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ANALYSIS OF NEW TRAWL DESIGN FOR THE NAMIBIAN HAKE FISHERY

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ABSTRACT

In this study a four panel mid-water trawl was designed with the aim to improve the current design and also to improve catchability of hake in Namibia. The behavioural patterns of the hake as well as the existing trawl design were taken into account while designing modifications to be used in the new trawl. The new design has a larger net mouth opening as well as dual functionality as a bottom and above-bottom trawl. The design was theoretically tested through use of various formulae and previous scientific data collected in trawl design. A blue print of the new proposed trawl was designed in 2D with AUTOCAD 3DMAX (V.23). The preliminary theoretical results of the study portray that the new design can be an effective and efficient substitute for the trawl currently used. Sea trials for the new design are recommended to confirm these preliminary results.

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1 INTRODUCTION

Namibia has a large and productive continental shelve rich in fish. Amongst them are three species of hake *Merluccius capensis* and *paradoxus* and the Benguella hake *(Merluccius polli)* which are similar hake species with a few physiological differences. Of the three, capensis and paradoxus form the basis of the hake sector in the Namibian fishing industry. Their distribution is displayed in Figure 1 below. The Namibian fisheries are well developed and contribute to almost 3.7% of the GDP (National Planning Commission, Ministry of Fisheries and Marine Resources, 2011). With the two coastal towns of Luderitz Bucht and Walvis Bay as the only two harbour towns and ports of Namibia, the fishing industry provides direct employment to roughly 14,000 according to 2010 data collected from the Ministry of Fisheries and Marine Resources (mfmr.gov.na). Of those, almost 9,000 jobs are created by the hake industry. There is much room for improvement in catch volumes in the Hake industry. One main characteristic about the species is that it vacate (lift off) the area on the seabed if the sun has set or is absent. A study by Johnsen, *et al*. concluded that catch volumes could increase if this behavior was taken into consideration when exploiting the species (Johnsen, Iilende, & Fisheries Research, 2007).

The most common trawl in utilisation in the industry is a bottom trawl with a very low vertical opening. This is not adequate for species such as hake that has a tendency to migrate vertically. For this reason, the improvement of the current trawl and or a design that increases the efficiency of the current trawl would be a great benefit.

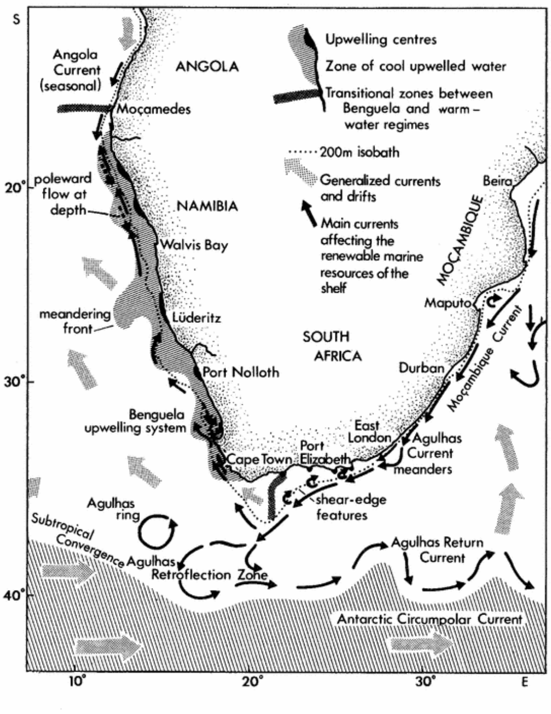


Figure 1.Hake distribution in southern Africa

1.1 Behaviour of Hake

1.1.1 *Merluccius capensis*

Also known as the shallow-water Cape hake, *Merluccius capensis* is found in the south-eastern Atlantic Ocean. It is also found on the west coast and it occurs as far north as Benguella in Angola, where its distribution overlaps that of *Merluccius polli*, the Benguella hake.

Capensis has an average length of approximately 50 cm and up to a maximum of about 120 cm. It lives close to the bottom on the continental shelf and upper slope at depths ranging from 50 to 500 m, however is usually not found below 400 m. Its preferred depth partly overlaps that of *Merluccius paradoxus* between 200-400 m.

Capensis is a carnivore. Juveniles feed on small, deep-sea fishes and crustaceans. Larger hake feed on squid and fish; as well as smaller hake and jack mackerel.

Capensis migrates vertically on a daily cycle, being demersal by day and nektonic by night. On a seasonal basis, it migrates southwards in spring and northwards in autumn. Spawning is reported either to be year-round, or to occur mainly from mid-spring to early summer in the months of October to January (Food and Agriculture Organisation).

1.1.2 Merluccius paradoxus

Also known as the deep-water Cape hake, *Merluccius paradoxus* is found in the south-eastern Atlantic Ocean along the coast of Southern Africa. Its range extends in decreasing abundance around the southern coast of Africa and into the Indian Ocean. It is most plentiful in the cold, nutrient-rich fishing grounds of the Benguella Current.

Merluccius paradoxus has an average length of between 40 and 60 cm, with a maximum of about 80 cm. It lives close to the bottom in muddy areas on the continental shelf and slope. It usually is found at depths of 200 to 850 m, although most commonly below 400 m. Juveniles feed on small deep-sea fish and crustaceans. Mature hake feed mainly on fish, squid, and crustaceans (Food and Agriculture Organisation).

1.2 Diel Variation

Diel variation in the vertical distribution of hake can affect catch rates. The species tends to migrate vertically from the bottom to depths of between seven and ten meters off the seabed. A comparative study of two vessels fishing at different times showed that CPUE was higher around noon compared to CPUE during the night; a fact corroborated by a study done by Johnsen, and Iilende (2007). According to this study,

> The day/night difference in commercial CPUE decreased with depth and increased with density of hake and varied with latitude, whilst no significant seasonal or annual patterns were observed. Further, the time of transition from night to day level was correlated with time of sunrise which changes with season. Hake catch rates at noon were estimated to be 27% and 86% higher than at night for M. Capensis and M. Paradoxus, respectively (Johnsen and Iilende, 2007).

1.3 Trawl designs used in the Namibian hake fishery

1.3.1 Bottom trawls

Bottom trawls are primarily utilised in the harvesting of hake in Namibian waters and various designs are employed with ground contact being one common denominator. These trawls are made up out of bottom and top panels, wings, bellies and a cod-end. The wings are important in the herding process and ends up in the "mouth" of the net where the bottom and top panels (and in some cases side panels) begin. The trawls might be made up of two or four panels, where one would have bottom and upper panels in two-panelled gear and ancillary side panels in four panelled gear (Seafish Fisheries Development Centre, 2005). The upper panel will include a roof, which will make it longer by one sector of netting than the bottom panel. This is important to mitigate escape routes of jumping, which is a common behavioural characteristic in hake. The bottom panel effectively starts with the fishing line connected to a footrope/bosom. This whole design or construction give rise to a net opening or entrance called the mouth of the net, where we differentiate between the vertical opening of the mouth sometimes referred to as the lift and the horizontal opening sometimes referred to as the spread-both essentially creating the "mouth." The bottom panel has bosom weighted to enforce a downward vertical effect at the mouth, whilst the top panel will have a headline with floatation incorporated creating an upward vertical movement.
Ground contact is essential in bottom trawls, therefore all bottom trawl design nets have the commonality of even spread of ground contact along the footrope of the net. As such the net is said to "fish" only once it is squared. By Namibian law, no contraption other than trawl doors must be used to keep the spread of trawls and thus bridles connected from the wing tips of the net to the doors are incorporated. These trawl doors also serve the purpose of keeping the net squared and maintaining its tubular or tunnel-like design and as such able to fish. Vertical openings vary with the different designs of bottom trawls, but the ones utilised for hake has a minimum opening of 3.5 m for the common bottom Spanish trawl and up to 11 m for the Albatross (an Icelandic design) net design. A typical bottom trawl design is shown in Figure 2 below.

