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SHRIMP FISHERY OF THE GAMBIA: A CASE STUDY OF SHRIMP FISHING GEARS

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ABSTRACT

The objective of this project is to study the causes of by-catch in shrimp fishing gears in The Gambia waters and to propose measures to reduce the catch of juvenile and undersized fish. Catch and discard of undersized fish by shrimp trawlers is a matter of concern. Four methods of by-catch reduction are studied in this report including the Nordmøre grate, grid, enlarged mesh and square mesh in order to determine the most appropriate method for by-catch reduction in The Gambia waters. Square mesh was found to be the most likely method to reduce by-catch and should be applied in shrimp trawl, shrimp drift gill net and stow net fisheries in The Gambia waters. The method is simple and does not require extra netting material. The diamond mesh netting of any of the gear can be turned to 90º and the meshes mounted through the bars to attain square shape meshes. This method is proposed as an aid to reduce by-catch and improve selectivity in the Gambian shrimp fishery.

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1 INTRODUCTION

Shrimps fishing gears have been identified as one of the main causes of fishing mortality in the world. Large amounts of by-catch of undersized fish of commercially important species are discarded, affecting stocks that could yield economic benefits in the near future (Lancaster *et al.* 2001). Mortality of juvenile fish due to the small mesh sizes in shrimp fishing gears has been a cause of concern to fisheries managers and marine scientists in coastal states.

Despite the stipulated minimum mesh size of shrimp fishing nets of 25 mm for stow nets, 50 mm for coastal shrimp trawls and 40 mm for deep sea trawls in The Gambia, (The Gambia Government 1995) large numbers of stow net cod-ends still have illegal mesh sizes of 17 to 20 mm (Ragonese 2001). Landings of commercially important juvenile fish species are frequent in stow net fishing in The Gambia's estuary. Shrimp drift gill nets are less destructive. Yet, small amounts of juvenile fish are also landed by this fishery.

The Gambia is a small country situated in West Africa between the latitudes 13°35'N and 13°03´N (Figure 1). It is bordered by the Republic of Senegal on all sides except the west coast, which is on the South Atlantic Ocean. The Gambia is an approximately 50 km wide strip of land stretching along the Gambia River, with an area of 11,300 km^2. The river and estuary are about 270 km^2, and provide spawning and nursery grounds for many fish and shrimp species. The Gambia has a coastline of 80 km and the population is estimated at approximately 1.5 million (Central Statistics Department 2002).

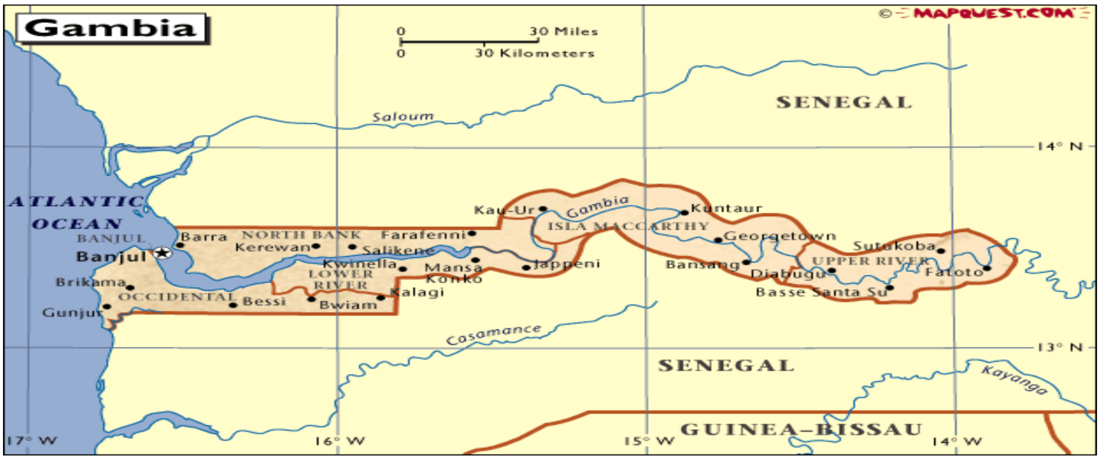

Figure 1: Map of The Gambia River (source: www.africanculture.dk/gambia).

The economy depends heavily on agriculture with groundnuts dominating the exports. Fisheries are the third most productive sector of the economy after tourism and continue to play a major role in the economy.

2 THE FISHERIES SECTOR

The Gambia has a 200 mile EEZ. Fishing also takes place in the estuary and river. The Department of Fisheries is mandated with the responsibility of planning, managing and developing the sector. The main policy objectives are:

a) To effect a long-term optimal utilisation of the marine and inland water fisheries resources.
b) To protect, safeguard and effectively manage the resources.
c) To conduct research on the resources in order to estimate biomass.
d) To improve the nutritional standards of The Gambian populace.
e) To increase employment opportunities in the sector.
f) To contribute to the foreign exchange earnings of the country.
g) To improve the economic environment of the sector.
h) To develop aquaculture.

The fisheries sector is divided into two sub-sectors namely: artisanal and industrial.

The artisanal fisheries sub-sector is the main provider of fish to the local people and it includes small-scale fisheries in marine, brackish and fresh waters. Average landings of fish, cephalopods and crustacean species are estimated at 19.0 tons per annum between 1981 and 2003 (Fisheries Statistics, Gambia 2005). Fishing is from traditional wooden boats. It is estimated that 40,000 people derive their livelihood directly from this sector. Facilities include traditional fishing boats, ice plants, drying, and smoking among other things.

The industrial fisheries sub-sector includes fishing vessels, fish processing plants and the work force. There are 11 fish processing plants in The Gambia engaging mainly in shrimp processing and preparing fish fillets for export. Eight of the 11 companies have EU Certification, qualifying for export to European markets. An average of 35 shrimp fishing vessels were authorised to exploit the shrimp resources from 1990 to 2003 for a period of not more than six months during every license period (January to June and July to December each year). Average landed shrimp was estimated at 690 tons per annum. *Penaeus notialis* dominated the shrimp catch. Banjul, the capital of Gambia is the main landing port for fishing vessels while Dakar, the capital of Senegal, is the landing port for most other fishing vessels. Fisheries observers are posted in all licensed fishing vessels to monitor activities as well as to record the catch. One or two Gambian fishermen (deck-hands) are also posted in every fishing vessel.

