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EXPERIMENTAL DESIGN OF A MIDWATER PAIR TRAWL FOR SMALL PAIR BOATS ON LAKE MALAWI

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ABSTRACT

This study looks at a midwater pair trawl as a possible fishing gear for exploiting the pelagic fish in Lake Malawi using the two boat technique. A new design of a midwater pair trawl was developed from a prototype. Linear dimension specifications of the prototype design were scaled down to the new design by calculations made using a ratio of the effective power of the new design 45 hp (total power 90 hp) pair boats to that of the prototype's 300 hp. Other specifications such as twine thickness were arrived at with due consideration of the fishing area. A full scale net was constructed and this could serve as a basis for further development of the fishing gear after testing. If proven viable, the fishing gear could be used by the small-scale commercial fisheries to exploit the pelagic fish resources in the deep open waters of Lake Malawi.

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1 INTRODUCTION

Malawi is a land locked country in southern Africa east of Zambia lying on the co-ordinates 9°S to 18°S and 32°E to 36°E. The highest point of elevation is Mount Mulanje at 3002 m, the lowest point is the junction of the Shire River and the international boundary with Mozambique at 37 m. It has a land area of 118,480 km^2 of which 94,080 km^2 is land mass and 24,400 km^2 is water area (CIA 2008) (Figure 1).

The economy of the country is agro-based with the fisheries sector contributing to employment, rural income and food security (Bland and Donda 1994). A 2003 survey estimated that 58,000 people were directly involved in fishing activities and over 230,000 in other ancillary activities related to the fisheries sector (ICEIDA 2005).

Malawi has five major water bodies which contribute to the national fish production namely Lake Malawi, Lake Malombe, Lake Chilwa, Lake Chiuta and the Shire River (FAO 2005). Lake Malawi is the major water body with the highest biodiversity of fish species in the world. The number of species in the lake is estimated in excess of 1000 species and 90% of these fish species belong to the family of Cichlids (Lewis *et al.* 1986, Ribbink 1991).

The southern portion of Lake Malawi is the most productive due to favourable limnological conditions. Up welling of nutrient rich metallimnetic water due to the southerly trade winds in the cool dry season gives rise to high primary productivity (Eccles 1974). The geological structure of the southern portion with gently shelving bottom down to 60 m makes it a good fishing ground. The central and northern parts of the lake have deep and steep shelves reaching depths of 200 m to 700 m with anoxic waters below 250 m depths (Figure 2).

Figure 1: Map of Malawi

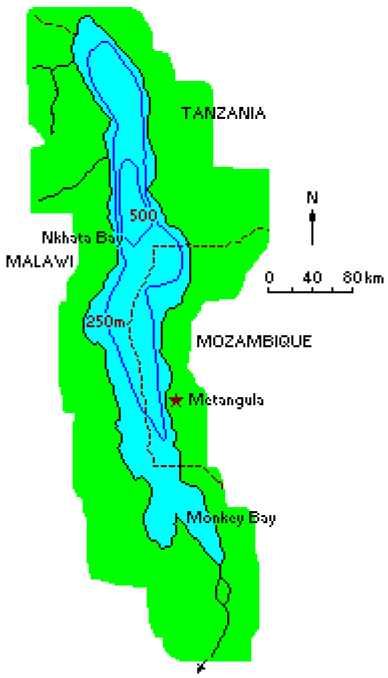

Fig. AFR-13-1 Bathymetric map of Lake Malawi (1).

Figure 1: Bathymetric map of Lake Malawi (International Lake Environmental Committee 2004).

Productivity in the central and northern part of the lake is low with most areas not favourable to the artisanal fisheries (Eccles 1974). The fishing areas in the southern part of the lake are exploited by the commercial fisheries as well as artisanal fisheries (Figure 3).

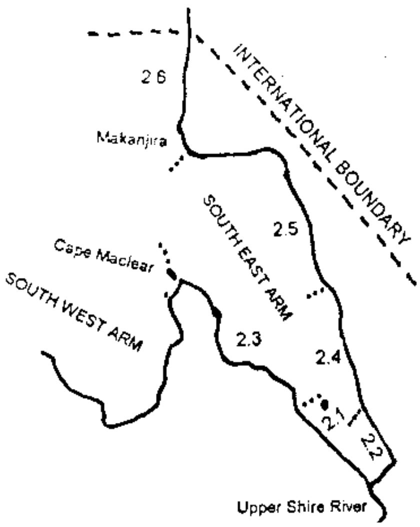

Figure 2: The southern portion of Lake Malawi (Tweddle *et al.* 1994)

For generations people living on the shores of Lake Malawi exploited the fish resources using traditional methods of fishing and fishing gears. The most common fishing gear used was the fish trap. Fishing was mostly done in the shallow inshore areas.

The introduction of purse seines in the ringnet fishery and use of motor boats in the early 1940s resulted in the development of a commercial fishery. The fishing gear was used to target chambo (*Oreochromis* spp.) (FAO 1976). Before this period other fishing gears like beach seines and gill nets had been used though at a small-scale as it was difficult to access the fishing grounds because of the continuous rising of the lake between 1915 and 1939 (Tweddle *et al.* 1994). Commercial trawling was introduced in 1968 by MALDECO (Malawi Development Corporation) a company owned by the Press Corporation. Midwater trawling with stern trawlers was introduced in the early 1970s (Turner 1992). Commercial trawling is concentrated in the South East Arm. Two categories operate in this area and these are semi-commercial pair trawl and commercial stern trawler operations.

Though the South East Arm is the most productive part of the lake, there has been a steady decline in catches of the most valuable fish species from 1976-1989 in the gillnetting fishery, chirimila fishery and trawling fishery (Tweddle *et al.* 1994). As trawling peaked in the area, large cichlid species of *Haplochromine* spp. and *Lenthrinops* spp. declined in abundance, and small cichlid species increased in abundance (Turner 1977). The decline in biomass was estimated at 50-70% based on demersal trawling in the shallowest part of the South East Arm between 1989 and 1994 with changes in species composition and distribution. A number of reasons have been attributed to this decline and include: increased effort resulting in overfishing, use of illegal fishing gear, use of small mesh fishing gears and agricultural practices that affect fish breeding for river spawners (Tweddle *et al.* 1994, Bulirani *et al*. 1999, Kanyerere 2001). In the South West Arm the stocks are relatively stable with the offshore northern part considered to be unexploited. The artisanal fishery is concentrated in the inshore shallow areas. One pair trawler also operates in the shallow inshore area (Duponchelle and Ribbink 2000). The offshore deep waters and in-shore waters are not strictly defined but generally mean waters of 50 m depth and above (Menz 1995). Studies of the pelagic zone of Lake Malawi indicated a biomass of 168,000 tonnes of which 87,000 tonnes (52%) was composed of *Diplotaxodon limnothrissa*, 33,000 tonnes of *Diplotaxodon* 'bigeye' spp., 8700 tonnes of *Copadichromis* quadrimaulatus, 5100 tonnes of *Engraulicypris* sardella, 13400 tonnes of Synodontis njassae and 16800 tonnes of *Rhamphochromis* spp. (Menz 1995). A potential yield of 34,000 tonnes per year was estimated in the pelagic zone (Thompson and Allison 1997). Demersal trawl surveys carried out by the SADC/GEF, Lake Malawi/Nyasa Biodiversity Conservation Project during the period 1998 and 1999 in the South West Arm showed that there is a sizeable stock in the offshore deep zone (Duponchelle and Ribbink 2000). Three pelagic Cichlid species are important in this zone namely *Diplotaxodon* spp., *Rhamphochromis* spp. and *Copadichromis* spp. Results of the study indicated that catches were generally higher in waters deeper than 50 m with *Diplotaxodon limnothrissa* being the dominant species. *Diplotaxodon limnothrissa* accounted for 3.8%, 7.8% and 9.7% in terms of weight at 50, 75 and 100 m depths respectively (Duponchelle and Ribbink 2000). Average catch for *Diplotaxodon* spp. which was the most abundant ranged from 0.8 kg to 2.0 kg per 10 km. This agrees with the trend observed in gillnet and midwater trawl surveys carried out by the UK/SADC Pelagic Fish Resource Assessment Project on Lake Malawi undertaken in 1992 and 1993 throughout the lake.

