FISHERIES TRAINING PROGRAMME
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Final Project 2005

GEAR MODIFICATION TO REDUCE BY-CATCH IN THE TANZANIAN SHRIMP FISHERY

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ABSTRACT

There has been a need to improve the selectivity for shrimp and fish in tropical shrimp fisheries areas like Tanzania to reduce by-catch in coastal fisheries. The reduction of juvenile shrimp and fish can constitute a strategy to minimise discard. A study was done to review the literature and to evaluate possible solutions for the Tanzanian shrimp fishery.

In this report, modified fishing gear with a selection grid and a square cod end is proposed which could improve the selection and reduce by-catch. The selection grid is made from aluminium mounted at an angle of 33° in the net section and has a length and width of 1.65 m and 0.8 m respectively, with bars 14 mm apart. Mesh size for the square mesh cod end was chosen 45 mm.

A full scale prototype of the selection grid and square mesh cod end was constructed. The proposed function of a designed grid system is that larger shrimp and larger fish are guided into the cod end, and that small shrimp and juvenile fish will escape through the sorting grid. The use of square mesh cod end gives an additional opportunity for juveniles to escape.

LIST OF ABBREVIATIONS

BOT	Bank of Tanzania
CPUE	Catch per unit effort
EAMFRO	East African Marine Fisheries Organization
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
FD	Fisheries Division
GDP	Gross Domestic Production
GRT	Gross Registered Ton
HP	Horse Power
Km	Empirical coefficient of fish morphology
Kgf	Kilogram force
L	Length of fish body
M	Larger number of meshes
m	Smaller number of meshes
MNRT	Ministry of Natural Resources and Tourism
M_{OC}	Mesh opening in the cod end
M_{OG}	Mesh opening of net
MSY	Maximum Sustainable Yield
NE	North East
PA	Polyethylene
PE	Polyethylene
R/V	Research Vessel
SSB	Single Side Band
SW	South West
SWIOP	South West Indian Ocean Project
TAFICO	Tanzania Fisheries Co operation
TAFIRI	Tanzania Fisheries Research
Tshs	Tanzania shillings
URT	United Republic of Tanzania
VHF	Very High Frequency
Y	Cutting ratio

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1 INTRODUCTION

By-catch has become a global fisheries management problem. Discard is estimated about 17.9 million metric tons annually (Elverson *et al*. 1994). According to (FAO 1999) estimates of total discard suggest it to be about 20 million tons. But an overview of global by-catch and discard suggests that discard data in fisheries worldwide is incomplete. This is due to the nature of the data collection; the data collection must be done at sea which is expensive and usually imprecise.

Target species usually have a minimum landing size for commercial purposes. When the smaller fish is retained in the fishing gear it becomes an unwanted part of the catch and is usually discarded. Much of the by-catch in a bottom trawl might not survive because it is damaged in the net, brought up from the depth too quickly, or thrown back too late. Management of by-catch has become a very important issue in fisheries management. Innovations in trawls technology to reduce by-catch and thus discard work best when unwanted species show a markedly different reaction to them (Glass *et al*.1999)

Most tropical fisheries deal with various species. Shrimp fisheries in tropical waters produce a large by-catch of fish resulting in large amounts of discard. This by-catch is composed of small shrimp and fish, in addition to shellfish, plants, jellyfish, crustaceans, crabs etc.

There is a high level of by-catch in tropical shrimp trawl fisheries. This is also true for Tanzania where the ratio of shrimp to by-catches ranges from 1:1 to 1:3 (Mahika 1992, Nkondokaya 1992). This includes undersized prawns and fin fish, mainly juveniles. This is bad for the fishery and also has a negative impact on fish species. The issue of selectivity of shrimp fishing gear is very important, as it constitutes the most important tactic to reduce the problem. Many other shrimp fisheries have successfully introduced fish exclusion devices and improved gear selections for prawns. It is against this background that the present study of reduction of by-catch in the Tanzanian shrimp fishery is proposed. The aim of this study is to review current knowledge to reduce by-catch and propose changes in Tanzania fisheries to reduce by-catch.

A study on size selectivity was conducted by the Tanzania Fisheries Research Institute (TAFIRI) to analyse the composition of the catch and by-catch. It was observed that most of the catch includes both juvenile prawns and fish (Haule 2001).

Shrimp is economically important in Tanzania in terms of annual export earnings as it contributes US$6.6 million in revenue (URT 2003). The shrimp fishery in Tanzania is done in brackish water, which is feeding and breeding ground for many species of fish and shrimp. During trawling the existing gears used do not select the type and size of the targeted species. Therefore it is quite difficult to regulate selectivity for all species through the minimum mesh size of cod end. There is a need to improve the size selectivity for shrimps in the industrial shallow water shrimp fishery.

Five common penaeid species have been identified in the shrimp fishery in Tanzania; *Penaeus indicus* (white prawn), *Penaeus monodon* (giant prawn), *Penaeus* *semisulcatus* (tiger prawn), *Metapenaus monoecros* (brown prawn) and *Penaeus japonicus* (flower prawn).

It is difficult to estimate the amount of fish caught, as by-catch in Tanzanian shrimp trawling. Trawler owners and crews are not cooperative and unwilling to give information with regard to by-catch. The main reason is that most of the by-catch is discarded at sea which is illegal. Reporting the amount of by-catch could lead to institutional management measures. Based on estimations that have been made by different researchers, it is evident that a substantial amount of fin fish is being caught as by-catch (Mgawe 1999).

By-catch has significant importance to the country in terms of human consumption (Mgawe 1999). Therefore it is important to determine how different mesh sizes and use of selective devices (grids) affect the size selection of the by-catch. Specimen with a length below their mature length can then grow bigger and be fished later.

Wise use of marine resources is very important for socio-economic development especially for coastal communities that are highly dependent on fisheries for their food and income. Development of good fishing methods for the Tanzanian shrimp fishery will maximise economic benefits and contribute to the sustainable use of marine resources.

The high discard in the Tanzanian shrimp fishery gives a negative image of this sector of the fishing industry. The issue of selectivity of shrimp fishing gear is therefore of vital importance.

The main objective of this study is to propose modified (model) fishing gears and selection devices that could improve the selection of adult prawns and fish of profitable size and in that way contribute to the reduction of by-catch.

2 TANZANIA FISHERIES

Tanzania is a coastal state bordering on the Western Indian Ocean. The country has a total surface area of 945,040 km^2 and a marine coastline 1450 km long. The coast has a narrow continental shelf, which is well endowed with inland water bodies. The marine territorial water area is 64,000 km^2 (MNRT 1997) and the Exclusive Economic Zone covers 223,000 km^2 (Government of Tanzania 2003). It has a population of 40 million (census 2000). Tanzania is the largest country in East Africa. Bordering all three great lakes of Africa (Victoria, Tanganyika and Nyasa) (see **Error! Reference source not found.**).