3 AN OVERVIEW OF THE SHRIMP FISHERY OF THE GAMBIA

3.1 Shrimp fishing in the estuary

Shrimp fishing in the estuary of The Gambia started in the early 1960s, when fishing was conducted less than 5 m from the shore line of Banjul at water depths not more than 1.3 m. Drag net pulled by two fishermen was the main fishing method. Each fishing period lasted for about 10 minutes before the net was hauled and the catch removed (Gambian fisherman).

Shrimp fishing in The Gambia estuary (Figure 2) involves an average of about 500 traditional Sene-Gambian dugout fishing boats measuring 3 to 4.5 m in length (FAO 2001) during the low seasons and about 1000 boats during the rainy (peak) season. *Penaeus notialis* (pink shrimp) is the main target and most abundant shrimp in the coast and estuary of The Gambia. Apart from the target shrimps, a diverse assemblage of juvenile fish and small crustaceans are captured. Senegalese fishermen commonly known to Gambians as *chubala* due to the nature of their fishing methods (stow netting) dominated the shrimp fishery in the estuary. *Parapenaeus longirostris* are found in the deeper waters (100 to 400 m) and are targeted by large shrimp fishing vessels more than 250 GRT.

Penaeus notialis are most abundant during the rainy season (July to September). During this period, shrimp fishermen from Senegal, Mali and Guinea migrate to The Gambia to exploit the shrimps in the estuary. Shrimp fishermen based in The Gambia repair the fishing units and some purchase new nets expecting a large harvest. The local fishing companies are the main market for the shrimps. They provide loans to fishermen in the form of fishing materials with agreements that the most valuable categories of shrimps must be sold to the loan providers. Repayment is deducted from the catch on a daily basis. Almost 90% of the higher grades are processed and exported. Local hotels, restaurants and supermarkets benefit from the remaining 10%. Undersized shrimps are sold at a reasonable price at the landing sites and local markets.

Data collection from the estuarine shrimp fishery started in 1994. The average annual shrimp production of 333.5 metric tons, valued approximately USD 600 thousand. A decline was observed from 1998 (Central Statistics Department in Gambia 2005).

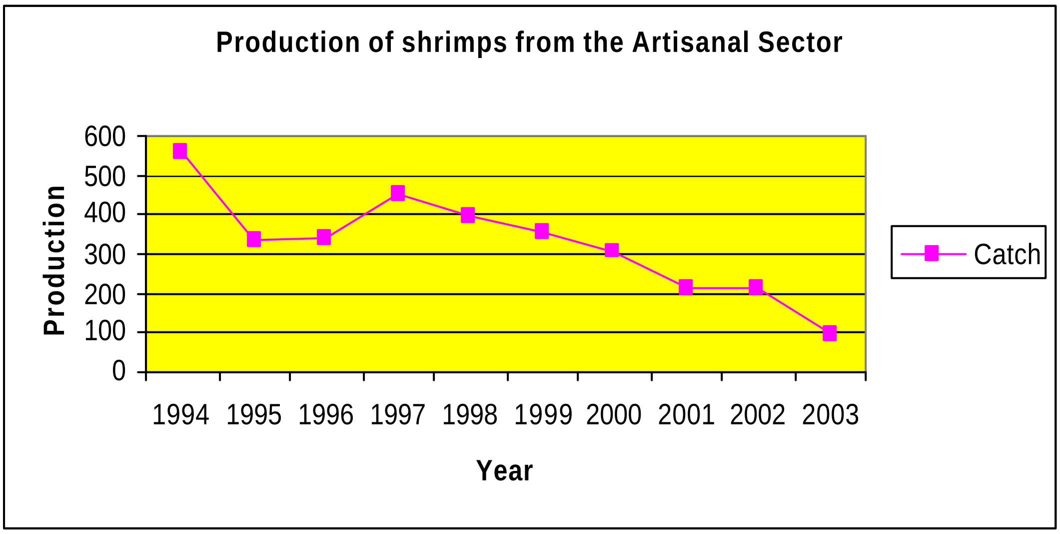

Figure 2: Production of shrimp from the estuaries of The Gambia (Central Statistics Department in Gambia 2005).

3.2 Stow nets

Stow nets are the main fishing gears employed in the estuary for shrimp fishing.