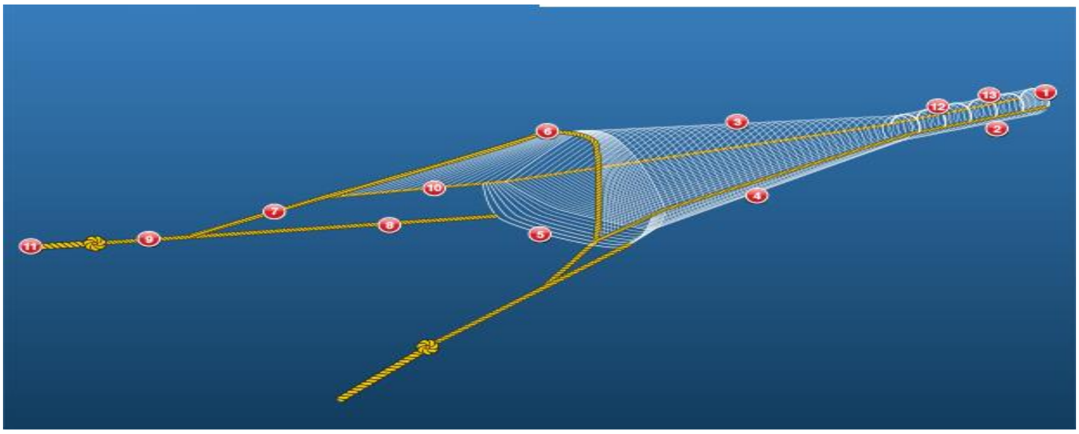


Figure 2. Bottom trawl (Euronet, 2014).
Key: 1 Codline, 2 Codend, 3 Upper Panels, 4 Lower Panels, 5 Fishing Line, 6 Headline, 7 Upper Bridle, 8 Lower Bridle, 9 Sweepline, 10 Flyline, 11 Trawl Warps, 12 Lifeline, 13 Ripline

1.3.2 Mid-water trawls

One type of trawl design not very much utilised is the different semi-pelagic nets that “fly” in mid-water. Their basic concept bears the same characteristics as bottom trawls, yet they are not dependant on ground contact as a means to keep them fishing as shown in Figure 3. They maintain their tunnel-like shape, opening and spread through a combination of specifically designed trawl doors and velocity of the vessel. Their footropes may not be as weighted as their bottom trawl counterparts.

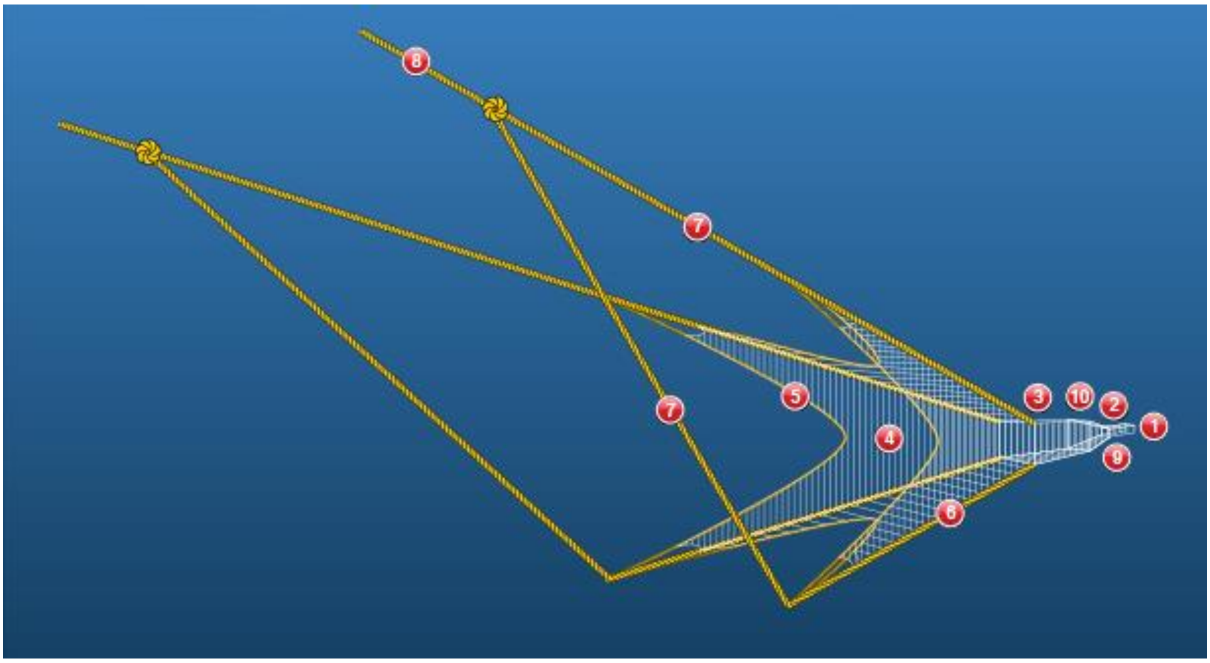


Figure 3. Pelagic trawl (Euronet, 2014)
Key: 1 Codline, 2 Codend, 3 Belly, 4 Front Section, 5 Frame Ropes, 6 Ripline, 7 Bridles, 8 Trawl Warps, 9 Round Straps, 10 Lifeline

There seems ample room for improvement in the trawl design. Taking into account the diel variation of hale, improved catch efficiency can possibly be attained by designing a trawl with dual functionality and a better vertical opening than the current low opening bottom trawls.

2 MATERIALS AND METHODS

A specific fishing vessel operating a particular conventional bottom trawl was selected as a base for the redesign. Blueprints and data on rigging details and gear performance was collected directly from present users and analyzed. A new trawl design was then prepared and compared to the prototype using general theoretical models/formulas available for fishing gear design Fridman (1986), MacLennan (1982) and Zhou (1981). Fridman’s formulae apply to both two and four panel trawls and are purely theoretical. These formulae tend to over-estimate resistances encountered in practice. MacLennan (applicable to four panel trawls) and Zhou’s (applicable to two panel trawls) formulae were derived for practical tests done at sea and present a more realistic view to resistances encountered. For the purpose of substantiating the findings the formulae of Zhou and Fridman with regards to the netting surface area was used for the prototype. In accordance with this the formulae of Fridman and MacLennan was applied to the new design.