According to Menz (1995) potential for increasing fish production lies in the offshore pelagic zone. The offshore northern part of the South West Arm and adjacent deeper waters of the South East Arm could be a possible area where a pelagic fishery can be developed since it is relatively unexploited (Duponchelle and Ribbink 2000). This potential, if utilised, would go a long way in meeting the demand for fish in the country as the human population is increasing rapidly. New technologies are required for the fishermen to access and exploit this fish resource. Efforts have been made to develop a fishing gear that would suit such a fishery, aimed at the small-scale fishermen. An open water seine chirimila targeting a small in-shore pelagic species, *Engraulicypris sardella* spp. (usipa) and *Copadichromis* spp. (Utaka) has been modified for the deep offshore waters with variable success. Notably two projects have worked on this fishing gear, the Likoma/Chizumulu Artisanal Fisheries Development project and the Small-Scale Offshore Fisheries Technology Development Project (ICEIDA 2005).

The aim of this study is to design and construct a midwater pair trawl for small boats on Lake Malawi to exploit pelagic fish. Pair trawling is not new to Lake Malawi, having been introduced through the FAO project in 1976. Pair trawlers using bottom trawls have been operating in the shallow waters of the South East Arm and South West Arm since the introduction of this method. Nine pair trawlers, 10 pair trawlers and one pair trawler have been operating in the South East Arm, South West Arm, and Domira Bay respectively (Turner 1992). Midwater trawls are used widely with small boats all over the world (FAO 2009). As such, this fishing gear suits the Malawian fishery conditions where the bulk of fishermen are in the artisanal sector. This can be a way of developing the small-scale commercial sector. But this is a new fishing gear and as such this study could improve domestic knowledge and technical abilities of the fishermen and technical personnel working in the fishing industry.

2 PELAGIC FISH SPECIES OF THE OFFSHORE WATERS

The pelagic fish in the offshore open waters are primarily composed of three genera of cichlid species *Diplotaxodon*, *Copadichromis* and *Rhamphochromis* and one small cyprinid species *Engraulicypris sardella* (Menz 1995).

2.1 *Diplotaxodon* spp.

Diplotaxodon species are distributed widely throughout the lake from the upper water column to 220 m (Turner *et al.* 2002). It is a deep water piscivore and zoopanktivore with upwardly angled mouth. Represented in the deep waters by two species *D. limnothrissa* and an undescribed species *D.* ‘’bigeye’’ (Menz 1995) (Figure4).

Figure 3 : Diplotaxodon limnothrissa (Turner 1996)

The species attain a maximum size of 12 to 15.5 cm and 40 to 60 g (Turner *et al*. 2002).

Maximum size is attained after three years. Breeding has been observed to take place in the South West Arm, from March to August. Females produce relatively few eggs and care for fry for the first few weeks of life by mouth brooding (Menz 1995).

These species are found in different habitats at different stages of life history showing a preference for a particular habitat, from eupelagic (open water above anoxic layer), deep shelf (soft bottom, 100-220 m), shallow shelf (soft bottom, 50-100 m) to reefs (water column near and above rocky shores and submerged reefs (Turner *et al*. 2002).

2.2 *Copadichromis* spp.

Copadichromis quadrimaculatus is a zooplanktivorous fish and represent the genus Copadichromis in the deep waters (Figure 5). The species is the largest of the utaka species attaining an average length of 15 cm at first maturity. It supports the major artisanal fisheries of the lake (Menz 1995).

Figure 4: *C. quadrimaculatus* (Source: www.Burnel.club.fr/galerieMal.htm 2009)

2.3 *Rhamphochromis* spp.

Rhamphochromis, locally known as ncheni is a silvery predatory cichlid with a large head, distinguishable from other haplochromine genera by the enlarged anterior teeth. There are different species but the most common one, *Rhamphochromis longiceps* attains a maximum length of 23 cm (Menz 1995) (Figure 6).

Figure 5: *Rhamphochromis* species (Oliver 1997).

Breeding has been observed to take place throughout the year. The species has a high fecundity compared to the other pelagic fish species ranging from 27-680 eggs per ripe female (Turner *et al.* 2002). The species are found in all habitats from eupelagic, deep shelf, shallow shelf, reefs, rocky littoral (benthic habitat on rocky shores) and margins (sandy/muddy shores, lagoons).

3 DESIGNING OF FISHING GEAR

Trawl net designing is a process that involves calculations of net specification and preparation of net plans for the trawl. The designer's knowledge and experience in behaviour and morphology of the targeted species is important in the process. Nowadays empirical methods of designing fishing gear have been replaced by analytical methods and are used in setting specifications of a design. The information for this process can be required from a prototype or from studies of the behaviour of fish. Scaling factors as described by Fridman (1986) can be used to decide on structural dimensions of the designed gear and also other parameters. It is important that the fishing gear matches the towing power of the vessel to be used. After determining the parameters the gear is drawn to scale using computer designing software.

A model may be made of the new design for testing in a simulated environment. This might be in a flume tank, pond, tunnel or even a swimming pool. Observations are made on the performance of the model and necessary adjustments made to the full scale design for optimum performance of the new fishing gear.

3.1 Midwater pair trawl

Midwater pair trawls are of a similar design as other midwater trawls (which are kept open by otter boards) though they may be designed to have a rectangular or box-like opening (FAO 2009). The opening of the mouth in a midwater trawl should be high in order to increase the fish herding area. The front part of the net is designed in such a way that it has large mesh sizes. As the fishing gear developed it became a known fact that large mesh sizes on the front parts of the gear greatly reduced the drag as water filtration is increased. Weights and floats are used to assist in the vertical opening of the net mouth. The trawl is rigged to bridles which are connected to warps. The warps then connect the trawl to the fishing vessel (Figure 7).

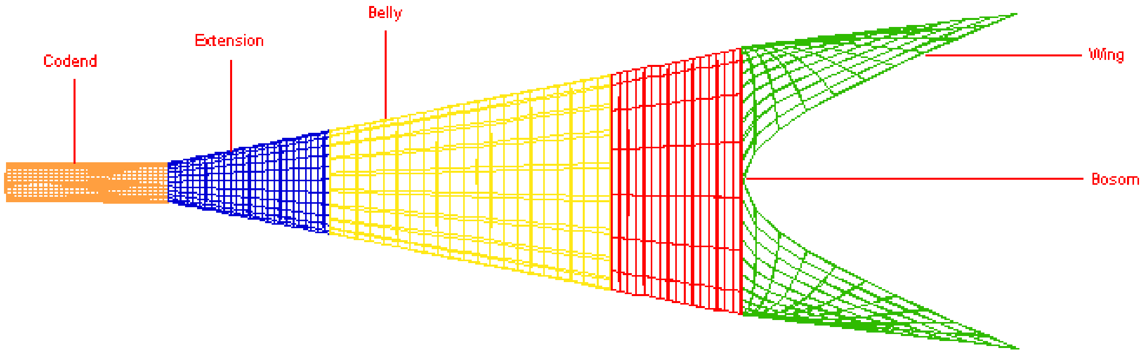

Figure 6: Main part of the midwater trawl net

3.2 Trawl net construction

Construction of the net begins with cutting to shape the netting material according to the design. Each section of the net is cut according to the cutting rates applied to the design. Reinforcement of the wings on the edges that the foot rope and head rope is to be attached to is done by doubling the twine on the outer meshes. Meshes on the bosom are also reinforced. Following the shaping and reinforcement is the assembly of the various sections which generally are wings, belly, extension and cod-end. This involves sewing the different sections together. The joined sections form a panel and a complete midwater trawl has four panels. Two of the panels form the lower and upper body of the trawl. The other two panels form the sides of the trawl. Lacing is done to join the panels. Lines are set on the laced sides to strengthen the trawl. Finally the foot rope and head rope are set on the wings.

