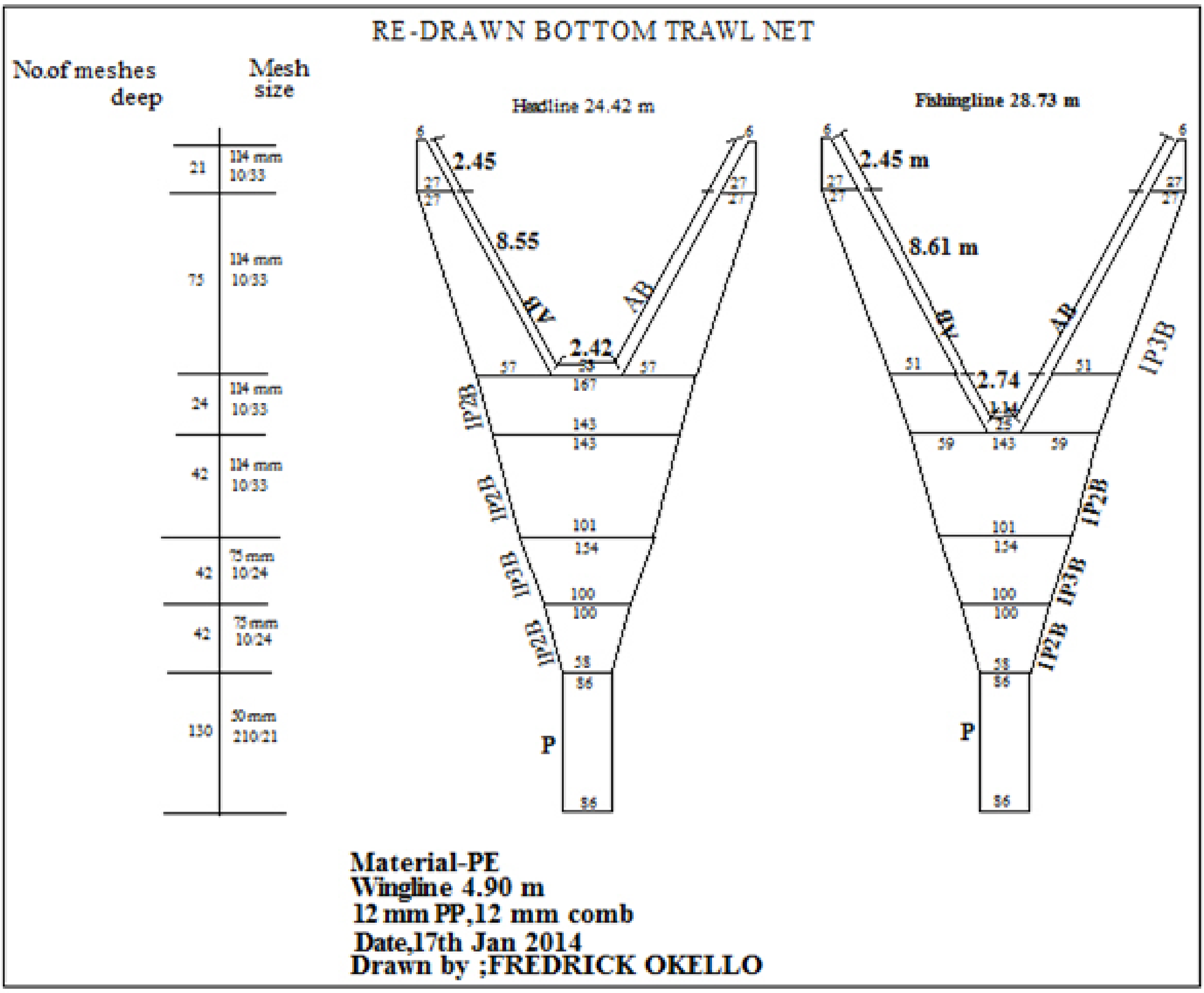
ANNEX

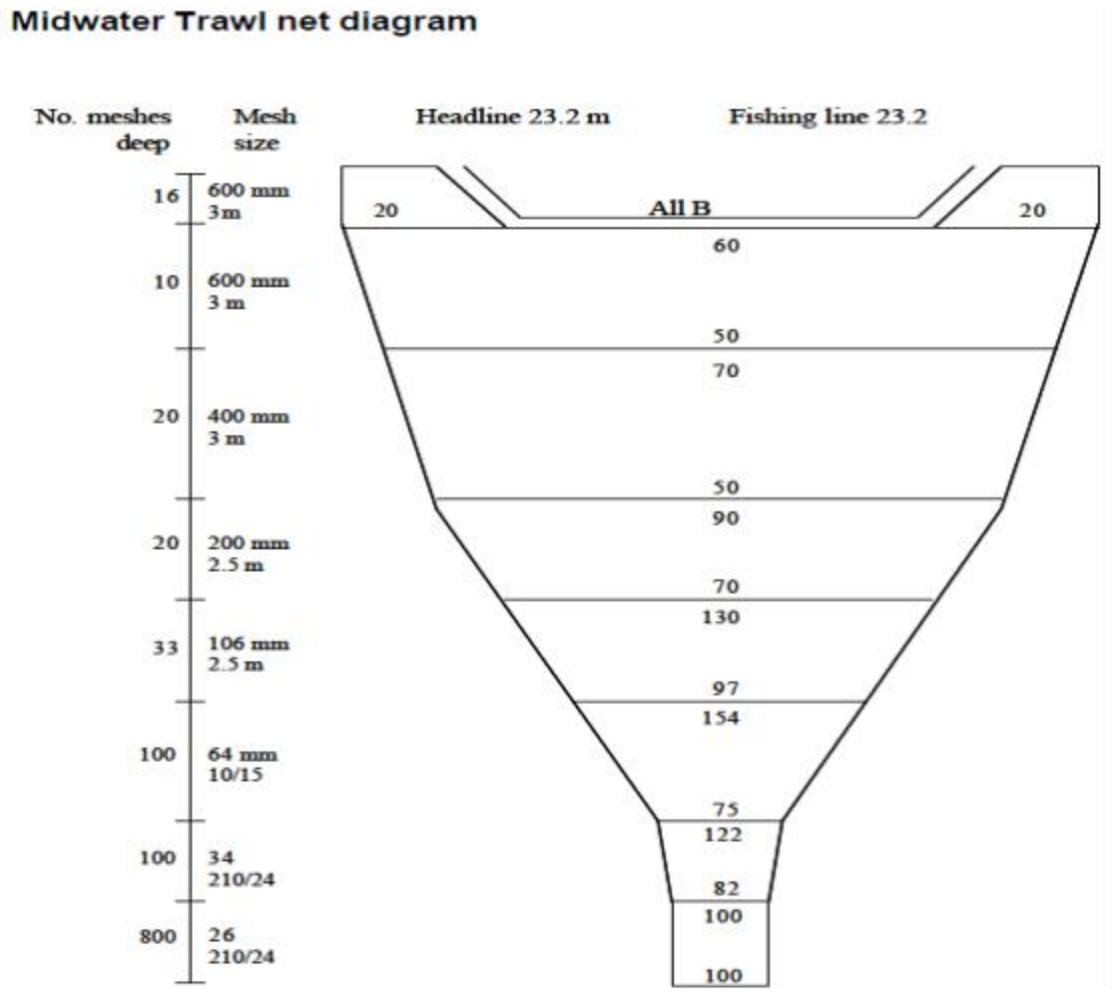
5.1 Annex 1: Bottom trawl net drawing from manufacturer