2.1 The Vessel

MFV Fisherbank is a wet fish stern trawler belonging to Hangana Seafoods Namibia. Operating along the Namibian, and coast targeting hake with a Spanish bottom trawl of 120m footrope, it fishes at speeds ranging between 3kts and 4kts. The specifications are as follows:

Build in Poland in 1972, overall length 48 m, breadth 10.99 m, draft 5.8m, 2200 bhp engine, and propeller 2.5 m in diam. with nozzle. Wire diameter: 24mm, trawl doors: Type Alcasador Extreme 5.5m², weight of 2200kg.

2.2 The prototype trawl

The prototype is a common low vertical opening bottom trawl with weighted bosom and long top wings for better herding. The bottom wings ends in two tips per side as incorporating a three bridled system. The prototype Spanish Trawl specifications are shown in Figure 4 below.

Prototype Spanish Trawl 120 m

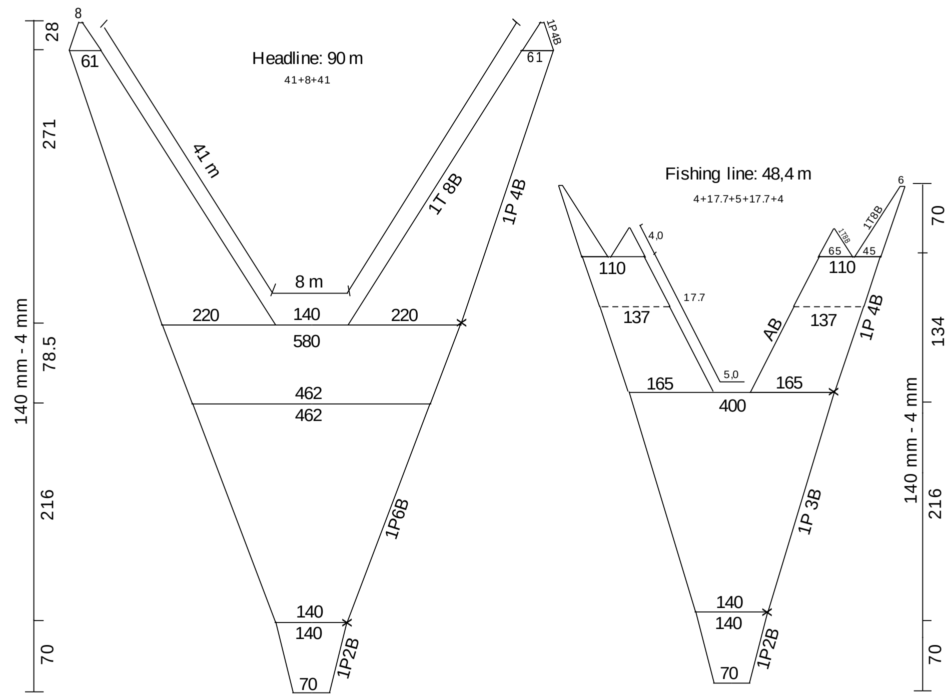


Figure 4. Spanish Trawl

2.3 Calculations and formulae

2.3.1 Available towing power of vessel

A vessel's towing is dependent on its engine brake horsepower (BHP) and towing speed. Fridman (1986) prescribed the following formula for calculating the available towing force as:

Equation 1 (Fridman, 1986)

$$Ft = P \times (KF - 0.7 \times V)$$

Where,

Ft: towing pull, in kgf

P: engine brake horsepower
V: towing speed in Knots
KF: empirical towing force coefficient, this coefficient ranges from 10 to 20 depending upon the type of propeller and the presence of propeller nozzle.

2.3.2 Projected twine surface area

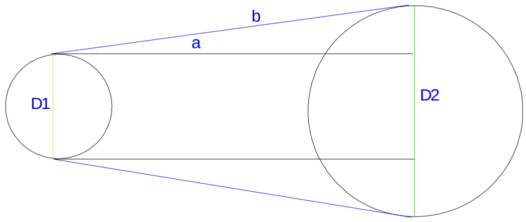
$A= ((N +n)/2))*H*4*a*d*10^{-6}$ (Fridman, 1986)
Where,
A: twine area (m^2)
N: number of meshes across the top of panel
n: number of meshes across the bottom of panel
H: number of meshes across the depth or height of the panel
4: number of bars in one mesh
a: bar length (mm)
d: diameter of twine

2.3.3 Netting resistance

The quintessence of force for the complete trawl in the water is dependent on all different forces and resistances encountered at certain depths and with various speeds; Fridman encapsulates his whole theory of hydrodynamics (Fridman, 1986) in relation to all the components in the following formulae:
Equation 2 (Fridman, 1986)
R^1= Ç x q x A
Where:
R^1= is the total netting resistance
$q= (\rho v^2) \div 2$...the function of the gravity of seawater (ρ) and velocity (v) of the vessel (known as the hydrodynamic stagnation pressure)
A= Surface area of net and or doors
Ç= derived from Fridman table... the function of angle of incidence of any given object.

2.3.4 Estimated angle of incident for the net cone

Equations 4 and 5 relating to estimated angle of incident for the net cone are detailed in Figure 5 below.



$tan \propto = a/b$

Equation 4 $\mathbf{C = D\pi}$
Equation 5 $\mathbf{D = C \div \pi}$

Where:
$\propto$ is the angle of incidence
Length of section(b)
D^1 is the calculated diameter at end of belly
D^2 is the calculated diameter at mouth opening
a= (D^1- D^2) ÷ 2 Equation 5

Figure 5. Incidence Angle of Netting Cone

Zhou (whose formula relates to two-panelled trawls) and MacLennan (relating to four-panelled trawls) also used the twine area and vessel's velocity but with constants calculated from actual tests done at sea. Therefore calculations according to Fridman are always over-estimate the resistance and in practice Zhou's and MacLennan's is more or less realistic and is encapsulated in the following formulae:
According to MacLennan:

Equation 6 (Lu Chi, 1988)

$Rp= [61 + 2 + 46.6 \times V^2 \div (1 + 0.0641V)]TA \div 9807$
Where:
Rp= Total netting resistance
V= Vessel's velocity
TA= Total twine area

According to Zhou:

Equation 7 (Lu Chi, 1988)

$D= R24.9V^2 \div (1+ 0.0516V)$ Where:
D= Total Netting resistance
R= Total twine area
V= Velocity of the vessel

2.3.5 Door resistance

The same formula as the trawl net is applied to establish the effect of the doors' drag to the total drag of the fishing gear. Where the parameters of area, hydrodynamic stagnation pressure and incidence angle are related to the doors.
Equation 8 (Fridman, 1986)

$R_x = q \times C_x \times A$

2.3.6 Warp resistance

The significance of the resistance of the trawl warps' effects on the total drag might sometimes be ignored, but it is of great importance and it also influences the shape of gears which is ultimately important in the final analysis of the drag of such gears (MacLennan, 1981). As such, Fridman's formula is applied.
Equation 9 (Fridman, 1986)

R̽= q x L x D x Ç̽

Where:
q= (pv²) ÷2...the function of the gravity of seawater and velocity of the vessel (known as the hydrodynamic stagnation pressure)
L= warp length
D= warp diameter
Ç̽= derived from Fridman table. The function of angle of incidence of any given object and calculated as follows:

Namibian rule of thumb for warp to depth ratio of 2.7 applies to this computation.
Equation 10 (Fridman, 1986)

Sinα= H/L

Where:
Sinα= Function of obtaining Ç̽ (drag coefficient).
H = Length of the warp
L = Depth of operation

The vessel's mean trawling depth for its trip on 11Feb.2014 applies, was used. Sagging was not accounted for in this calculation.