4 FISH DETECTION

Midwater trawling can best be described as aimed trawling. The location and depth at which the fish is aggregated in the water column is vital (Gabriel *et al.* 2005). Fish detection during fishing is achieved through the use of fish finding devices. Important devices in fish finding are echo sounders, sonars and various sensors. These devices which are acoustic instruments transmit sound waves around the swept area and receive feedback from the targets in the area. Depending on the signal strength of the target an echogram is made on a monitor. The echogram gives details of the objects in the beam of the acoustic device. This helps the user to make an informed decision on his intent.

5 DESIGNING A MIDWATER TRAWL FOR LAKE MALAWI

5.1 Selecting a prototype

A prototype was selected from a number of designs in the FAO Catalogue of fishing gear designs (FAO 1978). A midwater pair trawl that has been used for fishing in the English Channel, S. North Sea with fishing vessels of 250-300 hp was chosen as a starting point for the study. The prototype midwater pair trawl design selected is shown in Figure 8.

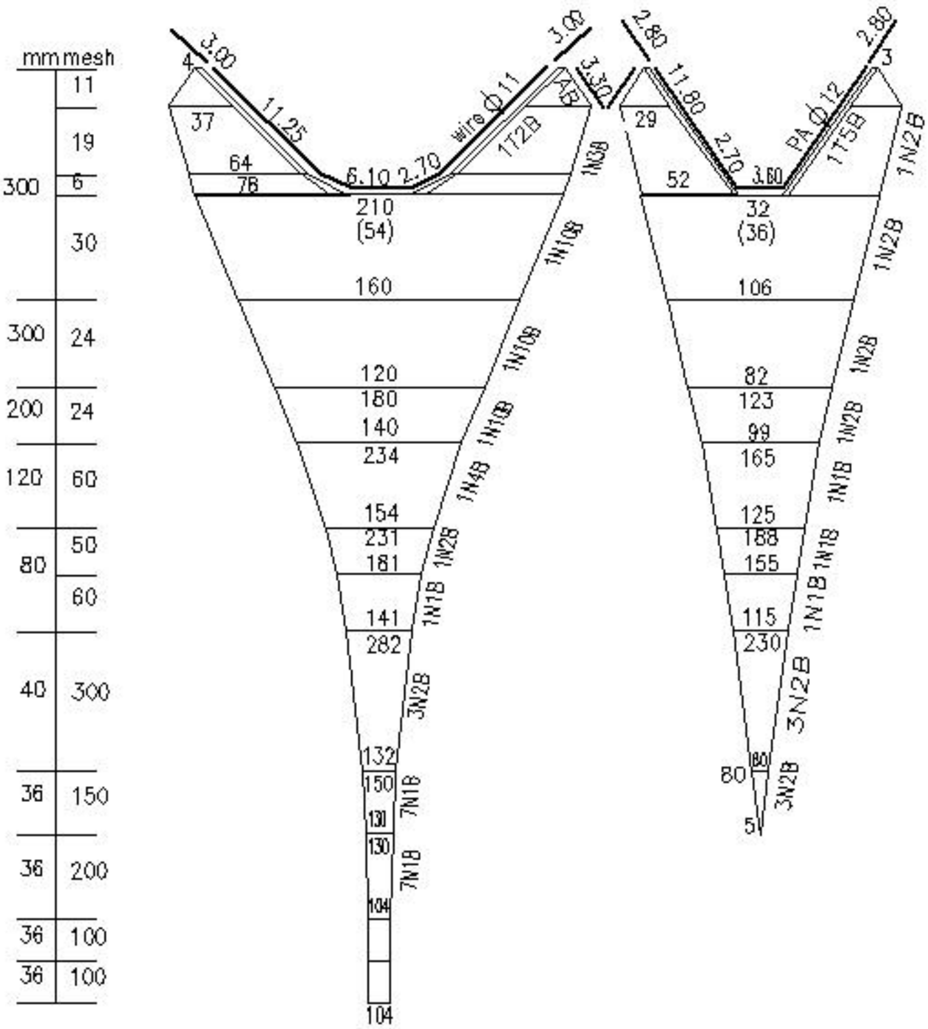

Figure 7: Prototype design of midwater pair trawl (FAO 1978). see details of specifications (Appendix 2)

5.2 Cod-end mesh size

Mesh size of the new trawl design is determined either by using a formula which gives the mesh opening in the cod-end such that the smallest commercial fish cannot gill or in a case that this mesh opening is not in conformity with regulations prescribing allowable mesh size for a particular fishing gear then the later prevail. The following formula by Fridman (1986) was applied to determine the initial cod-end mesh opening of the new design:

$$M_{oC} \approx \left(\frac{2}{3}\right) \times M_{oG}$$

3.1

Where,

M_{OC}: mesh opening of cod-end

$M_{OG:}$ mesh size of gillnet for particular fish species in selectivity trials and used in formula to estimate mesh opening of trawl net cod-end.

$$M_{oG=} {}^{L}\!/\!_{K_m}$$

Where:

L= length of the body of fish from tip of snout to the base of the caudal fin.

$K_{m=}$ empirical coefficient depending on the morphology of the fish and found by experimental fishing with gill nets. K_m =5 for elongated fish, K_m = 3.5 for medium fish and K_m = 2.5 for thick or deep bodied fish.

5.3 Scaling a new design from the prototype

The prototype linear dimensions and meshes in the sections were scaled down in a ratio of 90:300 for the basic working specifications which were adjusted accordingly; 90 being the effective power of two boats of 45 hp and 300 the horse power of the prototype pair trawl.

5.4 Calculation of the twine area

The twine surface area of the trawl was calculated as this has influence on the drag of the trawl. This gives the designer an idea of the size of net in relation to the available power to pull it through water at the desired trawling speed. Calculation of twine surface area was done using the following formula according to Prado (1990).

$$S = \frac{N + M}{2} \times H \times 2 \times a \times d \times 10^{-6}$$

3.2

Where,

S: surface twine area (m^2)
N: number of meshes at the top of the section
M: number of meshes at the bottom of the section
H: number of meshes in the height of the section
a: stretched mesh (mm) in section
d: diameter of twine (mm)

5.5 Calculation of towing resistance of new trawl design

Towing resistance calculation of new trawl design was done using the following formula according to Fridman (1986)

$$R = C_x \cdot q \cdot At \qquad \textbf{3.3}$$

Where, R= resistance of the trawl (kgf)

C_x= hydrodynamic coefficient

C_x which is hydrodynamic coefficient is determined by calculating the angle of incidence in the trawl body, in this case the angle between the extension section and the belly section (Fridman 1986).

$q = p.v^2/2$ stagnation pressure (kgf/m^2)
p = mass density of water
≈ 100 kgf-sec/m^4 (105 for sea water)
V= velocity of gear relative to the water or water relative to gear (m/sec)
At= total twine area of the trawl

5.6 Calculation of towing pull

The towing pull of the 45 hp pair boats was calculated so that a determination could be made on fitness of the trawl with available power. The formula for calculating towing power of the vessels was used according to Fridman (1986).