Figure 1: Map of Tanzania showing major water bodies and rivers (Magellan Geographic 1997).

The standing stock of marine fish resources is not well known. From a fishery resource survey carried out by the Norwegian Research Vessel R/V Dr FRIDTJOF NANSEN in 1982/1983 the standing stock of marine fishes in waters below 20 m depth was estimated between 100,000 to 210,000 metric tons (Iverson *et al*. 1984), while the potential yield has been estimated at 25,000 to 44,000 metric tons per year

There is limited scientific information on prawns off the Tanzanian coast to aid planning management and rational exploitation. The SWIOP Project estimated a lower MSY of 1,050 metric tons in 1990. The fishing industry in Tanzania is divided into industrial and artisanal fisheries. Industrial fisheries contribute about 5% of the total catch and the small-scale artisanal fishery in inshore waters accounts for over 95% of marine fish landings (Jidawi and Othman 2002). In 2003 a there was a total catch of 49,270 metric tons and the number of fishers was over 1900.

According to Fisheries Master Plan 2002, fish provides 30% of the animal protein consumed by the Tanzanian population. Both the industrial and artisanal fisheries sectors contribute 2% to 3% to the GDP (BOT 2001).

The Fisheries Act No. 6 of 1970 concerns exploitation and conservation of the fisheries resources. The law empowers the minister responsible for fisheries to make such regulation as:

Restricting the fishing time: this regulation was introduced in 1990 and trawlers are allowed to operate from 06.00 am to 18.00 pm**.** This is aimed at reducing the fishing pressure and maximising the conflict between industrial prawn fishers and artisanal fishers. Normally artisanal fishers set their nets at night and haul in the morning. (Haule 2001)

Zoning system; this regulation was introduced 1988 and was aimed to spread and balance the fishing effort, reduce fishing pressure at one fishing ground and encourage fishing vessels on another less exploited. (Haule 2001)

Closed fishing season: this was introduced 1990. The closed season is from December to March. At this time of year many juveniles were observed in the catches, so it was mainly introduced to allow the prawns to breed.

Vessel observers; a regulation to put fisheries observers onboard fishing vessels started in 1987. Fisheries staff as observers whose duty is to ensure adherence to the laws and regulations, to gain experience and sometimes engage in scientific research.

Restriction on capacity; restrictions on the size of the shrimp fishing vessels were introduced in 1997. The maximum GRT was 150 and the capacity of the vessel was reduced to 500 horse power (HP).

Registration and fishing licence fees; when the vessel is commissioned for the first time it is subjected to pay registration fees, and a fishing licence is paid annually. This is charged per GRT, and the rates vary with vessel size, flag state of the ship and shore infrastructure (Wilson 2004).

Other regulation; fishing companies are obliged to submit their monthly fishing data to the director of fisheries, restricting the number of fishing nets in each vessel to two during any trawling time etc.

Tanzania fisheries are categorised as artisanal or commercial. Artisanal in marine as well as in fresh water is primarily inshore, which is done by fishermen using simple gears and small boats. Inspite of a long coastline, about 80% of the total fish supply is from fresh water (Table 1)**Error! Reference source not found.**).

Table 1: Fisheries production in Tanzania from 1991 to 2001 (FD 2003).

Year	No of fishers	No. of vessels	Fresh water production (tons)	Marine water production (tons)	Total (tons)
1991	76,952	24,245	272,370.10	54,342.70	326,712.80
1992	61,467	19,955	291,615.00	43,886.20	335,501.20
1993	61,493	20,976	294,782.10	36,684.80	331,466.90
1994	61,493	20,976	228,003.60	40,785.40	268,789.00
1995	61,493	22,976	207,139.00	51,073.30	258,212.30
1996	75,621	22,976	262,572.10	61,241.20	323,813.30
1997	75,621	22,976	306,750.00	50,210.00	356,960.00
1998	78,672	22,298	300,000.00	48,000.00	348,000.00
1999	78,672	22,298	260,000.00	50,000.00	310,000.00
2000	102,329	30,169	271,000.00	49,900.00	320,000.00
2001	100,997	29,939	283,384.00	52,939.00	336,318.90

Artisans contribute more than 95% of the total fish landed. The estimated per capita fish consumption is about 6 kg per year. The contribution of the fisheries sector to the GDP was 2.9% in 1999 (URT 2003).

Fisheries export products include fish fillets, prawns, lobsters, crabs, seashells, beche-der-mer, octopus, fish maws, squids and aquarium fish. Out of the total national export value for1998, fisheries products comprised 12.3%. The total fisheries export value in 2000 was about US$75.5 million. Apart from that, about US$0.5 million were obtained in 2001 in government benefits from revenues from licences and loyalties. (Table 2: Prawn export (quantity and value) in Tanzania from 1988 to 2001(FD 2003).

Year	Export (tons)	Product value (US$)	Product value (Tshs)	Royalty revenue (US$x1000)
1988	1,281	4,072	456	63
1989	1,187	4,046	685	94
1990	1,188	5,382	1027	106
1991	1,085	6,841	1441	95
1992	904	4,815	1694	110
1993	950	4,877	1976	242
1994	1,192	5,964	3656	252
1995	924	5,062	2916	254
1996	1,083	5,497	3211	352
1997	852	4,321	2556	259
1998	2,142	10,760	6994	646
1999	1,154	5,128	3788	307
2000	1,218	5,645	4476	340
2001	1,175	5,851	5119	446

The marine fisheries sector is primarily artisanal and employs more than 20,000 permanent fishers. Due to the low capacity of poor fishing vessels used by artisan fishers, fishing is mainly concentrated in the near shore waters where stock is either low or high.

3 MATERIAL AND METHOD

The selection of by-catch reduction devices was mainly based on literature reviews and verbal advice from gear specialists bearing in mind the condition in Tanzania. The performance of fishing gears depends on their design and operation. It also depends on the condition of the fishing ground, such as depth substitute and currents and behaviour of the species it encounters. The approach taken in this project is to describe the existing fishing gear, fishing ground and the behaviour of the target species and by-catch. Experience has shown that introducing new fishing techniques is most likely when existing gear needs some changes

In this study we use one of the trawl net designs used in Tanzanian shrimp fishing for a double rig, outrigger trawler with 450HP. All calculations in this study were done manually. A Design CAD 2000 computer programme was used for drawing and design work. All dimensions of lines are in metres, panel sizes in the number of meshes and extended mesh length in mm.