3 RESULTS

3.1 The new trawl design

Various factors were considered prior to the designing of the new design- mesh sizes, area, towing speed and twine diameter. A bigger net mouth opening (due to the species' vertical migration) was the primary goal with the design and was accomplished with bigger meshes and the addition of side panels. The result was a four panel semi-pelagic trawl, designed to fit into the confines of the Spanish trawl with regards to overall length and twine surface area; yet to have a bigger net mouth opening than the prototype due to the addition of side panels and mesh size difference.

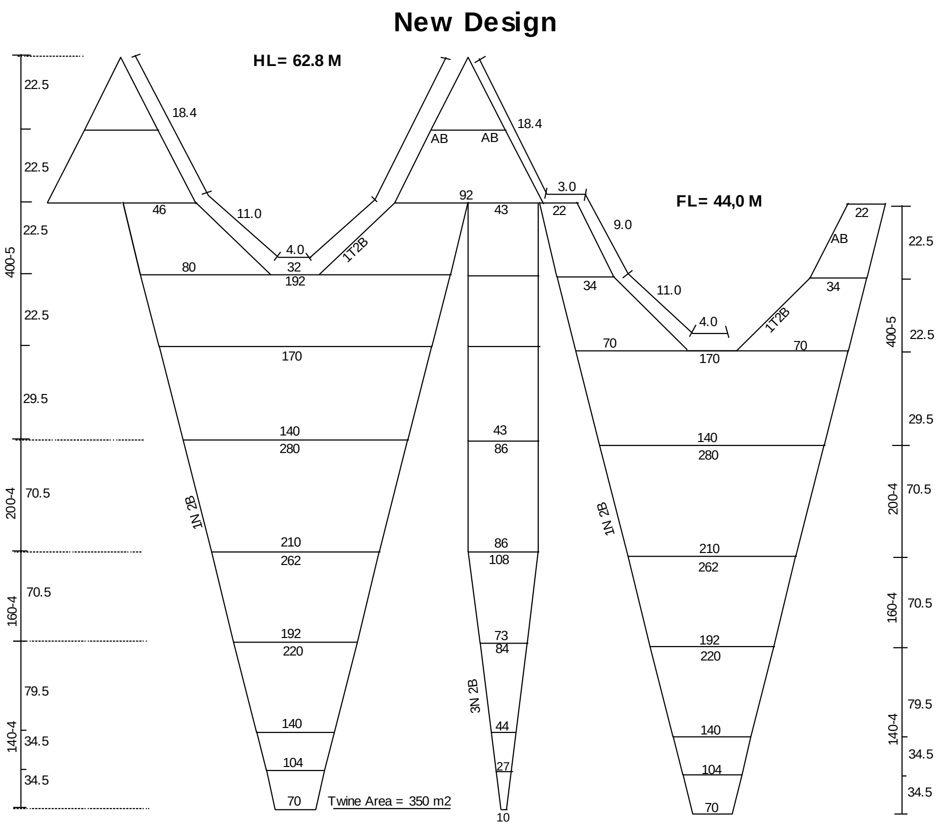


Figure 6. New trawl design

In Figure 7, the vessel's towing power (having a breaking horse power of 2200BHP) is displayed at different towing speeds, bearing in mind that the species are harvested at speeds between 3kts and 4kts.

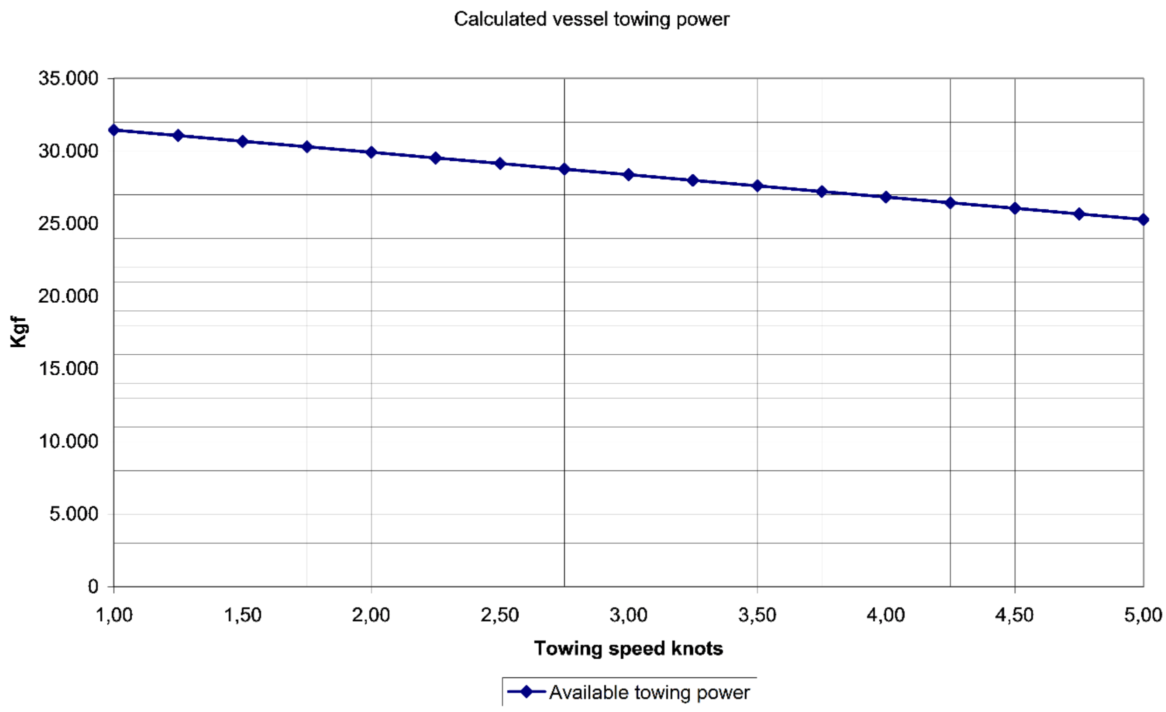


Figure 7. Vessel towing force

The Tables 1 and 2below exemplify the surface area of the prototype and new design respectively that consist of the same analysis as the area of a trapezium, where one factor the height, top and bottom lengths. In this case however, said three lengths are characterised by the number of meshes at the top, bottom and height of each panel, as well as the twine diameter, mesh size and a constant factor.