Formula used: $F_t = \frac{P. (K_F - 0.7v)}{3.4}$

Where,
Ft= towing pull (kgf)
P= engine brake horse power (hp)
K_F= an empirical towing force coefficient which ranges from 10 for trawlers with a conventional propeller and 15 for trawlers equipped with controllable pitch propellers.
V= the towing speed.

6 RESULTS

6.1 Cod-end mesh size

Determination of the mesh size in cod-end when designing a new fishing gear is of great importance. Fisheries authorities all over the world have in place regulations that govern permitted mesh size for different fishing gears (Fridman 1986). The same also applies to trawl nets and in Malawi the minimum cod-end mesh size is 38 mm. But this mesh size has been observed to be too small as many immature fish are caught (Kanyerere 2001). Calculation of the cod-end mesh opening such that the smallest commercial fish could not gill according to the Fridman (1986) formula gave a mesh opening of 36 mm (Appendix 1), smaller than the permitted mesh size in the fishery. For the new midwater trawl design the minimum mesh size was set at 42 mm following allowable mesh size in regulations.

6.2 New midwater pair trawl design

Having set the technical parameters of the design, drawing of the trawl net plan was done using DesignCAD Pro 2000. This is a computer designing software. ISO standards in regard to textile materials and drawing of net plans were followed. A new design is presented in (Figure 9).

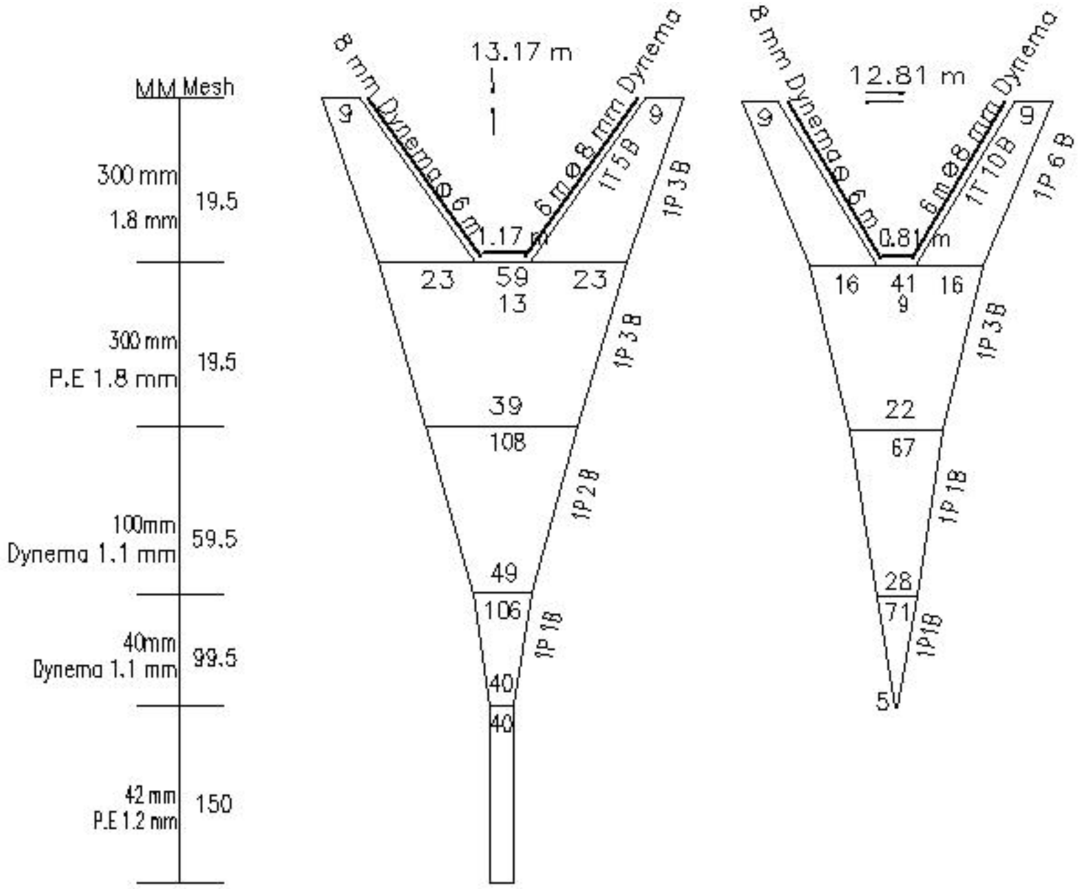

Figure 8: New design for a midwater pair trawl. See details of specifications in Appendix 3.

6.3 Netting twine area of the new midwater pair trawl design

The total twine area of the new pair trawl design (Figure 9) was calculated using formula 3.2, according to Prado (1990). The total calculated twine area is 12.2 m^2. The calculations are summarised in Table 1.

Table 1: Twine area of the new midwater pair trawl design in (m^2)

Upper and lower panel	Twine area in section	No of sections	A(m^2)
Cod-end	0.60	2	1.20
Extension	0.64	2	1.28
Belly 2	1.03	2	2.06
Belly 1	1.03	2	2.06
Wings	0.34	4	1.36
Twine area			7.96
Twine area for side panel			
Extension	0.33	2	0.66
Belly 2	0.62	2	1.24
Belly 1	0.66	2	1.32
Wings	0.26	4	1.04
Twine area			4.26
Total twine area			12.22

6.4 Towing resistance of new midwater pair trawl design

Towing resistance of the new midwater pair trawl design was calculated using formula 3.3, and results are summarised in Tables 2 and 3. As observed from Tables 2 and 3 trawl resistance and stagnation pressure are little at low speed but as the trawl is dragged at a high speed the resistance and stagnation pressure increase significantly. For the low hanging ratio of 0.2 it shows that the trawl resistance is slightly low compared to the 0.3 hanging ratio.

Table 2: Trawl towing resistance in (Kgf) at various speeds in knots and net hanging ratio of 0.2

Speed (knots)	Velocity (m/s)	Stagnation pressure (q)	Resistance (Kgf)
1.00	0.51	13.23	82.59
1.50	0.77	29.77	185.83
2.00	1.03	52.92	330.36
2.50	1.29	82.69	516.18
3.00	1.54	119.07	743.30
3.50	1.80	162.07	1011.72
4.00	2.06	211.69	1321.43
4.50	2.31	267.91	1672.43
5.00	2.57	330.76	2064.73

Table 3: Trawl towing resistance in (Kgf) at various speed in knots and net hanging ratio of 0.3

Speed (knots)	Velocity (m/s)	Stagnation pressure (q)	Resistance (Kgf)
1.00	0.51	13.23	87.45
1.50	0.77	29.77	196.76
2.00	1.03	52.92	349.79
2.50	1.29	82.69	546.55
3.00	1.54	119.07	787.03
3.50	1.80	162.07	1071.23
4.00	2.06	211.69	1399.16
4.50	2.31	267.91	1770.81
5.00	2.57	330.76	2186.19

Towing pull of the pair boats was calculated using formula 3.4 and the results are summarised in Table 4. As the results show in the Table 4, the pair boats have more pulling force at low speed and decrease as the speed increases.

Table 4: Towing pull of the pair boats in (Kgf) and speed in knots

Speed (knots)	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
Towing force(Kgf)	837.00	805.50	774.00	742.50	711.00	679.50	648.00	616.50	585.00

Figure 10 shows the relationship between total towing power of 45 hp pair boats and the resistance of the trawl net. The trawl head rope and foot rope is hung at 0.2. As the speed of the vessel increases the drag in the net increases and maximum towing speed is reached at 3 knots. Beyond this point there is little pulling power from the vessel.