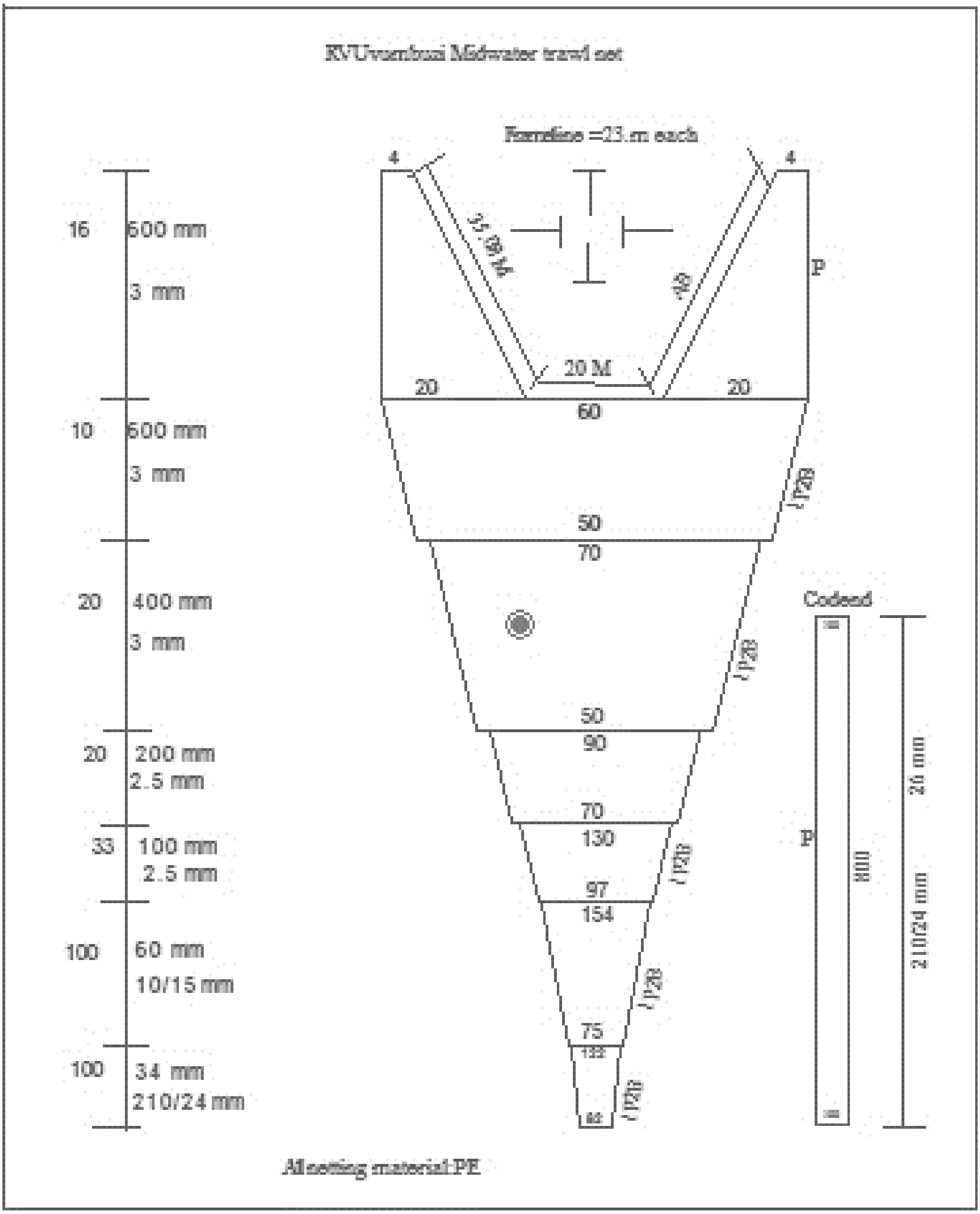
5.2 Annex 2: Bottom trawl net re-drawn



5.3 Annex 3: Pelagic net drawing from manufacturer



5.4 Annex 4: Pelagic net re-drawn



5.5 Annex 5: Research Vessel Uvumbuzi


R.V. UVUMBUZI