3.1 Formulation and technical requirements

Calculation, design method and technique are very important for the development and construction of a trawl. While documenting or modifying the required characteristics of a new trawl, one must consider the behaviour of the fish the trawl is going to catch (Fridman 1986).

There is no dependable mathematical model for describing the interaction between the trawl and the fish during the trawling process. One way of taking specific fish behaviour into account is to base the new trawl design on characteristics of a well-known and proven trawl. Another way is to try established designs from other areas of fisheries, or to apply new design ideas based on information on the behaviour of the desired fish obtained by such means as ecological research, direct visual observations or echo sounding.

The various requirements for a new trawl may often not be compatible with one another. For example, the requirement for maximum fishing power and minimum hydrodynamic resistance at minimum cost contradict one another. Compromise decisions must be taken to handle such contradictions (Fridman 1986).

The formulation of technical requirements should involve a review of:

- characteristics of fishing conditions and of fishing grounds and of species to be caught;
- characteristics of the trawlers to be employed;
- desired characteristics of possible trawl prototypes and criteria for selecting the most suitable;
- characteristics of trawl operation such as speed, depth and tow duration;
- special requirements of trawl performance such as for rough or smooth ground.

Finally, after these technical requirements are formulated, the main technical characteristics of the gear, such as principal dimensions, drag and sheer forces, buoyancy and ballast needed for desired performance can be tentatively set.

3.2 Calculation of mesh size

The forward part is from wings through the bellies, leads the fish to cod end, and the aft part, the cod end retains the catch. Different experiments and observations have shown that most fish behave differently in the two parts. In the forward part they are calm while in the cod end they are active and try to escape through the mesh (Fridman 1986). The mesh opening in the cod end M_{oc} should be such that the smallest commercial fish will not gill. This can be estimated from:

$$M_{OC} = 2/3 \times M_{OG}$$

Where M_{OG} is the mesh opening of the net designed to capture fish of the same species and size. In this term M_{OG} may be estimated from,

$$M_{OG} = L/km$$

Where L is the length of the fish body from the tip of the snout to the base of the caudal fin and km is an empirical coefficient depending in the morphology of the fish and found by experimental fishing with gillnets.

A first approximation, it is possible to take the value of coefficients:

Km = 5 for narrow fish
Km = 3.5 for medium fish
Km = 2.5 for thick or deep bodies

From this formula the body of the fish to be retained is not more than112 mm.

Mesh opening of the cod end net suitable for fish to be retained in cod end, not less than 112 mm:

$M_{OG} = L/Km$
$=112/2.5$
$=45$ mm

From the expression the mesh opening of the trawl cod end should be:

$M_{OC} = 2/3 \times M_{OG}$
$= 2/3 \times 45$mm
$= 30$mm

3.3 Two options for measuring the selectivity

3.3.1 One trawl towing two similar trawls

Double rig trawling or outrigger is when one trawler tows two similar trawls simultaneously side by side (Figure 2). The grid is attached to one of the twin trawls. Thus the size frequency distribution of shrimp and fish from the two cod end allow the calculation of the selectivity parameter of the uncovered test cod end as used in commercial fishing.

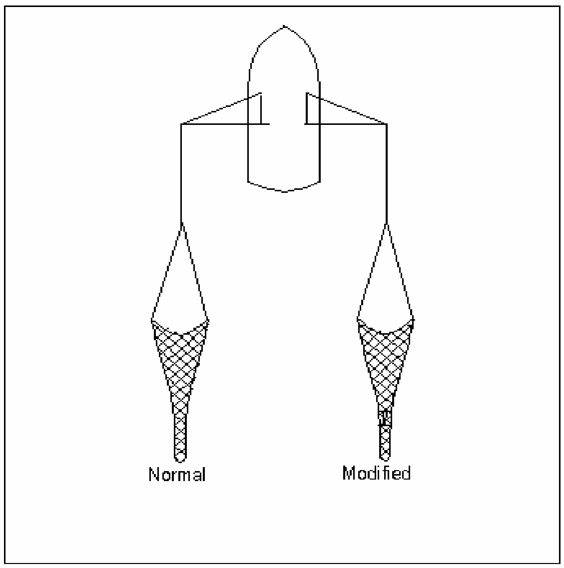

Figure 2: Two similar trawls towed simultaneously.

3.3.2 One trawl with over net

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Another way of measuring selectivity is to use one trawl with over net. The top cover with small meshes is attached over the grid (Figure 3). The small net with cod end retains the fish escaping from the grid. The catch in the over net provide a measurement of catch escaping through the grid and hence allow the grid selectivity to be commercial fishing estimated.

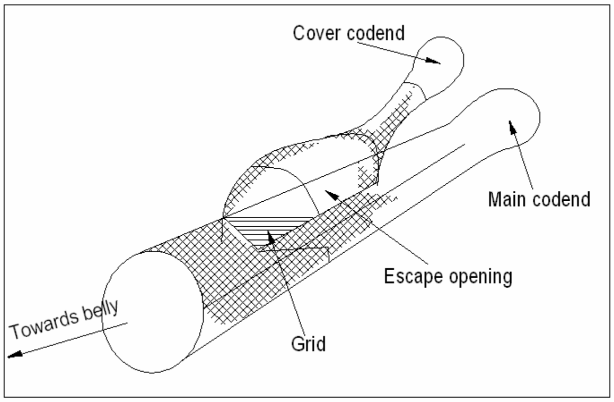


Figure 3: A diagram of cod end with over net

4 SHRIMP FISHERY

The Tanzanian shrimp fishery has a long history but was only carried out by artisan fishers up to the 1950s (Austrand and Carles 1996). The East African Marine Fisheries Research Organization (EAMFRO) did the first experiment on shrimp trawling in 1959.
Today, the shrimp fishing industry in Tanzania is divided into industrial and artisanal fisheries. Industrialists use trawlers in inshore waters and artisanal fisherman use traps and dragnets in wading waters to catch shrimp. The total annual shrimp catch is estimated at 2000 tons and is divided roughly equally between the industrial and artisanal fishermen (Mgawe 2000).

Table 3: Shrimp production in Tanzania from 1988 to 2001(FD 2003).

Year	**Industrial catch (tons)**	**Artisanal catch (tons)**	**Total catch (tons)**
1988	615	678	1338
1989	689	935	1859
1990	961	1953	2935
1991	669	15557	2450
1992	664	679	1264
1993	597	1232	1829
1994	1014	390	1417
1995	812	1302	2260
1996	770	1882	2664
1997	699	1887	2500
1998	996	1804	2800
1999	688	1412	2100
2000	910	1190	2100

Before the Liberalisation Policy, only the Tanzanian fisheries corporation (TAFICO) was operating a few trawlers for the shrimp fishery but in 1987 the licensing of foreign trawlers started. Many companies entered the shrimp fishery and the number of applicants has been increasing every year. The industry is becoming more competitive with each company trying to maximise the number of fishing days.