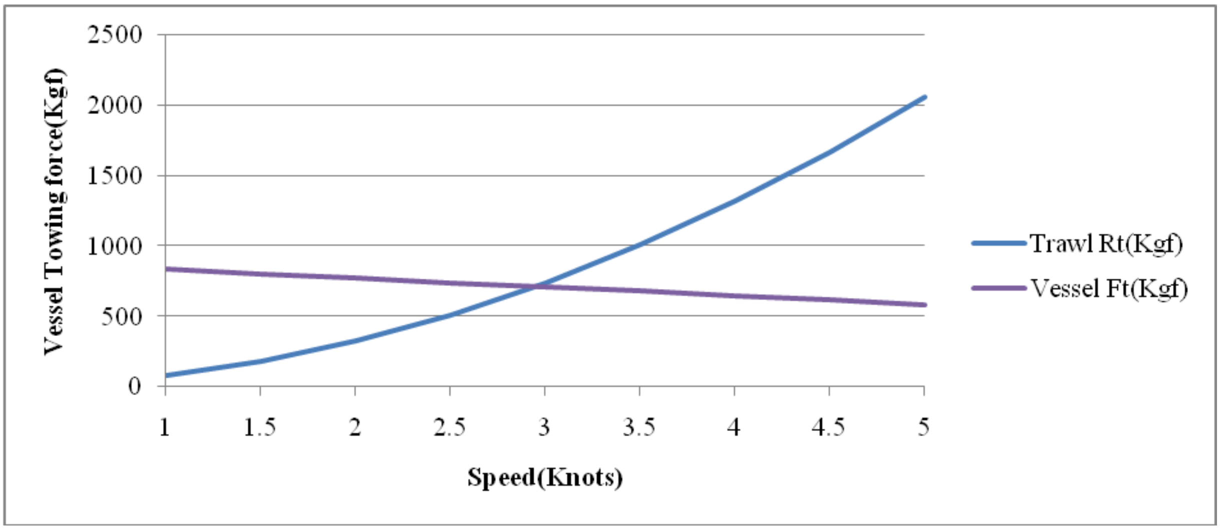

Figure 9: Comparison of vessel towing force (Kgf) and trawl resistance (Kgf) at 0.2 hanging ratio

Figure 11 shows the relationship between total towing power of 45 hp pair boats and the resistance of the trawl net. The trawl head rope and foot rope is hung at 0.3. As the speed of the vessel increases the drag in the net increases and maximum towing speed is reached at 2.8 knots. Beyond this point there is little pulling power from the vessel.

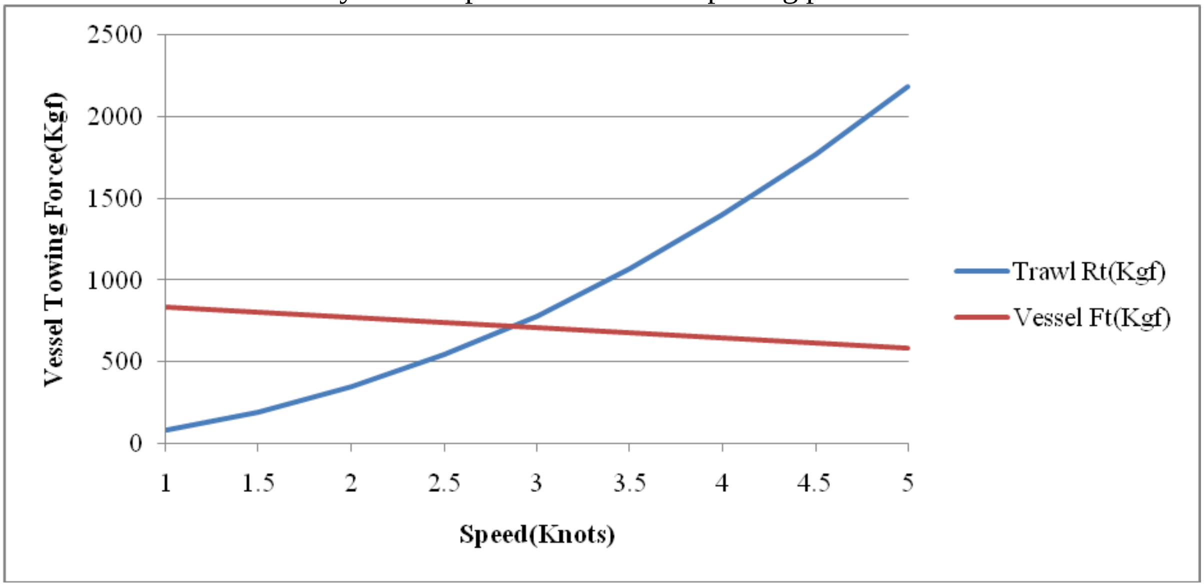

Figure 10: comparison of vessel towing force (Kgf) and trawl resistance (Kgf) at 0.3 hanging ratio

6.5 Materials

The materials for construction of the net were chosen upon their availability from suppliers. Machine knit netting sheets were used in the construction of the trawl net. The netting sheets used were of different sizes and fibre material. These netting sheets were used:

- P.E. netting sheet 500 meshes long and 49.5 meshes deep, 30 mm stretched mesh size and 1.8 mm twine diameter was used for wings and upper belly sections.

- Dynema netting sheet 1000 meshes long and 99.5 meshes deep, 100 mm stretched mesh size and 1.1 mm twine diameter was used for the lower belly section.
- Dynema netting sheet 2000 meshes long and 199.5 meshes deep, 40 mm stretched mesh size and 1.1 mm twine diameter was used for the extension section.
- P.E netting sheet 2000 meshes long and 199.5 meshes deep, 42 mm stretched mesh size and 1.2 mm twine diameter was used for the cod-end.
- Danline rope of 12 mm diameter was used as frame line on the laced edges of the trawl panels.
- A dynema rope of 8 mm was used for the foot rope and head rope.
- Twines of different sizes were used to join the sections, lacing, strengthening of the wing edges and bosom.

6.6 Net construction

With the trawl net plan complete, the net makers at Fjardanet were consulted on the viability of the plan and their suggestions were taken into consideration. Construction of the net took place at Fjardanet Ltd in Isafjordur (Iceland) from 14 January 2009 to 11 February 2009.

Construction of the net began with cutting to shape the netting material according to the design. Each section of the net was cut according to the cutting rates applied on the net plan (Figure 12).

Figure 11: Net shaping at Fjardanet, Iceland.

Reinforcement of wings on the edges that are attached to the foot rope and head rope was done by doubling the twine on the outer meshes. Reinforcement of the bosom outer meshes was done. Following the shaping and reinforcement was the assembly of the various sections which generally are wings, belly, extension and cod-end. This involved sewing together sections and since sections differed in mesh sizes it meant taking more meshes on the section with small meshes to join to the section with big meshes. Then the panels formed from this process were laced together to form a complete body of a midwater trawl. Lastridge lines were attached to the seams to strengthen the trawl from the belly to wings and also the cod-end as these parts were made of P.E. material. Meshes on outer part of the wings were strengthened by doubling the mesh and a gable was set on the wing end. Then finally the foot rope and head rope were set on the wings.

6.7 Fish finding equipment

For the study a planked boat of an overall length of 7.6 m, beam overall of 2.8 m, Load water line 6.5 m, displacement 2900 kg and with a carrying capacity of up to 2 tonnes is designated for midwater pair trawling. A similar boat type is used in bottom pair trawling on Lake Malawi (Figure 13).

Figure 12: Open plank boat (Source: www.flickr.com 2009)

A search on the internet was made to look for fish finding devices that could be fitted to the vessel and trawl for better performance. The devices searched for were echo sounders, sonars and sensors (Figures 14 and 15). These devices assist in locating of fish schools and positioning of the trawl net. A number of low priced products were found. A simple illustration of installation of the devices in the boat is shown in (Figure 16).