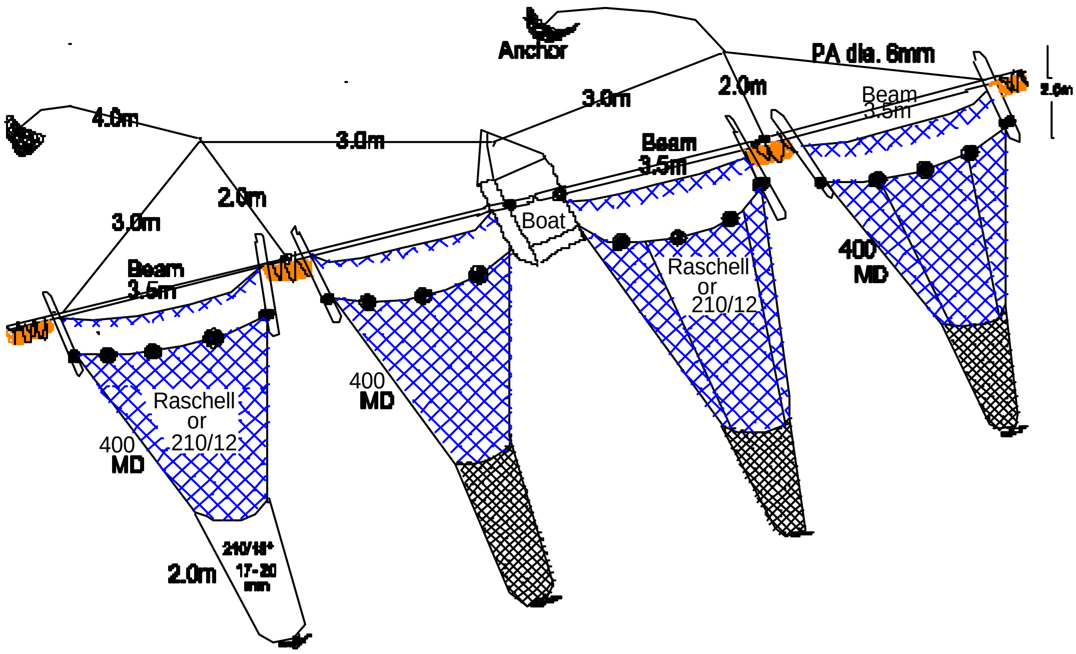

Figure 3: Fishing methods of stow nets.

The stow net is a passive fishing gear operated in the estuary only during the high tide period to target shrimp. Every unit comprises of at least four nets (Figure 3). Two mahogany beams from each side of the canoe are joined together and supported by a polyurathene buoy. The boat and beams float on the water. Every net is aided by a beam on the headline to support the mouth widely opened. In addition, 2 m vertical poles are placed on each side of the mouth as an aid for vertical opening of the mouth.

The maximum height of the mouth is estimated at 8 m in the water. The beams are set once and the nets are set on the beams every day. Every fishing season lasts between 5 and 9 days and then there is no fishing for almost the same number of days before the next fishing period starts. The nets are set on the beams every fishing day with the mouth against the current, which allows shrimp by-catch to swim into the nets (Sarr 2005). The stow net is considered one of the most destructive fishing gears to juvenile fish species occurring in the same area as the *penaeus shrimp.*

Specifications of the present nets are as follows:

- 25 mm minimum mesh size (Fisheries Regulations 1995).
- Total length between 10 and 14 m.
- Netting material: Raschell (most common) and nylon knotted multifilament (210/12 for the belly and 210/18 for cod-ends).
- Colours: Blue, green (most common) and brown on the bellies and black on the cod-ends (fishermen preference).
- Net constructed as two seams.

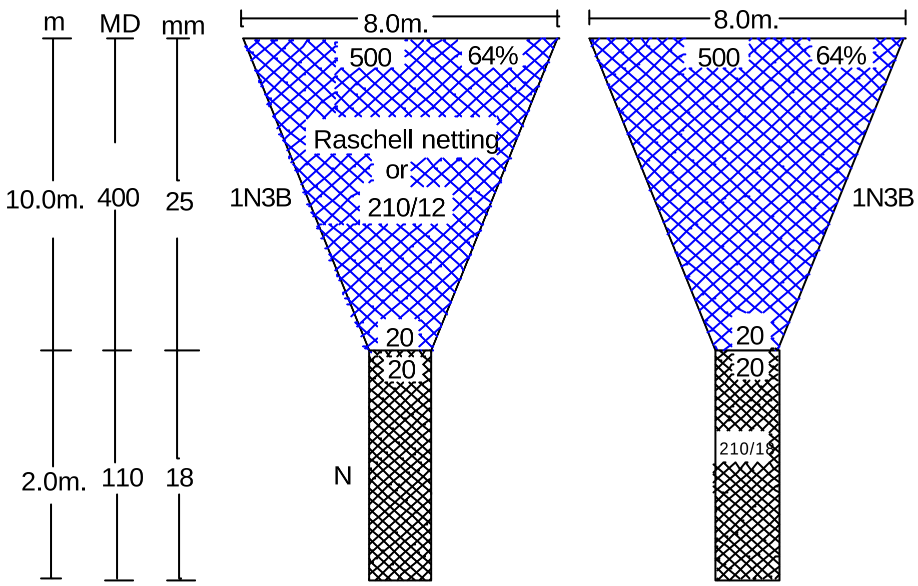

Figure 4: Design of present stow net operated in The Gambia estuary (Sarr O, Gambian stow net operator).

As can be observed (Figure 4), both the bellies and cod-ends have diamond shaped meshes, however, landing undersized fish and shrimps. A mesh size of 18 mm is still being used despite the regulations, which specify 25 mm as the minimum size (Sarr 2005). This increases landings of juvenile fish and shrimp.

3.3 Shrimp drift gill net (*fele-feleh)*

The shrimp drift gill net fishing method was imported to The Gambia by Malian fishermen in the late 1990s with the intention of exploiting the *penaeus* shrimps as well as recruiting and training Gambian fishermen. At present, Gambian fishermen dominate the operations. There are about 20 shrimp drift gill net boats in operation competing with stow nets in the estuary, targeting the *penaeus notialis* shrimps. Every boat operates only one net at a time. The shrimp drift gill net boats operate the same period as the stow nets but at shallow waters no more than 6.0 m depth, close to the mangrove swamps outside the estuaries.

Shrimp drift nets are constructed as one strip of netting wall and set to drift by the current. One end of the gear is attached to the boat while the other end drifts (Gerrior 1996). Alternatively, the gear may be left to drift independently (Brandt 2005). Fishing operations in The Gambia are conducted only at night between 18:00 and 07:00 hours on specific days of the month throughout the year notably during the full moon (*wameh)*. The net is hauled every 20 minutes to remove the catch. Compared to stow nets, small amounts of by-catch of juvenile fish and shrimp are experienced using shrimp drift gill nets. One of the prominent drift gill net operators in The Gambia (*Jammeh*) reported that the shrimps concentrated on the centre of the drift net and overlapped with some small size fish. The latter is abundant on the top section of the net and the smaller size shrimps are most common on the lower section of the net.