There was an increase in fishing effort (no. of industrial fishing vessels) in the late 1990s at the same time CPUE declined (Table 4).

Table 4: Licensed trawlers and catch (FD 2003).

Year	No. of shrimp trawlers	No. of fishing days	Catch of shrimp (tons)	Catch of fish (tons)	Average CPUE KG/Std day	Fish /shrimp catch
1988	12	1476	615	988	441	1.5
1989	13	2166	689	979	318	1.4
1990	09	1574	961	647	610	0.7
1991	11	1315	669	461	509	0.7
1992	15	1560	664	463	426	0.7
1993	10	1462	597	398	408	0.7
1994	16	2513	1014	576	404	0.6
1995	19	2108	812	766	385	0.9
1996	12	1779	770	599	433	0.8
1997	16	2019	699	610	334	0.9
1998	17	2778	996	538	358	0.5
1999	17	2252	688	610	306	0.9
2000	20	3352	910	958	271	1.1
2001	20	3882	1194	1010	307	0.8

The fisheries sector is still faced with problems of increased fishing effort, which hurts profitability and may lead to over fishing, especially in inshore marine waters where most of the artisanal and industrial shrimp fisheries are taking place (Jidawi and Othman 2002). The open access nature of the fishery (artisan) caused increasing in fishing effort and also removes the ability of the sector to maximise social benefits.

4.1 Artisanal shrimp fishery

Simple fishing crafts e.g. the dug-out canoe is the most commonly craft used in small scale fisheries. It is propelled by oars and poles or, if operated in open waters, occasionally equipped with sails but most concentrated in the near shore shallow waters (Figure 4).

Figure 4: A type of outrigger canoe used in the artisanal fishery in Tanzania.

Several traditional fishing techniques are employed including various local traps and small seine nets as briefly described below:

Fixed traps "stake screens" made of mangrove stakes are pushed into the bottom closely together and form an enclosed area with a narrow entrance. There is also another type of trap with the same design as the above mentioned but made by using manufactured material such as wire mesh or nylon netting.

Small beach seines are normally operated by two fishers by dragging the net along the beach in shallow waters of up to 1m deep. Normally the two fishers operate on foot or in dug out canoes during the low tide (Haule 2001).

Other fishing gears include mosquito nets, designed beach seines, which are commonly used by women for seining in shallow waters during the low tide. Scoop nets, cast nets and ring nets are also used in the artisanal fishery.

4.2 Industrial shrimp fishery

Fishing gear is the name for all auxiliary gear that can be used for catching, trapping or getting any aquatic organism, animal or vegetal (Sainsbury 1996). From various technical classifications of the principal types of fishing gears it is possible to use trawl nets for shrimp fisheries. The trawl net is considered to be an active gear; this involves the towing of an open mounted net into water by using a powerful vessel. It is a large funnel-shaped bag net dragged in water to collect fish and other products found along its passage. The mouth of the gear is tapered sections of net, which form the wings. The vertical opening of the mouth is maintained by the floats on the headline and the weight of the chain on the fishing line. The wings in the front increase the sweep area and herd the prey in the nets path down to the body and hence to cod end. The head line or float line is at the upper side of the trawl mouth and floats are fixed to its ends. At the lower side of the mouth there is a strong fishing line called "foot rope or ground rope" and normally its weight is increased using a chain, in addition sweeping tickler chains are put on the ground rope to plough over the sand and muddy sea bed (Figure 5).

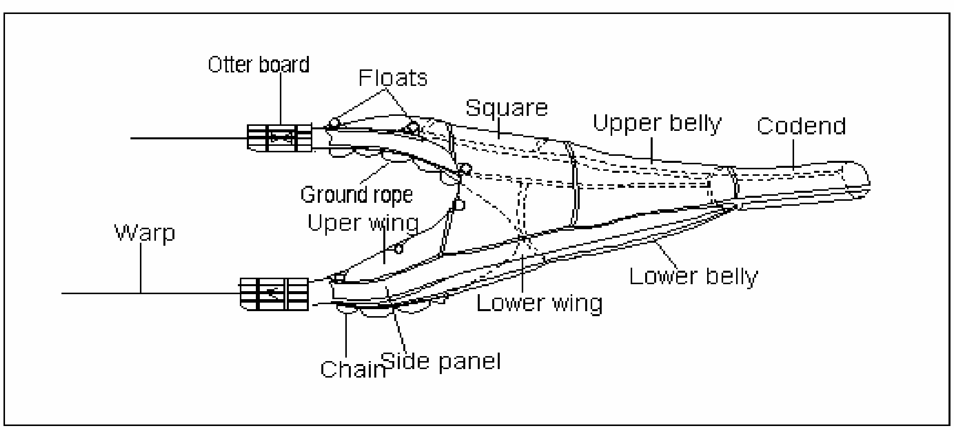


Figure 5: Diagram of different sections of a shrimp trawl net made of four panels.

The head line is shorter than the fishing line and the upper side of the net overhangs the fishing line to ensure that any shrimp jumping out from the sand or muddy is retained in the net and therefore cannot escape upwards. The front part of the net is tapered to the closed cod end, which acts as a funnel of netting closed at the real end. The operation can be carried on the surface, mid water, or bottom. The shrimp trawl is towed on the seabed (bottom) where the shrimp are hiding in the sand or mud.

Most of the trawlers use the four seam semi balloon net design. The net webbing material for the trawl net is PE 360d-400d. The wings and body have mesh sizes ranging from 50 mm to 60 mm while for the cod end meshes size range from 40 mm to 45 mm and all vessels use rectangular, flat, wooden otter boards (Figure 6).