Figure 13: Sonar (Source: Echo sounders and sonars www.boatbandit.com [Accessed 16 January 2009])

LOWRANCE X88DF by: Lowrance The very picture of high-detail, feature-packed, dual-frequency 50/200 kHz LCD sonar performance for depths to 1,700 feet!*

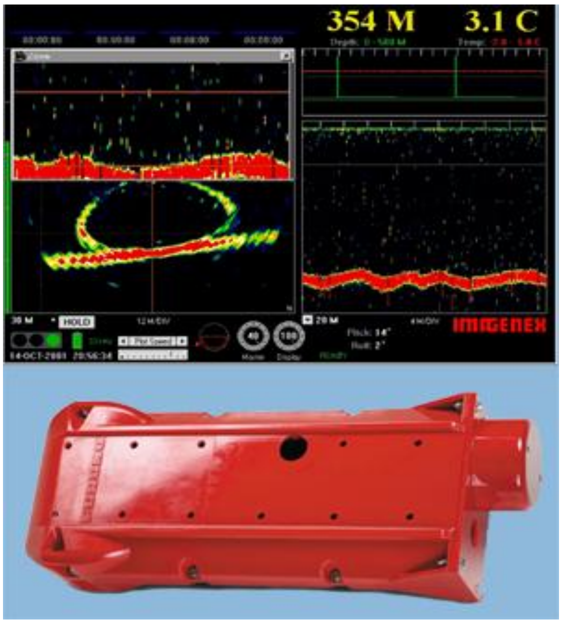

Figure 14: Trawl sonar (Source: Echo sounders www.furuno.no [Accessed 16 January 2009])

In the absence of a net sounder, an approximate method for trawl positioning can be used. The method has been used in the midwater trawl fishery before acoustic devices were fully developed. According to Prado (1990) warp angle A in Figure 17 is measured using a protractor or other devices and then estimated from a horizontal scale of graph that has estimated depth of trawl, length of warps and angle of inclination (Prado 1990: 83). The depth of the trawl can also be measured by marking the warp one meter aft of block and in case of the proposed boats of transom. A line is dropped vertically and then the distance between it and the wire is measured. The measured distance is correlated in a table giving trawl depth and warp length (Prado 1990: 83).

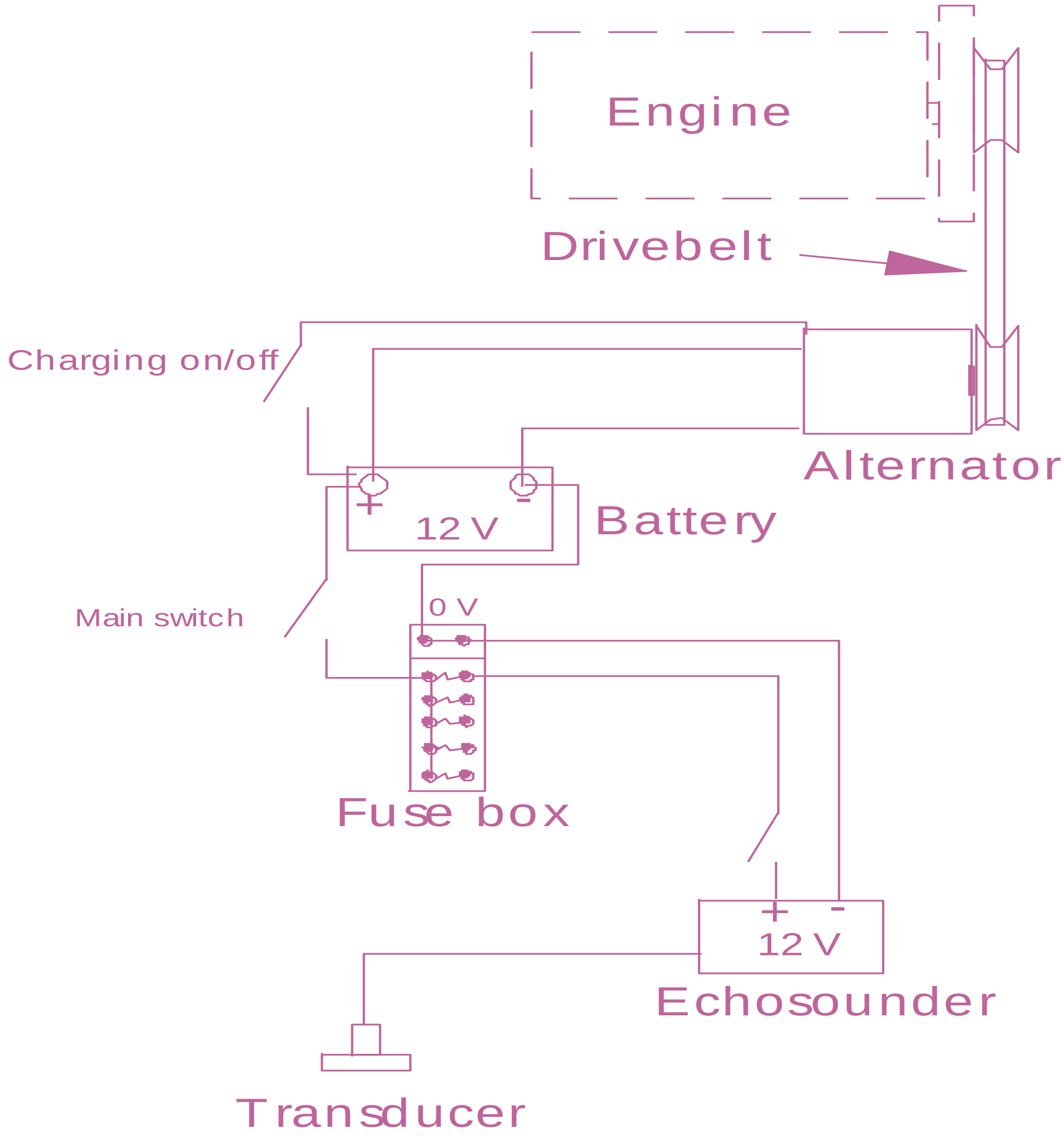

Figure 15: A basic arrangement showing echo sounder and DC connection

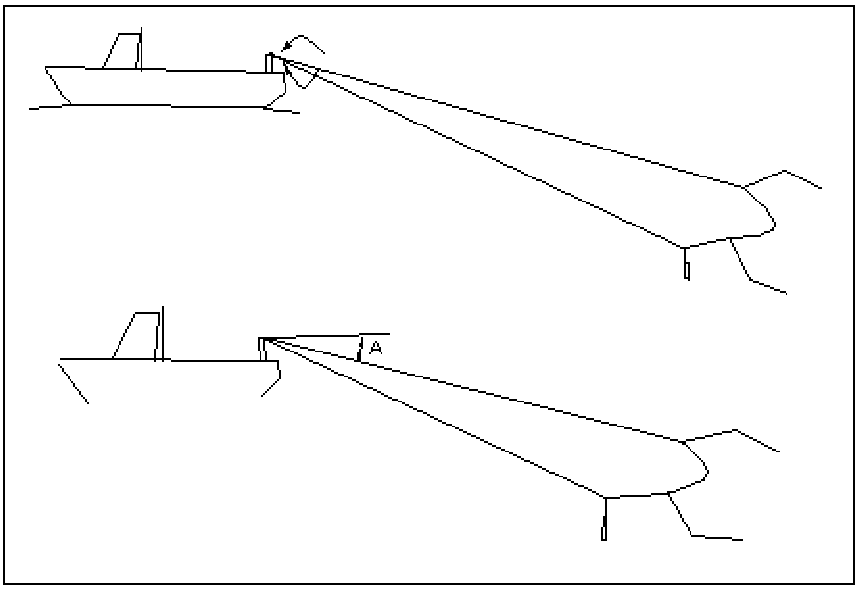

Figure 16: Warp angle A during trawling estimated with a protractor or string.