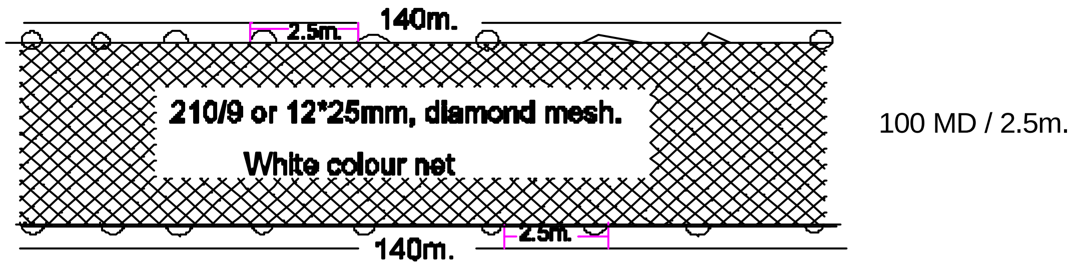

Figure 5: Design of present shrimp drift gill nets operated in The Gambia estuary. The netting is diamond mesh.

Specifications of the shrimp drift gill nets are as follows:

- 25 mm mesh size.
- Recommended length not to exceed 100 m. (120 to 140 m was in used before October 1st 2005).
- Maximum depth allowed 2.5 m.
- Netting material is nylon either of 210/6, 210/9 or 210/12.
- Colour of netting is white (fishermen's preference).

4 MANAGEMENT MEASURES OF THE ESTUARY SHRIMP RESOURCES

Fishing for pink shrimps (*p. notialis)* is a tradition and livelihood to all shrimps fishing villages in the Gambia. The fishery is directly managed by the Department of Fisheries and partly by fishermen at the community level. Although management measures still need to be implemented to reduce by-catch of juvenile fish and minimum cod-end mesh sizes need to be enforced. In March 2005, the Department of Fisheries of The Gambia organised a meeting with leading shrimp operators from all of the shrimp landing sites in the country to discuss the use of illegal mesh size on cod-ends of stow nets contravening the Fisheries Regulations, 1995 (The Gambia Government 1995) and (Funabashi *et al*. 2004). The meeting concluded with recommendations geared towards sustainable management of the resources as follows:

i. Shrimp drift gill nets (*fele-feleh)* are prohibited in the estuary (*bolong)* especially in the waters of Mandinary, Lamin, Faraba Banta, Bonto and Pirang.
ii. Shrimp drift nets can only operate outside the main channel (*canal)* of the estuary.
iii. Total length of the shrimp drift net must not exceed 100 m, and maximum depth of 2.5 m.
iv. Fishing operations of shrimp drift gill nets should be at least a distance of 100 m from stow nets.
v. Every fisherman must respect the 25 mm minimum legal mesh size.
vi. Stow net (*mujass)* mesh size (belly to cod-ends) must be no less than 25 mm.
vii. Defence nets should be allowed on stow nets but only beneath the cod-ends.
viii. All stow net fishermen must not operate more than four nets (two pairs).
ix. Only fish fishing will be allowed in the Kerewan straights. This means that stow nets and shrimp drift gill nets are prohibited in the area.
x. Fisheries personnel are empowered to conduct inspections of nets and catch without disturbance from anyone and are mandated to confiscate catch / nets that contravene the regulations.

The recommendations were effective from 1 October 2005, and all shrimp operators were urged to comply.

5 SHRIMP FISHING VESSELS

Shrimp vessels can be from 8.0 – 40 m in length, 32 - 437 GRT. Outrigger twin trawl is the most common fishing method but single stern trawling is also widely used. The minimum legal mesh size for the cod-end is 50 mm for inshore vessels and 40 mm for offshore vessels (The Gambia Government 1995). Licensed fishing vessels less than 250 GRT are authorised to operate in the coastal waters outside the 7 Nautical Mile (NM) limit. Likewise fishing vessels over 250 GRT can only operate beyond the 12 NM (The Gambia Government 1995).

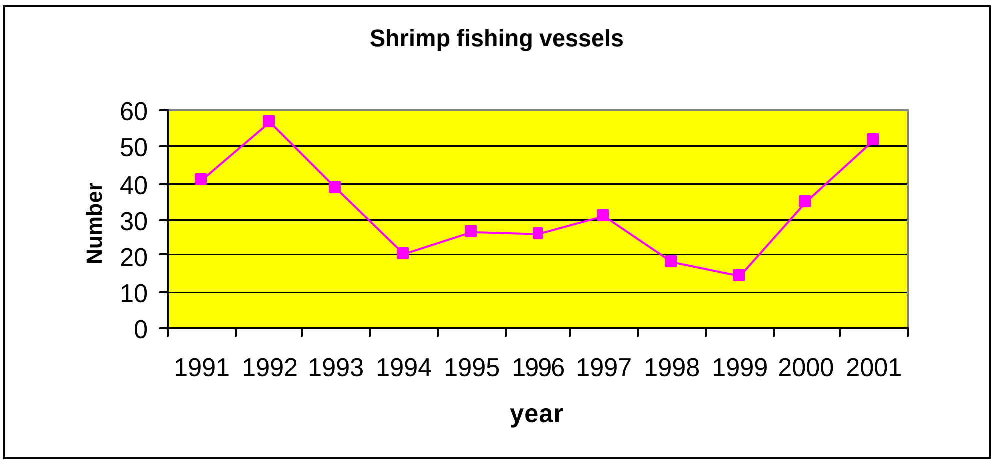

Figure 6: Number of registered shrimp fishing vessels operating in The Gambia waters (Fisheries Department of the Gambia 2005).

Catch of shrimps from the fishing vessels started to increase in 1986 to 1525 metric tons compared to 208 metric tons in 1985. The highest catch of shrimps, 5019 tons, was recorded in 1987 (Figure 8). There was a sharp decreased in shrimp catch of over 90% in 1988 and 1989 respectively compared to 1987. Catch of shrimp increased to 2535 tons in 1990 when the number of shrimp vessels was 22, and decreased by 69% in 1991 when the shrimp fishing vessels were 41. There was variation in catch between 210 and 602 metric tons from 1992 to 2003 when registered shrimp vessels were between 14 and 60 respectively (Figure 6).