Table 1. Prototype Area

Net panel	**No. Of meshes on top**	**No. Of meshes bottom**	**No. Of meshes deep**	**No. Of bars in each mesh**	**Twine diam**	**1/2 mesh size**	**m2**	**No. Of panels**	**Total**
Wing tips-B1	45	6	70	4	4	70	2,20	2	4,4
Wingt ips-B2	65	5	26	4	4	70	1,12	2	2,2
Top wing tips	61	8	28	4	4	70	1,19	2	2,4
Top Wings	220	61	271	4	4	70	46,91	2	93,8
Lower wings	165	110	134	4	4	70	22,70	2	45,4
Roof	580	462	78,5	4	4	70	50,39	1	50,4
Lower belly 1	420	140	218	4	4	70	75,20	1	75,2
Upper belly 1	462	140	216	4	4	70	80,10	1	80,1
Belly 2	140	70	70	4	4	70	9,06	2	18,1
									372,0

Table 2. Netting area new design

Net panel	**No. Of meshes on top**	**No. Of meshes bottom**	**No. Of meshes deep**	**No. Of bars in each mesh**	**Twine diam**	**1/2 mesh size**	**m2**	**No. Of panels**	**Total**
Wing tips	1	92	45	4	4	200	7,4	2	14,73
Top wings	46	80	22,5	4	4	200	5,0	2	9,98
Roof	192	170	22,5	4	4	200	14,3	1	14,34
Belly1	170	140	29,5	4	4	200	16,1	2	32,19
Belly2	280	210	70,5	4	4	100	30,4	2	60,80
Belly3	262	192	70,5	4	4	80	22,5	2	45,07
Belly4	220	140	79,5	4	4	70	17,6	2	35,26
Belly5	140	104	34,5	4	4	70	5,2	2	10,37
Belly6	104	70	34,5	4	4	70	3,7	2	7,40
Side panel 1	43	43	22,5	4	4	200	3,4	2	6,81
Side panel 2	43	43	22,5	4	4	200	3,4	2	6,81
Side panel 3	43	43	22,5	4	4	200	3,4	2	6,8
Side panel 4	86	86	70,5	4	4	80	8,5	2	17,1
Side panel 5	108	73	70,5	4	4	80	9,0	2	18,0
Side panel 6	84	44	79,5	4	4	70	6,3	2	12,5
Side panel 7	77	27	34,5	4	4	70	2,2	2	4,4
Side panel 8	27	10	34,5	4	4	70	0,8	2	1,6
Lower wing	22	34	22,5	4	4	200	2,2	2	4,4
Bunt	34	70	22,5	4	4	200	4,1	2	8,2
									316,8

3.2 Angle of incidence for netting: Both trawls

3.2.1 Prototype

The following were found through calculations:

Calculated diameter of belly (D^2): 20m
i.e.: C= #meshes x size of meshes x E^1
= 882 x 140mm x 0.5
= 62m
Thus: D= 62 ÷ 3.14
= 19.74 / 20m

Also then with relation to the Ç the following were found:
D^1= (#meshes x size of meshes x E^1) ÷ 3.14
= (280 x 0.14 x 0.5) ÷ 3.14
= 6.2m
a= (D^1- D^2) ÷ 2
= (20 – 6.2) ÷ 2
= 6.9
b= #meshes x size of meshes x E^2
= 216 x 0.14 x 0.86
= 26
$\propto$= $\tan^1$ a/b
= $\tan^{-1}$ (6.9/26)
=14.86 / 15°
This then relates to a Ç of 0.55

3.2.2 New design

The following were found through calculations:
Calculated diameter of belly (D^2): 28m
i.e.: C= #meshes x size of meshes x E^1
= 436 x 400mm x 0.5
= 87.2m
Thus: D= 87.2 ÷ 3.14
= 27.77 / 28m

Also then with relation to the Ç the following were found:
D^1= (#meshes x size of meshes x E^1) ÷ 3.14
= (376 x 0.4 x 0.5) ÷ 3.14
= 23.9 / 24m
a= (D^1- D^2) ÷ 2
= (28 – 24) ÷ 2
= 2
b= #meshes x size of meshes x E^2
= 23 x 0.4 x 0.86
= 7.9 / 8m
$\propto$= $\tan^1$ a/b
= $\tan^{-1}$ (2/8)
=14.03 / 14°

This then relates to a C_x of 0.55.

Netting angle of incidence is illustrated in Figure 8 below.

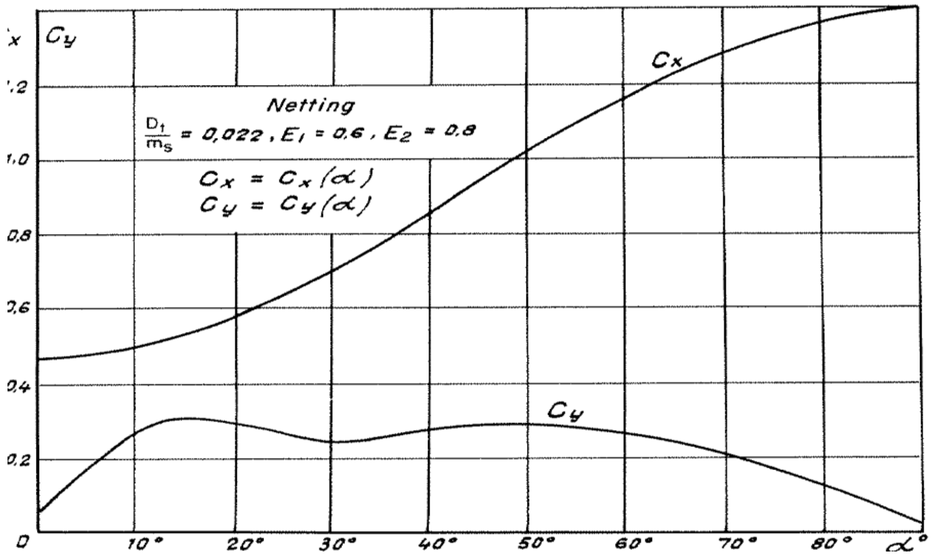


Figure 8. Netting Angle of incidence

3.3 Drag coefficient for the trawl doors

A general assumption for its drag coefficient relating to that of rectangular cambered doors was used to calculate its resistance due to limited information on this doors. Therefor a drag coefficient of 0.5 was assumed.
The same basic formula applies for this trawl doors (at zero velocity) as that of the Twine surface area.

3.4 Angle of incidence of trawl warps and drag coefficient (at zero velocity)

Depth= 350Fa/641m
Warp= 1800m
Diameter= 24mm

Sinα= H/L
= 641/1800
=0.356
α= 20.86
C_x= 0.32, derived from Figure 8

Table 3 below outlines drag coefficients for straight ropes.