Fishing gear handling equipment is important for a midwater pair trawl to perform properly. A winch is a main component in a fishing vessel and a hydraulic winch of 18 hp to 20 hp and a capacity of 2 tonnes, warp length 500-375 m and wire diameter of 6-8 mm is capable of doing the job for the trawler of 45 hp (Prado 1990: 128). A hand winch of 2 tonne capacity, 0.41 m length between the flanges, 0.22 m flange diameter and shaft diameter of 0.1 m, 375 m warp length and wire diameter of 6 mm could be a viable option (Figure 18).

Figure 17: Hand winch. Spur Gear Series 2 LM and HM Models BW Models 2 US Ton Capacity. (Source: www.pacificmarine.net)

7 DISCUSSION

It has been the priority of the fisheries department in Malawi to develop appropriate fishing gear for the low income artisanal fisheries and small-scale fisheries so that they are able to exploit the offshore fish resources (ICEIDA 2005).

Work worth noting on fishing gear development is on an open water seine locally known as chirimila operating in waters of 40 m depth and targeting a pelagic fish species *Copadichromis* spp. The fishing gear has been the subject of a number of studies looking at its modification for offshore deep water use. The Likoma/Chizumulu Artisanal Fisheries Development project looked at the modification of the chirimila seine net. Currently the Small-scale Offshore Fisheries Technology Development Project which is a government initiated project with assistance from the Icelandic International Development Agency is looking at the development of chirimila for offshore fishing (ICEIDA 2005).

In this project a midwater pair trawl was a fishing gear chosen for study because it is a proven fishing gear for exploiting pelagic fish and also it works well with small vessels. Other conditions such as the level of development in the fishery played a role since the fishery has a small mechanised sector and the bulk of fishermen are in the artisanal sector.

A number of steps have to be followed to design a viable midwater pair trawl. Net designing and construction is a complex task which requires the designer to be innovative and at the same time practical. In the process of designing and construction a number of designing requirements have to be considered and at the same time allowance has to be made for certain aspects of designing to satisfy working conditions. A prototype was chosen from FAO Catalogue of Fishing Gear Designs (FAO 1978). This is a fishing gear that has been used in the English Channel. A number of modifications were made to the prototype. The modifications took into consideration the power of the fishing boats which in this case is small and the trawl net had to match with this power in such a way that the drag during trawling does not result in speed lower than required to capture the fish.

Currently stern trawlers owned by MALDECO fishing company operate midwater trawls at 2.5 to 3 knots when targeting *Diplotaxodon* spp. (pers. communication). For this study the same trawling speed was applied. The sections in the prototype were of varied net twine size and this was seen as a constraint if looked at from the point of view of future developments as it would be difficult to maintain the trawl due to lack of materials. It is advisable to use readily available materials as it is both economical and time saving. In the new design cod-end mesh size was set slightly above the minimum mesh size allowed by government regulations in Malawi which is 38 mm.

The mesh size in the cod-end was set at 42 mm in due consideration of observation that more immature fish are caught in trawl nets with 38 mm cod end (Kanyerere 2001). In the wings and top belly, the mesh size was maintained as in the prototype. Bigger meshes in these parts have been known to reduce drag of the fishing gear as there is high filtration of water. Studies have also shown that there is limited escape of fish from the big mesh as evidenced by some midwater trawl nets having ropes in the front part (Gabriel *et al*. 2005). Fish are known to only actively try to escape when they are confined in the cod end. The original prototype was made for 300 hp, so a scaling factor of 90:300 (90 hp is the total power of two 45 hp pair boats) was used to scale down the linear dimensions of the new design. Changes were made in the number of sections and twine diameter of netting. The new design has fewer sections and this considerably reduced working time during construction. There was a change in netting material from polyamide in the prototype to two types of netting material in the new design. In the new design polyethylene and Dynema was used. Availability of these materials in the required quantities allowed timely construction of the trawl net. Thicker twine for the wings and top belly were incorporated so that the trawl will not suffer damage due to touching the bottom which is unavoidable as the density of fish is highest close to the bottom and depth is not uniform. Wings were lengthened in the new design with the aim of increasing horizontal mouth opening. The tentative design was matched with the towing power of the designated boats which in the study are 45 hp pair boats (90 hp total power) and 7.6 m overall length.

For any trawl to work it has to match the available towing power. In a comparison of the trawl resistance and towing power at two different hanging ratios of 0.2 and 0.3 it became clear that 0.3 hanging ratio gives a better mouth opening of the trawl and maximum trawling speed for the targeted fish species. A considerable reserve power is necessary after matching the trawl resistance to the towing power. This is important in midwater trawling as it is aimed at trawling and sudden manoeuvres require extra pull. Lack of reserve towing capability would result in engine overloading. Having set the specifications a scaled drawing in DesignCad 2000, a computer designing software resulted in a tentative net plan that was a modification of the prototype. This plan was taken to the net makers for validation and suggestions they made were taken in. The complexity of designing was seen on actual construction of the net which showed that practice and theory sometimes conflict. Shaping of the net resulted in different mesh numbers in some sections of the new designed net. This made it necessary to revisit the drawing after the net construction to reflect the changes.

A midwater pair trawl net is dependent on other working parts being operational. The rigging has to be correct for proper opening of the mouth and shape. This also prevents tearing of the trawl from shearing forces. Handling of the fishing gear on-board and fishing operation is important. Two methods are suggested; the use of a winch or alternately a system of rollers on both boats placed on the fore peak and transom. By the manoeuvre of one of the boats the fishing gear is shot out or hauled. This system is currently being used in the fishery by two boat pair trawlers using demersal trawls in shallow waters.

To do trawling with this type of fishing gear, fish detection devices are required. In midwater trawling the trawl position and targeted fish range is important. Devices like trawl sonar and echo sounder can help solve this problem when installed in the boat (Figures 14 and 15). An attempt is made to illustrate how they can be arranged with power being tapped from the engine to run the devices (Figure 18). In the absence of these devices, an approximate method of determining the trawl position using angle of inclination and measuring distance between warp and point of inclination have been discussed in a previous chapter.

The boats operating the trawl net will also need slight modifications and this could be increasing the freeboard by adding a deck. A wheelhouse is important as part of the modifications so that the devices are protected from the elements. The boats currently in use are open to the elements. Similar boats are used in Lake Tanganyika in the purse seining fishery after successfully modifying them. Previously they were used as water taxis and have an overall length of 9-20 m (Morissens and Lessent 1979). These boats could be studied to have an idea of how to modify the boats for midwater pair trawling.

Communication cannot be neglected and this will be needed in the successful implementation of the fishing operation. At present most small boats don’t have VHF radios in Malawi. Radio communication is important between the captains of the boats.

All this work will not be worth much if the fishing gear is not tested. For this to take place collaboration will be sought through linking this study to the Small-scale Offshore Fisheries Technology Development Project.

8 CONCLUSION

This study is a preliminary work in the development of two boat midwater trawls suitable for Malawian fisheries conditions. It requires in depth assessment of this fishing gear through testing on the lake as this a prerequisite for fishing gear undergoing development. A number of performance factors need to be satisfied such as catch rate, handling and selectivity. For this to materialise, knowledge and technical abilities need to improve. All this requires funds to be available for the necessary work. Looking at the trends in Malawian fisheries, development of fishing gears for fisheries resources in deep offshore waters is a task that cannot be put aside any longer.