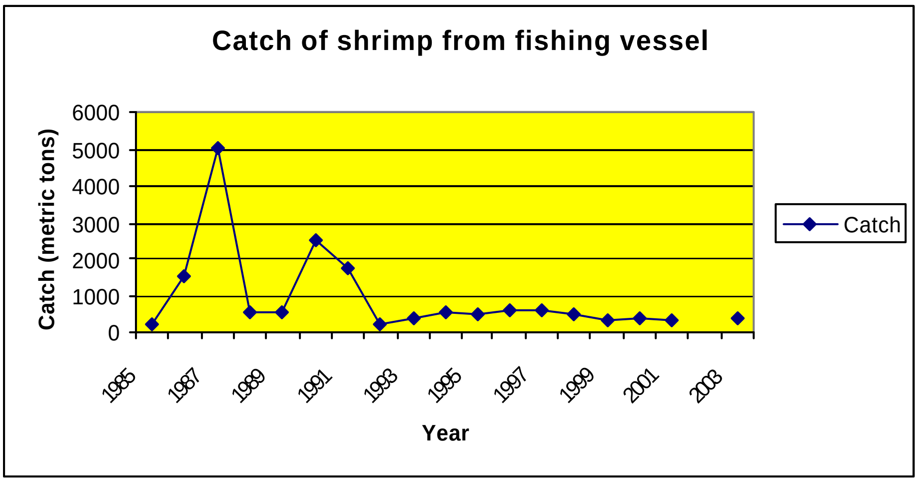

Figure 7: Catch of shrimp from industrial fishing vessels. Data for the year 2002 was not available.

6 SHRIMP BEHAVIOUR

Shrimps in tropical waters spawn offshore and the juveniles migrate to grow up in the estuary (*bolongs)* where they live for several months before returning to the sea as sub-adults (Stoner, 1991). A broad understanding of their behaviour is required to develop fishing technology aimed at meeting the requirements of responsible fishing.

6.1 Penaeus notialis

Penaeus notialis (pink shrimp) occurs in the muddy grounds of the estuary and along the coast of The Gambia (Vidy G *et al.* 2004). The coastal water shrimp has a wide geographical distribution, occurring in the coastal waters of some parts of Africa between Mauritania (Cape Blanc 21ºN) to Angola including The Gambia. It is found between 10 m and 100 m depths at temperatures between 18 - 24ºC. Annual hydro-climatic changes, characterised by upwelling seasons appear to be the cause of well defined reproduction periods during the rainy season (Loeuff 1999). Shrimp avoid light and tend to move out from the muddy grounds for feeding during night when they become vulnerable to capture.

6.2 Parapenaeus longirostris

Parapenaeus longirostris occurs in the deep waters of the Atlantic Ocean. The species has a wide geographical distribution existing in the Spanish South Atlantic Region, in the Eastern Atlantic waters off Morocco through the Atlantic Oceans, as well as the Mediterranean and its adjacent seas ending in Angola. Due to its economic value, the species is widely targeted off the coasts between Morocco and Senegal including The Gambia, Guinea Bissau and Gabon (Sobrino 1999). It is less abundant on the continental shelf area of Sierra Leone and Liberia. Large shrimp vessels >250 GRT are exploiting the *p. longirostris* in the continental slope off The Gambia.
The shrimp species inhabits sandy and muddy grounds between 100 and 400 m depths in water temperatures between 8 to 15ºC and can migrate into coastal waters during upwelling periods.

7 SHRIMP TRAWL SELECTIVITY

By-catch reduction devices are aimed at catching mature fish and shrimps and permitting the juveniles and sub adults to escape from the nets (Hameed and Boopendranath 2000). Although the impact of catching undersize fish and untargeted species is still poorly understood, the amount caught is often too large, and therefore causes concern to the public and Marine Research Institutions worldwide (Andrew 1994).

Shrimp trawls are often poorly selective and indeed retain large amounts of undersized fish and shrimps (Ambrose 2004). By-catch reduction devices such as grids, Nordmøre grates, square meshes and enlarge mesh sizes, have been practiced in many coastal states aimed at reducing by-catch of undersized fish. The Nordmøre grate, which was developed in Norway and is used in America, Canada and some European countries among others, would allow only shrimps and a few other small size fish to pass through the grates and to the cod-end while permitting larger fish to escape. Although the technology is successful in temperate seas, the direct transfer of technology has not been possible to tropical waters due to fish size characteristics and behavioural differences between shrimps and fish (Isaksen *et al.* 1993).

The "grid" is a sorting device designed to reduce by-catch from shrimp trawls. Stainless steel was initially used but it needs buoyancy (floats) to prevent the material from sinking. The present grid was developed by using polyethylene material to make it lighter. It consists of outer frame bars parallel to each other on the horizontal and vertical axis. Small plastic bar spacings are used within the frames to allow the target shrimp to pass through into the cod-end. The grids are often rigged to the cod-end at an inclining angle between 30 and 45º sloping at the back and with an outlet on the top to allow untargeted species to escape. The device has been proven successful in the brown shrimp (*crangon crangon)* fishery occurring in the coastal waters and estuaries of the North Sea (Polet 2000). The section of the grid must be determined. A guiding funnel of meshes, large in circumference, is required to fit to the grid (Grimaldo 2005).

In the shrimp fishery of Mozambique, the grid was designed to focus on reduction of catches of "only the very smallest fish" and retained the larger ones for human consumption. However, the method did not work due to unforeseen circumstances. The Government of Mozambique instead preferred to increase the cod-end mesh size of shrimp trawls in order to release the smaller size fish and shrimps and retain the mature fish and shrimps for export and human consumption (Isaksen and Larsen 1993).