Table 3. Drag Coefficient: Warps (Fridman, 1986)

TABLE 3.3.—THE DRAG COEFFICIENTS FOR STRAIGHT ROPES

α^{o}	C_x	α^{o}	C_x
0	0,12	50	0,70
10	0,20	60	0,90
20	0,32	70	1,12
30	0,41	80	1,25
40	0,56	90	1,30

3.5 Calculated Total Gear Resistance

Table 4. Total Resistances

Warp diam	**0.024**	Vessel HP	**2,200**
Warp m	**1800**		

Twine area	Knots	Cx netting	Cx wire	Cx door	q	Door area	Warp area	Vessel kgf	MacL	Zhou´s	Fridman total
320	1.00	0.5	0.32	0.5	13.2	11	86.4	31,460	3,426	2,004	2,555
320	1.25	0.5	0.32	0.5	20.7	11	86.4	31,075	4,197	3,110	3,993
320	1.50	0.5	0.32	0.5	29.8	11	86.4	30,690	5,118	4,450	5,750
320	1.75	0.5	0.32	0.5	40.5	11	86.4	30,305	6,184	6,019	7,826
320	2.00	0.5	0.32	0.5	52.9	11	86.4	29,920	7,388	7,812	10,222
320	2.25	0.5	0.32	0.5	67.0	11	86.4	29,535	8,725	9,825	12,937
320	2.50	0.5	0.32	0.5	82.7	11	86.4	29,150	10,188	12,055	15,971
320	2.75	0.5	0.32	0.5	100.1	11	86.4	28,765	11,773	14,496	19,325
320	3.00	0.5	0.32	0.5	119.1	11	86.4	28,380	13,475	17,145	22,999
320	3.25	0.5	0.32	0.5	139.7	11	86.4	27,995	15,289	19,999	26,992
320	3.50	0.5	0.32	0.5	162.1	11	86.4	27,610	17,211	23,053	31,304
320	3.75	0.5	0.32	0.5	186.1	11	86.4	27,225	19,237	26,305	35,936
320	4.00	0.5	0.32	0.5	211.7	11	86.4	26,840	21,362	29,749	40,887
320	4.25	0.5	0.32	0.5	239.0	11	86.4	26,455	23,583	33,384	46,157
320	4.50	0.5	0.32	0.5	267.9	11	86.4	26,070	25,896	37,205	51,747
320	4.75	0.5	0.32	0.5	298.5	11	86.4	25,685	28,298	41,210	57,657
320	5.00	0.5	0.32	0.5	330.8	11	86.4	25,300	30,785	45,394	63,885

Figures 9 and 10 below illustrate the resistance calculated for the old and new designs.