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LIST OF REFERENCES

Bland, S.J.R. and Donda ,S.J. 1994. *Management Initiatives for the Fisheries of Malawi*. Department of Fisheries. Bulletin No 9.

Bulirani, A.E.,Banda,M.C., Palsson, K.P.,and Weyl,O.L.F.1999. *Fish Stocks and Fisheries of Malawian Waters*. Resource Report 1999. Government of Malawi, Fisheries Department.54pp

CIA 2008.The World FactBook <http://www.cia.gov/library/publications/the world factbook/geos/mi/html> [Accessed November 23, 2008].

Duponchelle,F. and Ribbink,A.J.2000. *Fish Ecology Report*. Lake Malawi/Nyasa/Niassa Biodiversity Conservation Project. SADC/ GEF

Eccles, D.H.1974. *An Outline of the Physical Limnology of Lake Malawi*. Limnology & Oceonography, vol.19, No 5(September, 1974) pp. 730-742.

FAO 1976. *An analysis of the various fisheries of Lake Malawi*. Based on the work of J.Turner. Rome,FAO/F1:DP/MLW/71/516 Technical Report 1: 73p

FAO 1978. Food and Agriculture Organization Fishing Gear and Methods, B. FAO catalogue of fishing gear designs. Farnham, Fishing News Books.

FAO 2005. Malawi Fisheries Country Profile. Rome: FAO <http://www.fao.org/fishery /topic/12309/en> [Accessed November23,2008].

FAO 2009. *Fishing Techniques, Midwater pair trawling*. In: FAO Fisheries and Aquaculture Department [online]. Rome <http:www.fao.org/fishery/fishtech/1006/en>.[Accessed 17 February 2009].

Fridman, A.L. 1986. *Calculations for fishing gear designs*. Fishing News Books. Farnham, Surrey, England.

Gabriel, O., Lange, K., Dahm, E and Wendt, T., 2005.*Von Brandt's Fish Catching Methods of the World*. Blackwell Publishing.

ICEIDA, 2005. Small-scale Offshore Fishing Technology Development Project. *Project document*. Fisheries Department. Ministry of Mines, Natural Resources and Environment in collaboration with Icelandic International Development Agency (ICEIDA).

International Lake Environmental Committee 2004. Bathymetric map of Lake Malawi http://anthropology.net/2007/09/03/climate-change-drove-human-evolution/bathymetric-map-of-lake-malawi/

Kanyerere,G.Z.2001. *Spatial and Temporal Distribution of some Commercially Important Fish Species in the Southeast and Southwest Arms of Lake Malawi: A Geostatistical Analysis*. Department of Fisheries. Bulletin No 43.30pp.

Lewis, D., Reinthal,P.,and Trendal,J.1986. *A Guide to the Fishes of Lake Malawi National Park*. Gland, Switzerland.

Menz, A. 1995. *The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa*.Scientific Report of the UK/SADC Pelagic Fish Resource Assessment Project. Natural Resources Institute.Overseas Development Adminstration.

Morissens, P. and Lessent,P. 1979. *The role of fishery technology in management and development of freshwater fisheries in Africa*. CIFA Technical Paper- CIFA/T6. 72 pp AC674/E

Oliver M. K. 1997. http://malawicichlids.com/mw08096.htm
Prado, J.1990. *Fisherman's Workbook*. Fishing News Books, Oxford .

Ribbink,A.J. 1991. *Distribution and ecology of the family Cichlidae: an overview*. In Cichlid Fishes Behaviour, Ecology and Evolution (M.H.A Keenleyside, ed.) London: Chapman & Hall.

Thompson, A.B and Allison, E.H.1997. *Potential yield of unexploited pelagic fish stocks in Lake Malawi*. Fisheries Management and Ecology. 4: 31-48

Turner,G.F., Robinson,R.L., Ngatunga,B.P., Shaw,P.W., and Carvalho,G.R. 2002. *Pelagic Cichlid Fishes of Lake Malawi/Nyasa: biology, management and conservation*.pp 353-367 in COWX, I.G (ed), Management and Ecology of Lake and Reservoir Fisheries. Fishing News Books, Blackwell Science Ltd, Oxford.

Turner, G. F. 1992. *Mechanised Fisheries of Lake Malawi*. GOM/UNDP/FAO Chambo Fisheries Research Project, Malawi. FI:DP/MLW/86/013, Field Document 23: 22pp.

Turner, J.L.1977. *Some Effects of Demersal Trawling in Lake Malawi (Lake Nyasa) from 1968 to 1974*. Journal of Fish Biology.Vol.10 pp 261-271.

Tweddle, D., Alimoso, S.B and Sodzapanja, G. 1994. *Analysis of Catch and Effort Data for the Fisheries of the Southeast Arm of Lake Malawi*. Fisheries Bulletin No 13. Department of Fisheries.

Appendix 1

Minimum cod-end meshes size calculation from formula 3.1:

MoC = $\frac{2}{3} \times MoG$ Where, MoG= $\frac{L}{Km}$

MoC: Cod- end Mesh size
L: length of fish species.
Km: Coefficient.

MoG= 190/3.5= 54.28571429
MoC= 2/3 x 54.28571429 = 36.19047619
MoC= 36 mm

Appendix 2

Table 5: Technical specifications of the prototype midwater pair trawl design

Lower &upper panel	Meshes in Section		Meshes Deep	Cutting Rate	Mesh Size (mm)	Twine Diameter (Mat Rtex)
	upper	lower				
Cod-End						
1	104	104	100	AP	36	1300
1	104	104	100	AP	36	1300
Extension						
1	104	130	200	7N1B	36	940
2	130	150	150	7N1B	36	650
3	132	282	300	3N2B	40	450
Belly						
1	141	181	60	1N1B	80	650
2	181	231	50	1N2B	80	650
3	154	234	60	1N4B	120	650
4	140	180	24	1N10B	200	940
5	120	160	24	1N10B	300	1200
6	160	210	30	1N10B	300	1500
Wings						
1	76	64	6	1N3B 1T2B	300	1500
2	64	37	19	1N3B 1T2B	300	1500
3	37	4	11	AB 1T2B	300	1500
				1T1B		
Side panel						
Extension						
1	5	80	150	3N2B	36mm	650
2	80	230	300	3N2B	40mm	450
Belly						
1	115	155	60	1N1B	80mm	650
2	155	188	50	1N1B	80mm	650
3	125	165	60	1N1B	120mm	650
4	99	123	24	1N2B	200mm	940
5	82	106	24	1N2B	300mm	1200
6	106	136	30	1N2B	300mm	1500
Wings						
1	52	29	25	1N2B 1T5B	300mm	1500
2	29	3	11	AB 1T5B	300mm	1500

Appendix 3

Table 6: Technical specifications of the new midwater pair trawl design

Lower &upper panel	Mesh Deep	Meshes in Section		Mesh Size	Cutting Rate	Twine Diameter	Twine Material
		Lower	Upper				
Cod End	149.5	40	40	42mm	AP	1.2mm	PE
Extension	99.5	40	106	40mm	1P1B	1.1mm	Dynema
Belly 2	59.5	50	108	100mm	1P2B	1.1mm	Dynema
Belly 1	19.50	39	59	300mm	1P3B	1.2mm	PE
Wings	19.5	23	9	300mm	1P3B 1T5B	1.2mm	PE
Side Panel							
Extension	99.5	5	71	42mm	1P1B	1.1mm	Dynema
Belly 2	59.5	28	67	100mm	1P1B	1.1mm	Dynema
Belly 1	19.5	22	41	300mm	1P2B	1.2mm	PE
Wings	19.5	16	9	300mm	1P6B 1T10B	1.2mm	PE