7.1 By-catch in shrimp trawls

Shrimp fishing has been classified as the main cause of destruction to the undersized fish resources, causing potential problems due to discards of large amounts of non-marketable fish. Mortality due to discards of undersized fish has affected recruitment of the present stocks and will certainly impact the future stocks as well as economic benefits (Lancaster *et. al*. 2001). In 1994, global by-catch from shrimp trawlers was estimated at around 11.2 million tons (Alverson *et al.* 1994). A yearly loss of landings due to discards in the European *Crangon crangon* shrimp fishery was estimated at approximately 16,100 tons of juvenile commercially important fish from the North Sea in 1996/97, affecting the stocks, fishery potential and contributions to the economy. Catch of undersized shrimp was also estimated at over 2/3 in numbers of the shrimp catch (Polet 2000). An estimated 200,000 tons of juvenile fine spotted flounder (weighted a ton) and a sufficient amount of undersized non marketable shrimps were fish by a fleet of small shrimp trawlers in the Sato Island Sea, Japan, discarded when already dead. The effects on the future stocks of these commercially important species was predicted and a method to prevent the shrimp trawlers from destroying the resources was considered (Tokai and Kitahara 1991). A stock of 1600 tons of gadoids could have been available in the Ísafjarðardjúp grounds if the shrimp fishing vessels in that area prevented undersized fish and shrimps from being caught in the nets during the 1974 – 75 fishing seasons (Thorsteinsson 1992). The present stocks have been affected due to high rates of mortality of small fish that could have been allowed to escape through the meshes and yield commercial benefits in present day fisheries and the future (Thorsteinsson 1992). Bigger shrimp trawls (Figure 9) were introduced in the Breidafjordur grounds in west Iceland when shrimps were discovered in the area. Shrimp catch increased by 2.3 times per vessel compared to the smaller trawls that were fishing with short belly trawls (Figure 10). Simultaneously, by-catch of small size fish increased considerably. The cause of the increase in catch was due to the longer bellies of the bigger shrimp vessels and the high towing speed of the net faster than the small size fish that occurred in the grounds.

An estimated 97% of by-catch was discarded in the Northwest Pacific resulting in the mortality of 4 million tons of fish resources (Alverson 1994). Countries in Southeast Asia, Central America and the Caribbean are utilising the by-catch for human consumption needs. Cuba for example, is utilising almost 70% of the by-catch from shrimp trawls as human feed (Teutscher, Pers comm.). This means, however, that the remaining 30% of by-catch of unmarketable fish species is discarded. Large catch of diverse assemblage of non-marketable fish, cephalopods and crustaceans are often discarded (Liggins and Kennelly 1996) and (Liggins *et al*. 1996). In most parts of NW Africa for example, there is a regulation that by-catch must be landed for human consumption. This has not been practiced in The Gambia. Instead, all fishing vessels registered to fish must land 10% of their catch to the government within the license period. Unwanted fishes are mostly landed at the ports of Banjul. Only vessels of African origin (Senegalese, Gambian) are utilising some of the by-catch in the local markets yet, the unwanted fish is discarded. Few fishermen from the artisanal sector are benefiting from the by-catch in exchange for food commodities and selling it at the landing sites (Jallow 1995). The agreement is irregular. Shrimp vessels often land large amounts of small sized fish (Alverson *et al*. 1994) especially in developing countries like The Gambia where surveillance of vessels at fishing grounds is irregular. Tables 1 and 2 show catches from shrimp trawlers in the continental shelf of The Gambia, indicating by-catch of commercially important species.

NIAM NIOKHO: Side trawl shrimp fishing vessel; GRT = 229, HP = 750, 2003.
Catch in metric tons.

Table 1: By-catch from shrimp trawls in The Gambian coast.

Species	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Shrimps	2.7	0.2	-	0.5	1.7	2.3	1.0	5.2	5.0	4.0	5.4	-	28.0
Sole fish	4.0	6.6	-	2.6	12.3	3.8	0.6	1.8	0.9	3.7	4.4	0.1	40.8
Demersal	34.8	16.9	-	19.6	29.0	16.8	11.6	5.8	4.0	2.3	5.6	1.1	147.5
Cuttlefish	8.8	2.3	-	1.0	9.1	4.6	0.7	2.4	1.6	0.3	2.0	0.3	33.1
Octopus	0.6	-	-	-	-	-	-	-	-	-	-	-	0.6
Squid	-	-	-	-	-	-	-	-	-	-	-	-	-
Pelagic	-	-	-	2.8	6.0	4.3	-	-	-	0.6	0.8	-	14.5
	-	-	-	-	-	-	-	-	-	-	-	-	-
Others	4.0	4.4	-	2.2	5.0	2.1	0.3	-	-	-	-	-	18.0
Total (Tons)	54.9	30.3	-	28.7	63.1	33.9	14.3	15.2	11.6	10.8	18.2	1.5	282.5
No. of hrs	359	118	-	170.35	476.17	217.05	102.09	385.34	429.34	509.24	495.20	11.30	3274.47
No of Days	20	11	-	11	24	12	6	25	24	25	29	2	189

TADORNE: Side trawl shrimp fishing vessel, GRT = 228**,** HP = 850, 2003. Catch in metric tons.

Table 2: By-catch from shrimp trawl in the Gambian coast, indicating non-target species of the demersal stocks (cephalopods, crustacean, fish and mulluscs).

Shrimps	0.3	-	-	0.2	1.3	1.5	1.0	7.6	6.0	3.2	0.8	-	21.9
Sole fish	0.9	5.2	9.0	0.8	9.3	3.7	2.3	6.6	3.9	7.8	0.3	-	49.8
Demersal	8.5	8.6	1.5	18.7	20.4	20.6	9.6	12.0	8.0	2.2	1.1	-	111.2
Cuttlefish	1.0	0.9	0.5	0.5	6.8	6.8	1.8	3.9	3.2	1.1	-	-	26.5
Octopus	-	-	-	0.5	0.2	-	-	-	-	-	-	-	0.7
Squid	-	-	-	-	-	-	-	-	-	-	-	-	-
Pelagic	-	-	-	-	-	-	-	-	-	0.2	-	-	0.2
Tuna	-	-	-	-	-	-	-	-	-	-	-	-	-
Others	-	-	-	0.8	0.7	2.0	-	-	-	0.7	-	-	4.2
Total (Tons)	10.7	14.7	11.1	21.5	38.6	34.6	14.8	30.1	21.1	15.1	2.2	-	214.5
No of hrs	104.10	136.12	111.05	82.30	266	204	107.05	463.55	555.27	405.45	19.06	-	2455.25
No of Days	7	9	6	6	16	12	7	25	30	22	1	-	141