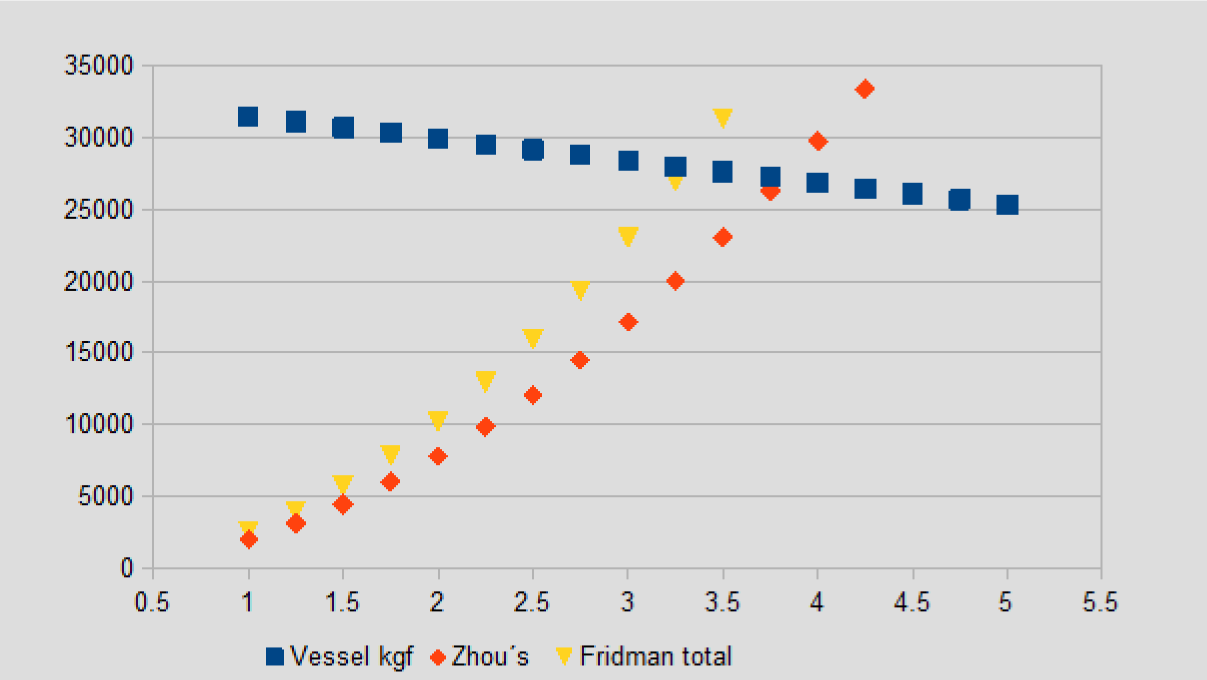


Figure 9. Prototype calculated resistance

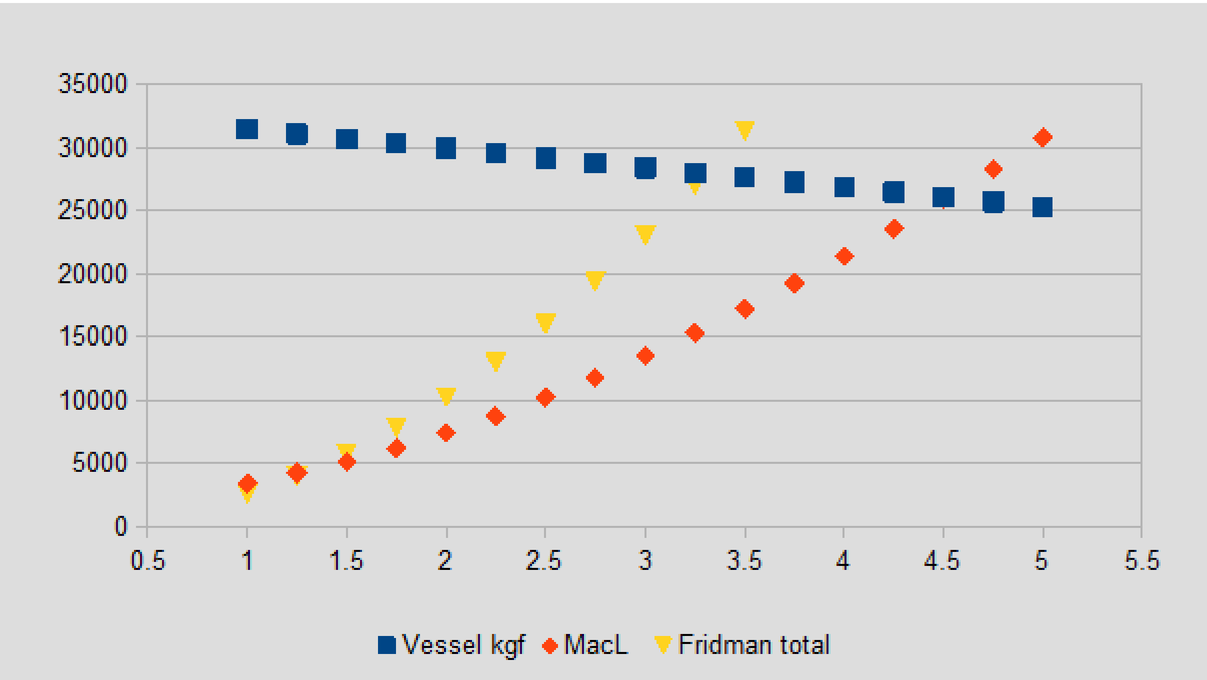


Figure 10. New design calculated resistance

4 DISCUSSION

The low opening trawls being utilized are not suitable for high night time CPUE when the fish lifts off the bottom, as such the alternative was to develop a new trawl to this effect.
The study tries to incorporate the specifications of a certain wet fish trawler as basis to model the proposed new design (Fridman, 1986). Cognizance was paid to its towing force as well as the current rigging of the vessel itself with regards to trawl warps and doors. It uses a 24mm

diameter warp and dual purpose trawl doors which will complement the incorporation of the new design.
The quintessence of force for the complete trawl in the water is dependent on all different forces and resistances encountered at certain depths and with various speeds. These forces and resistances act on the trawl net drag due to netting surface area. Both the prototype and new design were tested against three different formulae to this effect.
Fridman’s formula, applicable to both two and four panel nets, is overbearing and totally based on theory and was used for both designs. Findings show that based on Fridman’s estimations the new design can be towed by the vessels used in the study and those of similar in horsepower. Zhou’s formula was designed through actual tests done at sea under working conditions and is used primarily for two panel nets; as such it was tested against the prototype as primary means. MacLennan’s formula also relates to practical tests and was tested for the new design as primary means. The study confirms better resistance curves for both Zhou and MacLennan than Fridman’s. Consequently the new design proved to be having lesser surface area, even though it may be a bigger trawl in design.
In modification and or re-designing a prototype, four pivotal areas must be considered. First is the drag of a net depends largely on net size or area, so there is an area factor to be manipulated. Secondly, there is a mesh size factor to be dealt with and clearly the bigger the mesh the smaller the drag; which was proved to be the case in having bigger meshes in the net mouth. Thirdly, there is a twine factor that depends on the twine diameter. Lastly, there is a towing speed factor to take into consideration. With all this taken into account the new design proved at the hand of various formulae that it is lighter yet bigger in design than the prototype.

The species are currently harvested at speed ranging between and 3kts and 4kts and can reach 4.5kts for the bigger factory vessels that can tow bigger gear. The study proves better results in towing speed for the new design (4.5knots with regards to MacLennan’s Formula) than the prototype in both formulae (3.8knots with Zhou’s formula and 3.4 with Fridman’s formula) tested for it.

The rigging of the prototype has negative effects on its net mouth opening. On-the-job measurements (through acoustics) estimate it to be 3-8 m. Thus the bigger vertical opening gives the new design an added edge over the prototype with regards to addressing the species’ vertical migration as well as its dual probabilities (being a bottom as well as semi-pelagic trawl at the skipper’s discretion).
The inadequacies of the prototype are well addressed in the new design and with a lighter gear, it could also prove to be more fuel efficient than the prototype.

5 CONCLUSION

Theoretical studies proved successful for the proposed new design as an initial stage. Possibilities on improvement, conclusion and actual implementation of the new design is a very reasonable probability to be conducted back home in Namibia. Aiding in this is also the knowledge gained theoretically as well as in designing with Design Cad 3D Max. The ultimate construction and utilization of the new design yields a lot of promise for the industry.
In the future, sea trials of the new design are recommended.

BIBLIOGRAPHY

Johnsen, E., Iilende, T. (2007). *Bottom Trawls*. Fisheries Research 2(7), pages 70-79.

Ferro, R. S. (1981). The calculation of the twine area of a trawl net. *Scottish information pamphlet*.

Food and Agriculture Organisation. (n.d.). *fao.org*. Retrieved from http://www.fao.org/fishery/species

Fridman, P. A. (1986). *Calculations for Fishinf Gear.* Surrey, England: Fishing News Books Ltd.

MacLennan, D. (1981). *The drag of four-panel demersal trawls*. Fisheries Research, page 23-33

MacLennan, D. N. (1981). Hydrodynamic characteristics of trawl warps.
mfmr.gov.na. (n.d.).

National Planning Commission, Ministry of Fisheries and Marine Resources. (2011). Annual Report 2010/2011. page 21.

Seafish Fisheries Developmnet Centre. (2005). *Basic Fishing Gear Booklet*. Manchester. Retrieved from www.rainbownetrigging.com. December 2012.

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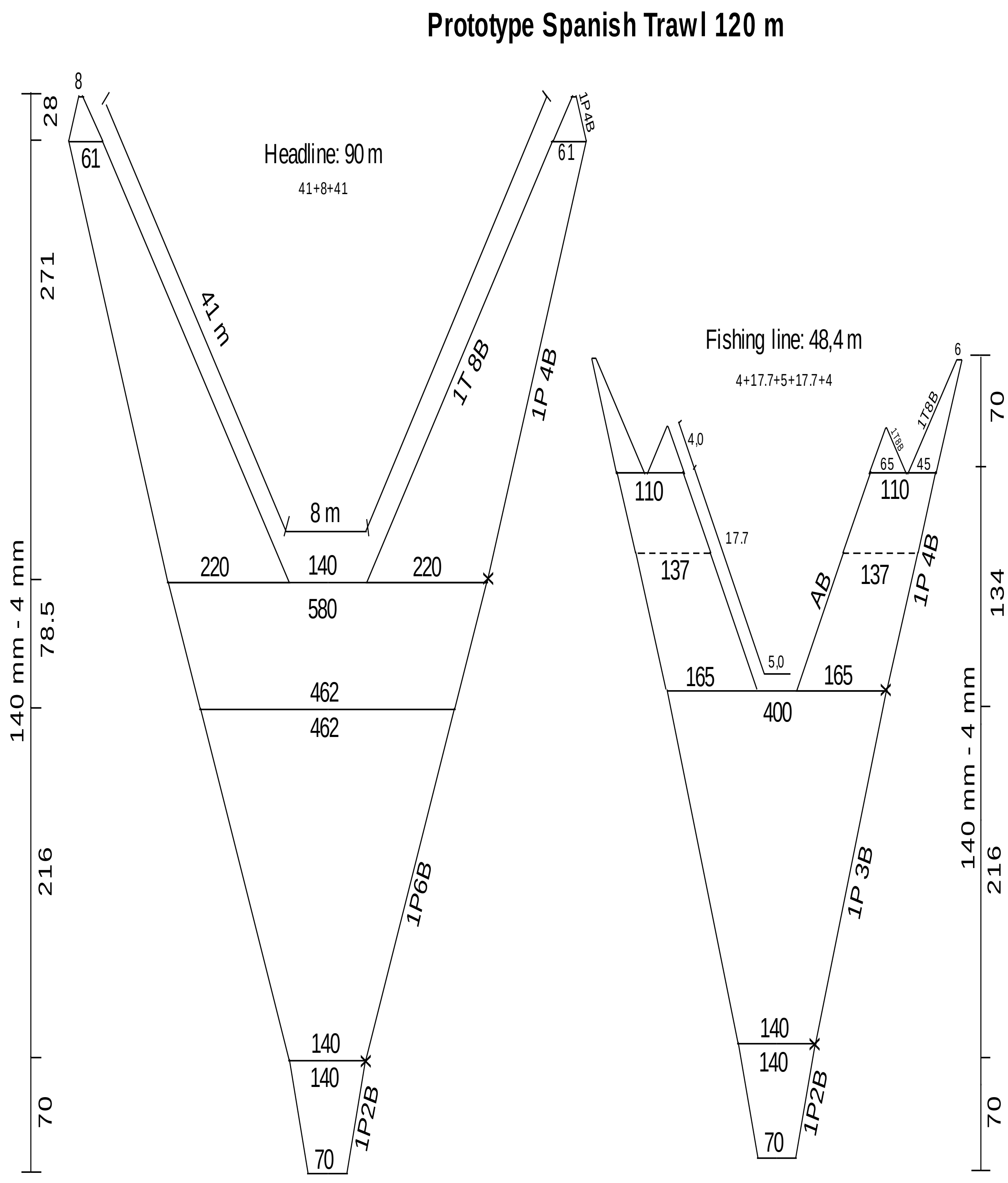
APPENDIX