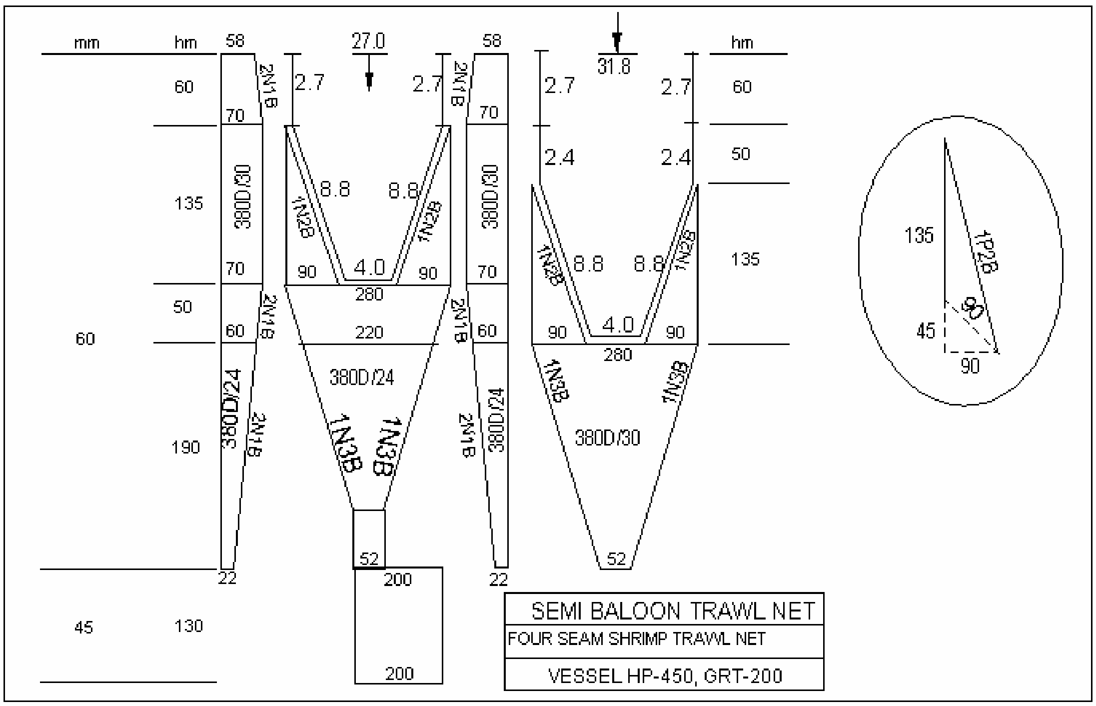


Figure 6: A drawing of trawl prototype used in Tanzania.

The otter boards are directly attached to the wings. Four chain bridles are then used to attach the otter boards to a wire bridle. Most of trawlers use steel wire, sizes ranging from 14 mm to 16 mm covered by PP rope for ground ropes. The rest use combination wires, sizes ranging from 16 mm to 18 mm. Short link chains are used to tie loops along the ground rope at 30 cm to 45 cm intervals. The loop constitutes 9-12 links of chain and sometimes they use sweeping tickler chains (Figure 7).

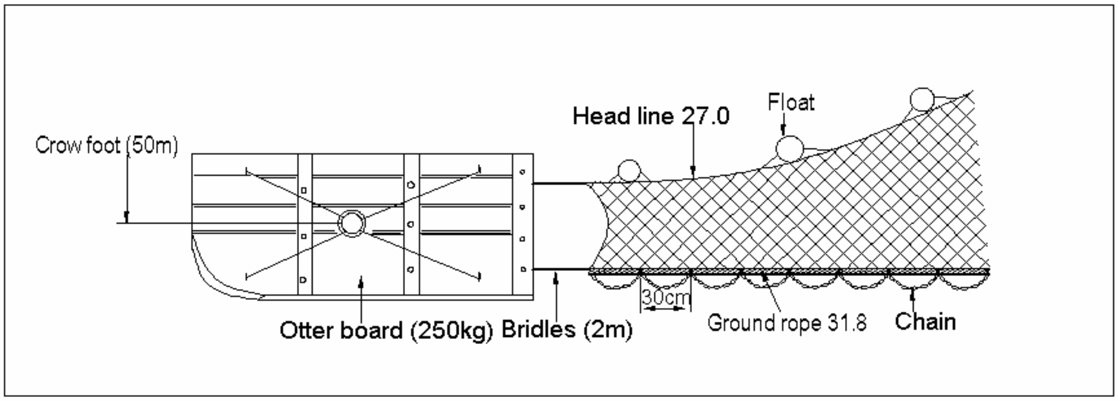


Figure 7: Diagram of trawl net wing and the trawl door arrangement used in Tanzania.

In this method a try net is used which is composed of a small trawl 3-5 m head rope and is used with miniature otter boards of 03-0.6 m which is used to obtain a sample of the sea bottom for shrimp before the main trawls are set out. The shrimp trawls are towed over the bottom at a speed of about 2.5-3 knots for two hours. By boom operation the cod end is hauled back and opened, the catch released onto the vessel deck where the fish and shrimp are sorted, washed, graded and stored.

Double rig trawling or outrigger trawling is the predominant method used (Figure 8); two similar trawls are towed at the same time, one on each side of the vessel. The booms are normally made of steel and are of 8-12 m long. The vessel is usually single decked and fishing activities are carried out on the deck in the aft. The vessel has no shrimp sorting machine, and all vessels have blast freezers and a freezing hold.

Figure 8: A Tanzanian shrimp trawler showing a double rig trawl.

The length of trawlers ranges from 17-38 m while the engine power of the vessels ranges between 240 HP and 500 HP. The maximum tonnage of the shrimp trawlers is 150 GRT. All trawlers carry SSB and VHF radios for communication and colour echo sounders used for finding fish.

5 FISHING GROUND

There are two monsoon seasons. The North East (NE) monsoon blows during the period from November to March and is normally characterised by high air temperature and low winds with relatively calm seas, while the strong winds of the South West (SW) monsoon occur between May and September (Bwathondi and Mwaya1984, Jidawi and Othman 2002). The South West monsoon also brings heavy rains and nourishes estuaries and coastal areas with a lot of nutrients (Haule 2001).

The shrimp fishery in Tanzania is conducted in brackish waters, which is also a feeding, and breeding ground for many species of fish and shrimps. Industrial prawn trawlers use the same fishing ground as the artisanal fishermen.

Usually vessels operate within 1-6 nautical miles of the coast at depths ranging between 3 and 20 m. The vessels are rationally divided into three groups and made to fish in three fishing zones on monthly rotational basis (Figure 9).

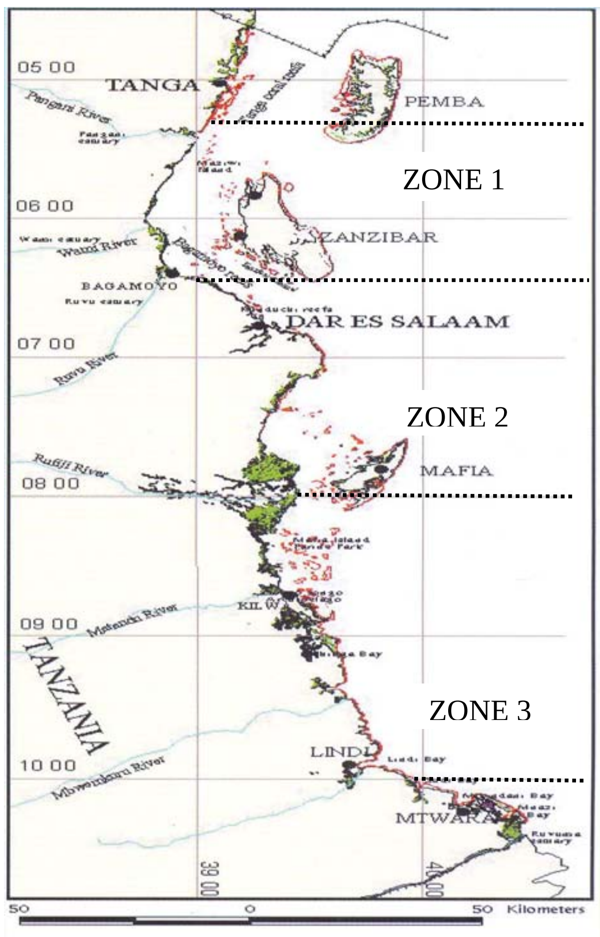


Figure 9: A map of Tanzanian showing three fishing zones (FD 2003).