7.2 By-catch in the estuary shrimp nets

Andrew 1994, found out that the Clarence River stow net fishery for school prawns (*Metapenaeus macleayi)* had comparatively little impact on finfish fisheries. Most fishing activities affect the nursery function of the estuary (Sobrino *et al.* 2005) especially fishing nets that use smaller mesh sizes on cod-ends like stow nets of The Gambia. Considering a stow net for pink shrimp (*penaeus notialis)* with illegal mesh sizes of 17 to 20 mm and or the minimum legal mesh size of 25 mm, exceptionally large catches of juvenile fish and shrimp are eminent.

8 METHODS TO REDUCE BY-CATCH

The Nordmøre grate operates by preventing active swimming fish and non-targeted fish from swimming into the cod-end of a shrimp trawl and indeed guides passive shrimp to swim through the grate into the cod-end. The active fish could have been considered by-catch if retained in the cod-end; but swimming out from the net eventually reducing catch without any effect on the catch of shrimp (Isaksen 1993). The advantages of the grates not only reduce incidental catch but also provide better quality catch, more money to the sorted catch, and less working time required to sort out the catch among other benefits. Australia and other coastal states have improved the device and have since proven success in the reduction of incidental catch. Canada has almost successfully eliminated by-catch of red fish in the *Pandalus borealis* shrimp fishery due to the Nordmøre grates. Despite the success of the device, it may not be available in The Gambia and even though it was, it could be expensive for the fishermen. "Norway and Russia agreed to introduce compulsory use of the grates in the shrimp fishery in both EEZs effective January 1997". Canada, Iceland and the United States of America have adopted the system in their respective fishing waters (Jallow 1995).

The introduction of the Nordmøre grid has alleviated concerns over the potential impacts of trawling by-catch in the estuarine prawn trawl fishery.

A method of enlarged mesh size aimed at increasing selectivity was developed in Mozambique and in the Sato Island Sea of Japan. The idea was to allow the smaller size fish escape through the increased meshes and retain the commercial size fishes. The technology was successful and soon accepted by the small shrimp trawl fishermen especially in Japan (Tokai *et al*. 1991).

8.1 Square mesh netting

It has been suggested that reducing the fishing circumference of the cod-end (i.e. increasing the hanging ratio) by mounting diamond meshes through the bars would attain square shaped meshes thus increasing selectivity (Broadhurst *et al*. 2003). It was also found out from a survey conducted in the Gulf of St. Vincent that cod-ends made of square meshes and narrow circumferences, reduce the rate of by-catch of small fish and juvenile western king prawns (Broadhurst *et al*. 1999a).

Three experiments on selectivity to compare square mesh and diamond mesh cod-ends were conducted in the fishing grounds of Ísafjarðardjúp and Húnaflói off the north coast Iceland from 1988 to 1990. Similar trawl riggings in the two shrimp fishing boats were used; the only difference was the cod-end rigging. The square mesh cod-ends were measured at 4.0 m deep and 100 bar stretched on both top and lower panels allowing three rows of diamond meshes at the cod-end for easy closure of the bag. The average mesh size in the diamond mesh cod-end was 36.8 mm compared to 39.9 mm in the square mesh cod-ends in both grounds. The ICES mesh gauge with a pressure of 4 kgf was used to measure the mesh sizes.

Table 3: Comparison of catch selectivity between diamond and square shape mesh shrimp trawl cod-ends in Ísafjarðardjúp and Húnaflói waters, 1988. Note: # means number.

	Ísafjarðardjúp		Húnaflói	
	Diamond	Square	Diamond	Square
Shrimp (kg h)	376	299	434	381
Shrimp count (kg)	442	302	503	337
Cod 0-group (# h)	130	8	6	2
Haddock 0-group (# h)	1245	457	0	0
Whiting 0-group (# h)	2472	376	27	4
Herring 1-group (# h)	232	1	4036	668
Herring 11-group (# h)	466	72	104	46
Capelin (# h)	842	133	1104	284

The results above indicate that square mesh nets are selective and catch generally consisted of the required sized fish and shrimps compared to the diamond mesh netting. In addition, about four graphs were provided, indicating the length distribution (carapace) of shrimps and by-catch of herring, haddock, whiting and capelin, caught by the two different mesh nettings. In fact it was found that larger quantities of bigger size fish (haddocks and herrings) were retained in the square mesh netting. Observations from underwater cameras have shown herring scales flowing out from the cod-end with no other observed defects to small escaping fish and shrimps (Thorsteinsson 1992). Sorting categories of the shrimps were much easier and faster with the square mesh compared with the diamond. More revenue was acquired. It was reported that the shrimp fishermen were convinced with the outcome of the results and satisfied with the effectiveness of the square mesh. It has now been decided in Iceland to use square mesh netting in all cod-ends of the inshore fishery (Thorsteinsson 1992).

Indeed, the method adopted in Iceland of using square meshes on nets operating in all inshore fisheries aimed at allowing small fish and shrimps to escape is something worth emulating especially in developing countries. There is evidence that square mesh netting on the cod-ends of shrimp trawls is not only convenient to release small size fish and shrimps from the catch, but also a useful method for conservation of small species for future use.

Mozambique is considering introducing larger mesh cod-ends to release the small size fish and shrimps and retain the larger, more valuable shrimps for export and utilise the fish for human consumption (Isaksen *et al*. 1993).

The uses of new technology, such as square meshes and grids, to name a few have immensely reduced the amount of untargeted fish species in shrimp trawls. A method that would allow the fish stocks to stabilise or grow must be imminent in order to meet the demand for future supply of fish resources. This could also be achieved by either increasing the mesh sizes (Tokai and Kitahara 1991), creating square shape meshes or attaching grids in the shrimp trawls.