Spanish Trawl

Vessel Fact File

Specifications: Mfv “FisherBank”

General information
- Year built: 1972
- Builder: Poland
- Type of vessel: Wet fish Trawler

1. Dimensions
- Length overall: 48 (m)
- Breadth: 10.99m
- Depth: 5.8m
- Gross tonnage:

2. Engine, Prop Shaft & Prop.
- Main engine: ABC – 1491(kW) 2200BHP
- Service speed: 820 RPM
- Prop Dimensions: 2600mm
- Nozzle (with): With

3. Compliment
- Officers: 5
- Crew: 17
- Total: 22

4. Capacities
- Fuel oil tank: 100 000L
- Fresh water tank: 60 000L
- Fish hold: 500m²

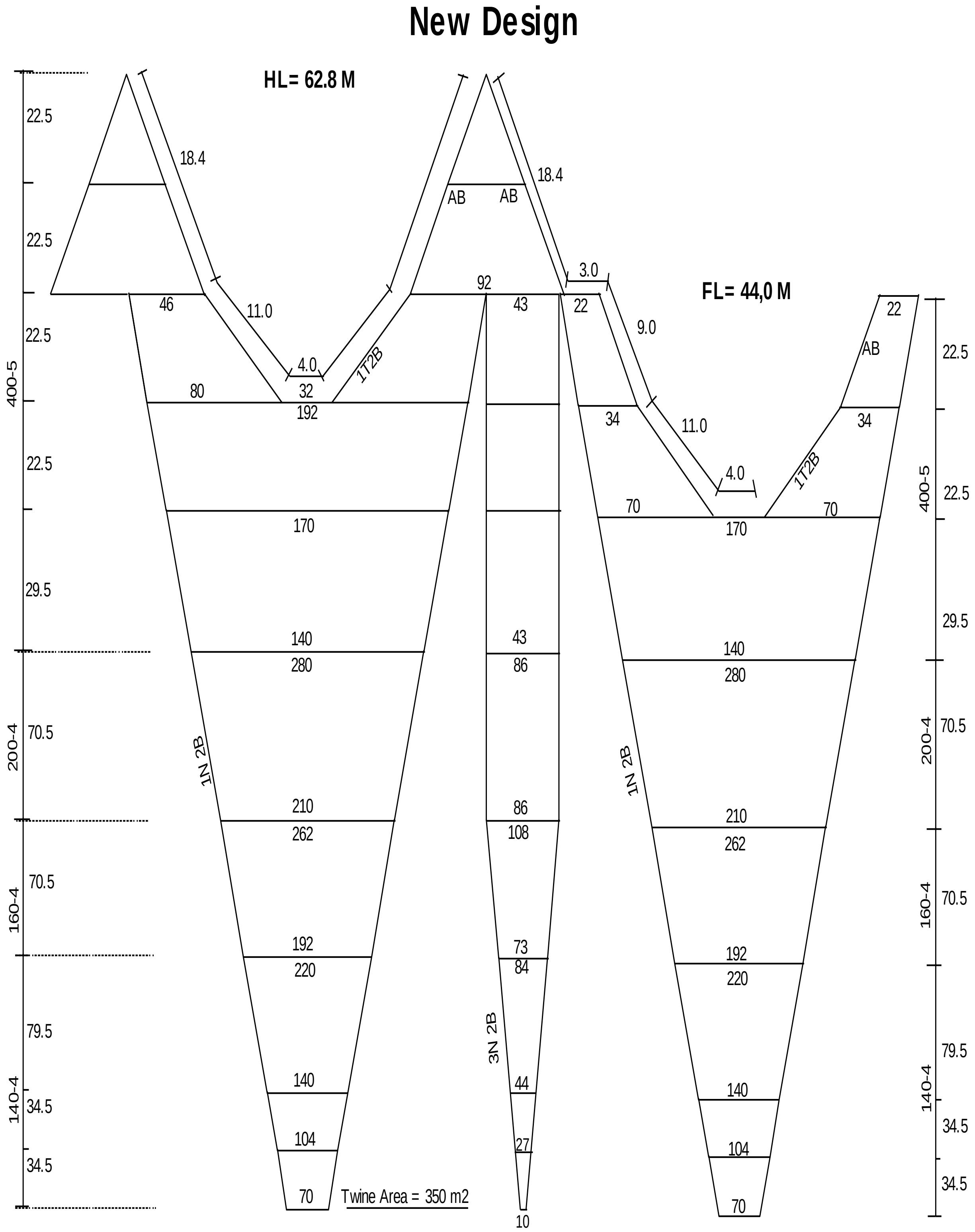
5. Navigation equipment:

6. Communication equipment:

7. Fish finding equipment:

8. Gear hauling equipment
- Split winch: Length:
- Warp diameter: 24mm
- Warp storage capacity: Port side 2000m / S/board side – 2000m
- Net drum
  Length:
  Diameter:

9. Trawl Door:
- Type & Dimensions – Alcasador Extreme 5.5m2


New Design
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FL= 44,0 M
18.4
18.4
AB
AB
AB
3.0
92
46
43
22
22
11.0
9.0
4.0
4.0
1T2B
1T2B
80
32
192
34
34
11.0
70
70
170
170
140
280
43
86
140
280
1N 2B
1N 2B
210
262
86
108
210
262
192
220
73
84
192
220
3N 2B
140
44
140
104
27
104
70
10
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22.5
22.5
22.5
22.5
29.5
70.5
70.5
79.5
34.5
34.5
400-5
200-4
160-4
140-4

New Design