The zoning system started in 1988. The main objective of this regulation was to spread fishing effort evenly over the fishing ground and minimise environmental degradation on a particular ground (Haule 2001). This system also encourages vessels to search for new fishing grounds and minimise conflict among trawlers and artisanal fisherman (Mongi 1990), but this has not solved the conflict.

6 SHRIMP BIOLOGY

The shrimp biology and behaviour in Tanzania is not well known, however the biological behaviour of most shrimp species around the world is similar (Gulland and Rothschild 1984). Most of the marine prawns fall under the order Penaeidae and normally referred to penaeids.

Penaeids are short-lived species with their life cycle usually ranging from 12 to 18 months (Gulland and Rothschild 1984). Like in many tropical areas, most shrimp species spawn offshore, then juveniles move into the estuaries where they grow before migrating offshore again as adults for spawning (Bwathondi *et al.* 2002). It is believed that spawning takes place throughout the year with peaks observed during the rainy season. According to Gulland and Rothschild (1984) penaeids live predominantly on or near sandy or muddy bottom substrate and among sea grasses in 5 to 10 m depths (Bwathondi *et al.* 2002). Penaeids are fast swimmers, seen to perform rapid forward movement and often try to jump out of the water when disturbed.

Five common penaeids have been identified in the shrimp fishing ground in Tanzania:1) *Penaeus indicus* (white prawn) 66% of total shrimp catch; 2) *Penaeus monodon* (giant prawn) 18%; 3) *Penaeus semisulcatus* (tiger prawn) and *Metapenaus monoecros* (brown prawn) 15% and 4) *Penaeus japonicus* (flower prawn) 1% (Bwathondi, *et al.* 2002).

7 RESULTS

From the shrimp trawl design used in Tanzania (used in the study) it was observed that the upper belly and the lower belly are not symmetrical (see Figure 3). There is an extension on the upper belly and the number of meshes on square is the same as the number of meshes on belly. In order to fit a grid section into the belly there is a need for modification, i.e. to change the cutting ratio from the square to the lower part of the belly and remove the extension (Figure 10).

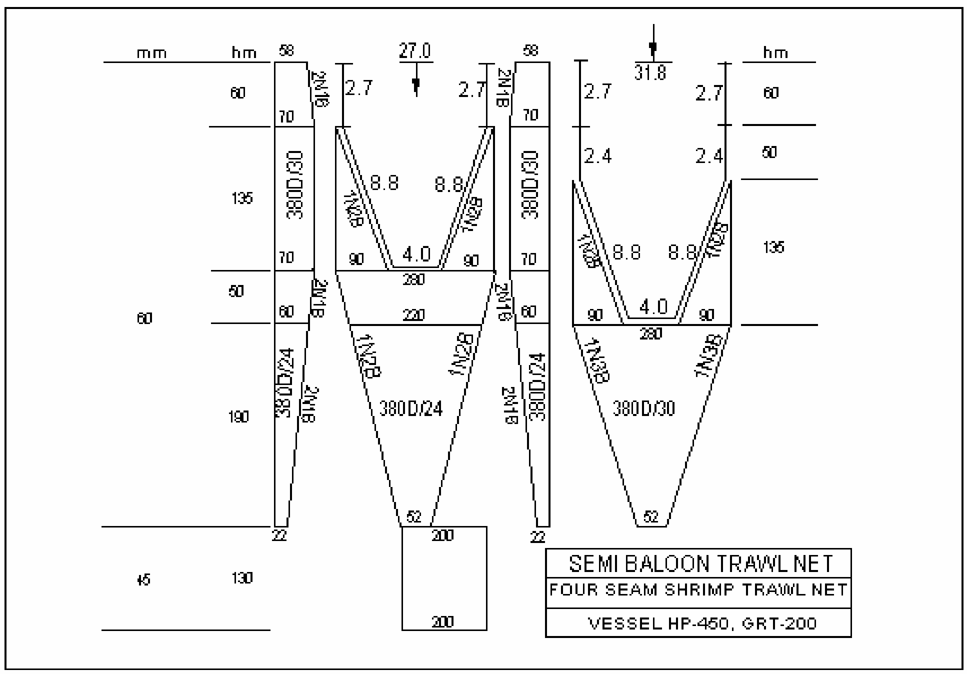


Figure 10: A drawing of trawl prototype used in study.

However, the upper belly will still not be symmetrical to the lower belly. The engineering of the design will be much better than the design used thus far as the attachment of the grid section is fine but the actual net will not look the same especially when joining the wings to the square. The drawings look the same size between the upper belly and the second belly and make a new square

Measurement of the grid is designed in relation to the size of juvenile shrimp and fish to allow them to escape, gear type and method of operation. Regarding the method of fishing operation, the grid is placed between the cod end and belly, which makes the lifting strops in their customary position. The efficiency of the fishing gear depends very much of these technical changes because inappropriate changes can make the gear inefficient.

The practical experiment is done with a full-scale prototype of grid section. All constructing problems were solved. Construction drawings containing all necessary information for the grid section was prepared (Figure 11).

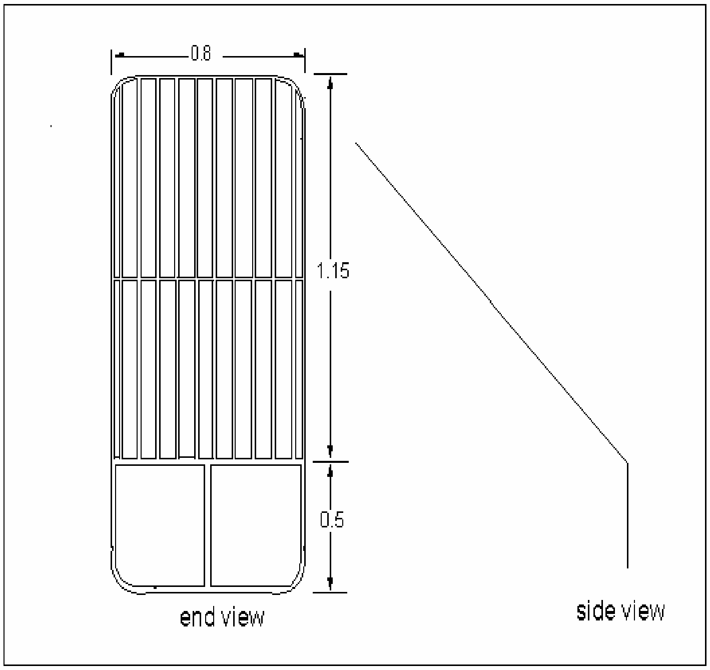


Figure 11: A diagram of the designed and constructed sorting grid used in study.

A full scale model of the sorting grid and square mesh cod end was constructed under supervision of gear experts at the Fjarðarnet Ltd gear loft in Isafjörður in Iceland.

The grid frame is made of aluminium and has a length and width of 1.65 m and 0.8 m respectively. It weighed approximately 4 kg (frame) and the calculated weight of the grid with bars is 22 kg. The top grid frame was used to make a prototype, the grid was installed 0.5 m from the front edge of the section and mounted the grid at 33° to the last ridge (Figure 12).

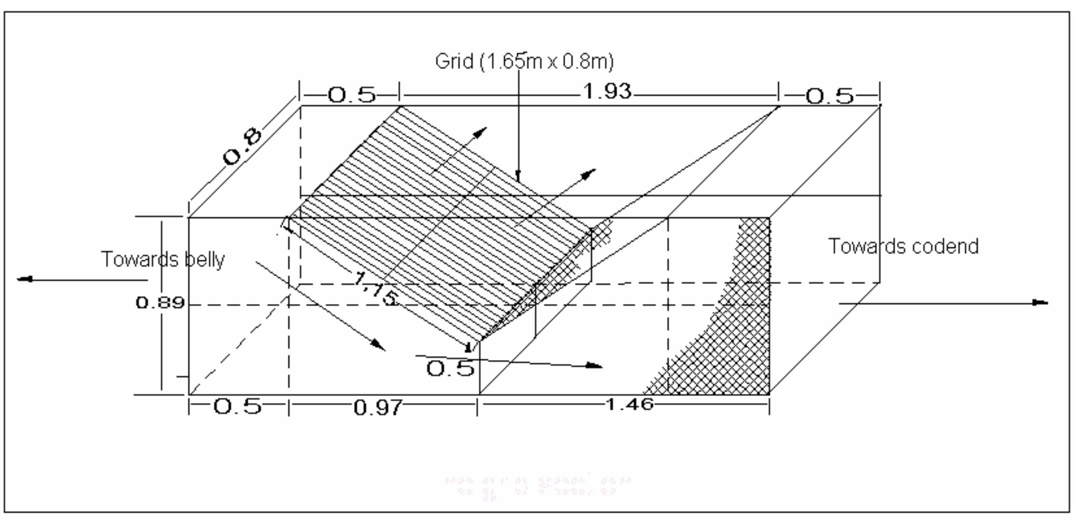


Figure 12: A diagram of the grid section designed and constructed in this study.

The theory is that the larger shrimp and fish are guided into the cod end, and that small shrimp and juvenile fish will pass through the spaces between the bars of the grid and escape. Small shrimp and juvenile fish passing through the sorting grid into the cod end will then have additional opportunity to escape through the square mesh cod end. In addition, the conventional trawl design selected for this study (Figure 3) was modified in order to fit the selective device and to improve performance.

A cod end with a square mesh will be attached at the back end of the grid section. The mesh size of the cod end is 45 mm. So the grid section will be attached between the belly and cod end and it may easily be removed from the system with zippers (Figure 13). The relationship between trawl net design, catching species and other technical requirements was investigated.

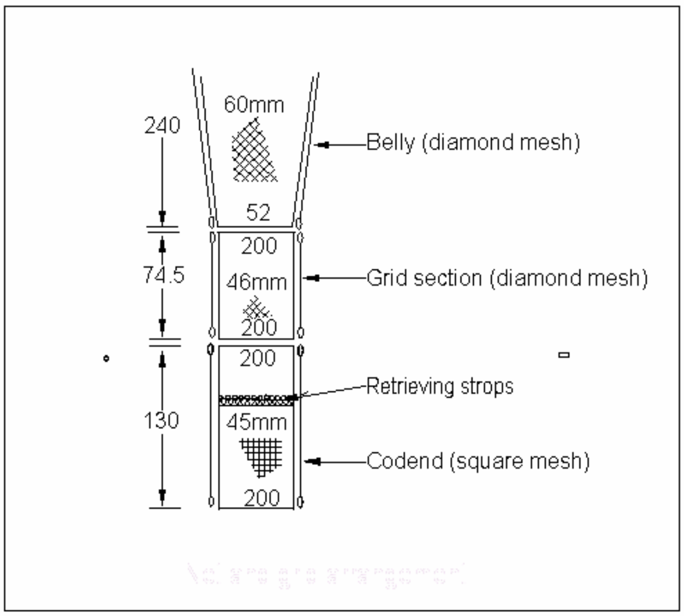


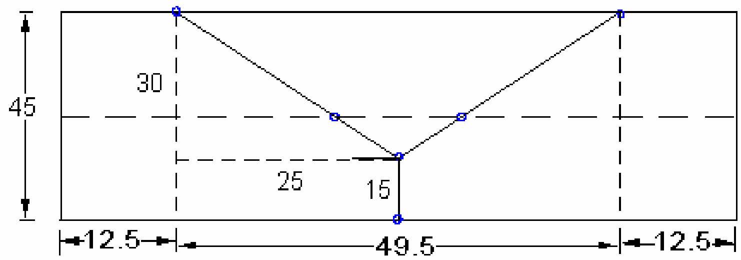
Figure 13: A diagram of grid and net arrangement (zippers).

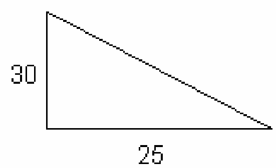
7.1 Tapering and cutting ratio

To determine the tapering of the net, the cutting ratio for the easy section of the net is calculated and this determines the right size of each section. To calculate the cutting ratio (Y) the following formulas were used (Thorsteinsson 1992, Gretarsson J. Personnel comments).

$$Y = M-m/2m$$

Where; Y is the cutting ratio
M is the bigger number of meshes of the piece of net to cut
m is the smaller number of meshes of the piece of net to cut.





$$Y = \frac{M-m}{2m}$$

$$= \frac{30-25}{2 \times 25}$$

$$= \frac{5}{50} \quad \frac{1}{10}$$

$$= 1N10B$$

Depending on the shape of the piece to cut out from a net section, the cutting ratio (Y) can be expressed by (T&B) or (N&B),

Where T is transverse cut
N is side knot and
B is bar of the mesh

7.2 Calculation for floats

This is also the weight of fishing gear in the sea to be considered. The weight of the grid in air is 22 kg. The weight of aluminium material in air is 22 kg while the weight of aluminium material in sea is 14 kg. The type of floats to use is a spherical float with a plastic centre hole. The diameter is 200 mm, volume 4lts, buoyancy Kgf 3.5, and max depth 350 m. The buoyancy is 80% of the weight in sea. This is considered to be the maximum buoyancy. Buoyancy is calculated by:

B = Weight in sea x 80%
= 14 kg x 80%
= 11 kg

The buoyancy required to make the grid float will be 11 kg. The number of floats is calculated by dividing the buoyancy of that particular float type into the calculated buoyancy.

. Number of floats = Buoyancy of floats/Buoyancy Kgf
= 11 kg/3.5 Kgf
= 3 pcs

8 LACING

The process of gathering and seizing together is called lacing, by winding around with twine and fasting at intervals with a hitch called a stop hitch (an overhand knot on close observation). In lacing four meshes are gathered from each panel. A hitch is made after winding the twine around the selvedge two times. At the centre line only two meshes are gathered. The twine used is 2 mm PA for this type of netting, while 3 mm PA was used for attaching the grid to the netting (Figure 14).

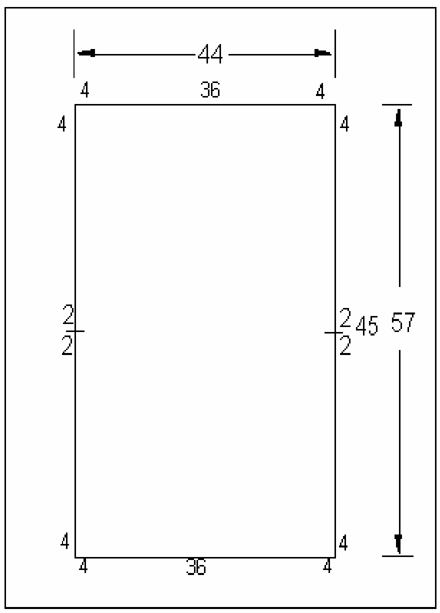


Figure 14: A diagram showing net selvedge used in study.

The top and bottom of the grid section have a rope running down the seam at the centre but not raced together with selvedge, this help to support the weight of the fish in the cod end.

9 DISCUSSION

The selection efficiency of a gear can be evaluated by studying the ratio of shrimp to by-catch in a haul. The ratio of shrimp to by-catch in Tanzania ranges from 1:1 to 1:3 (Mahika 1992, Nkondokaya 1992) measured in volume. Although not documented, it is assumed that there is a high concentration of juvenile shrimp and juvenile fish in the catch. Shrimp gear selection is an issue in Tanzania, and reduction of juvenile shrimp and juvenile fish is considered an important task. Modification of commercial fishing gears in order to make them more selective could improve the selection and reduce by-catch. But modification of fishing gears can affect catching efficiency and gear performance. The problem of acceptance may also occur when a modified type of gear is introduced in an established fishery (Valdemarsen, and Suuronen 2001).

In this study the, modification was conditioned by the availability and cost of gear material in Tanzania, in order to provide a cheaper solution, which would be easy to construct, operate and maintain. Increased cost and reduced earnings are unattractive to fishers. It is therefore important that such modifications have a minimum effect on the overall fishing operation. Close cooperation between the fishing industry, scientists and other stakeholders will be necessary in the process of developing and introducing more environmentally friendly fishing technology.

Generally, the smaller the mesh, the smaller the fish that will be retained in the cod end. In tropical areas like Tanzania, most by-catch comprises small specimen of about the same size as the target shrimp species. Therefore it is difficult to exclude the fish by-catch based on size selectivity by controlling the cod end mesh size (Brewer *et al*. 1998). A proposed modified fishing gear with a selection grid and a square mesh cod end could improve the selection and reduce by-catch. This could exclude small shrimp and small fish while maintaining medium and bigger ones in the cod end. Shrimp or fish with a length below their mature length can then grow bigger and be fished later. This can lead to reduction of fishing mortality of small sizes of fish and a higher yield per recruit (i.e. more value).

Selective devices such as grids may help reduce by-catch and in addition there is opportunity for juveniles, which pass through the grid to escape through a square mesh cod end. However, the reduction of by-catch may, to some extent, contribute to an increase of biomass of shrimp predators, leading to increased mortality by predation on shrimp (Bianchi 1992).

Consequently, the biomass of shrimp may decline on one hand, on the other hand removing huge quantities of small shrimp and fish by-catch may lead to changes in the fish dominance structure or depletion of some stocks (Jin 1996).

The reduction of non targeted animals using grid or other gear configurations e.g. square meshes (Broadhurst and Kennelly 1994) would lead to smaller catches to be sorted on board, cleaner catches of target species and consequently longer tow times and lower fuel cost per unit of target species caught.

10 CONCLUSSION

Tanzania has been encouraging the by-catch utilisation by making laws prohibiting discard at sea, but this is not enough.

It is very important to analyse the composition of by-catch on board and know the size distribution of juvenile shrimp and juvenile fish. This will assist in designing the bar distance.

After having modified the gear, selected the grid and square mesh cod end as possible selective devices, it is necessary to carry out experiments in the Tanzanian shallow water shrimp fishery to measure and verify the effects of the device on the catch composition.

ACKNOWLEDGMENTS

My heartfelt thanks to people who assisted me in developing this work. .In particular my supervisor, Mr Einar Hreinsson, his instruction is invaluable and his patience commendable; excellence guidance and help all the time.

I also thank Dr Tumi Tomasson, Director of the Fisheries Training Programme and Mr Thor Asgeirsson Deputy Programme Director for giving me the opportunity to participate in this programme and for their guidance and assistance.

My thanks are due to the Director and staff of the MRI for giving me a good learning environment and the necessary facilities during my stay in Iceland. Also I extend my gratitude to Mr Larus Palmason of Sudurnes Comprehensive College, all lecturers, and gear experts at the Fjarðarnet Ltd who enlightened me a great deal in diverse subjects and made my study a success.

Special thanks to the Director of Fisheries and Principal of Mbegani Fisheries Development Centre in Tanzania, for allowing me to attend this course in Iceland. Last but not least, my family who has graciously put up with my extended absence.

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