Square mesh has been deemed the most appropriate method for The Gambia fishery because of its low cost; it is also easy to mount and requires no additional cost for fishermen in terms of netting material. The diamond mesh of the same netting would simply be mounted from the bars to attain square shape meshes (Broadhurst *et al*.

2003). By using this technique, most small fish from shrimp trawls, stow nets and drift gill nets are expected to swim out from the net through the square meshes.

Stow net fishing methods are believed to be the main causes of mortality of juvenile fish assemblages in the estuary of The Gambia where spawning of many commercially important fish and shrimp species occurs. The causes are most likely the 17 to 20 mm illegal mesh sizes employed at the cod-ends of single stow nets as well as the diamond shape meshes in the same section. Modification of the net is proposed (Figure 8) designed to eliminate or reduce by-catch of juvenile fish and shrimp for future economic benefit. The increased hanging ratio on the side panel is based on recommendations by Broadhurst (2003).

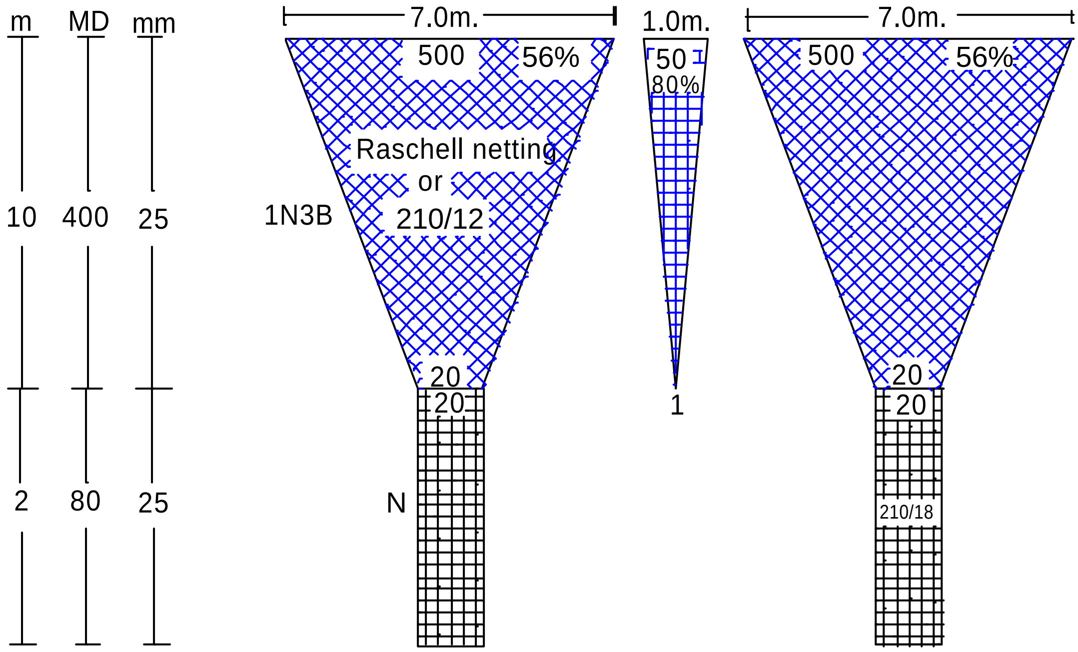

Figure 8: Proposed modifications of shrimp stow nets. Square shape meshes are placed throughout the Cod-ends and side panels.

Shrimp drift gill nets operating in the same area as the stow nets are indeed less destructive compared to stow nets. Yet, undersized fish of different species are also captured despite the minimum legal mesh size of 25 mm. This could be attributed to the diamond shape meshes throughout the netting wall. Some fish are found on the top section of the net while smaller size shrimps are found at the bottom of the net. The modification below (Figure 9) is proposed as a solution. The scenario is not necessarily to exclude catch of fish from the net but to retain only sizeable fish in the net and allow juvenile fish to swim out from the square meshes.

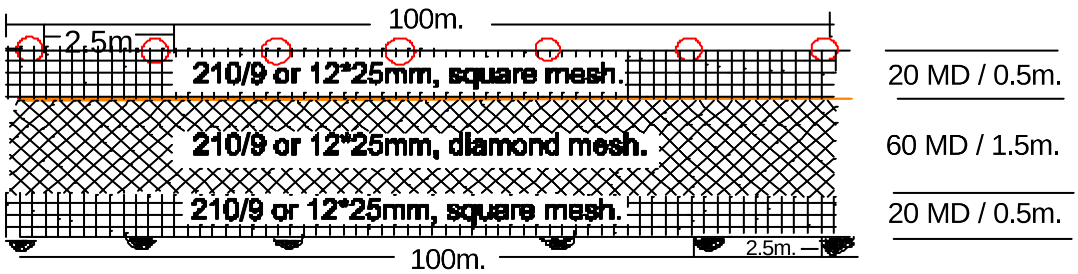

Figure 9: Proposed modifications of shrimp drift gill nets. Square mesh net at 0.5 m top and bottom of the net.

There has been no consideration neither from the Gambian authorities nor fishermen to estimate losses of marine fish due to catch of juvenile fish and shrimps from the estuary dating back to the 1960s. No one can imagine how many thousands or millions of tons of commercially important fish could have been available in The Gambia waters if fishing was conducted responsibly.

8.2 Disadvantages of square meshes in shrimp trawl cod-ends

The disadvantages of using square meshes in shrimp trawl cod-ends are as follows:

i. Individual fish gilled in the square meshes from a large catch tend to be very difficult to remove from the meshes (Broadhurst *et. al*., 1999b).
ii. Not all the species with a girth width almost equal to the square meshes survive through the meshes.
iii. A minimum quantity of undersized fish and shrimps could be retained in the net (Thorsteinsson 1992).
iv. Some knots of the twisted PE 380 denier*48 became loose when fishing operations were in progress (Thorsteinsson 1992).

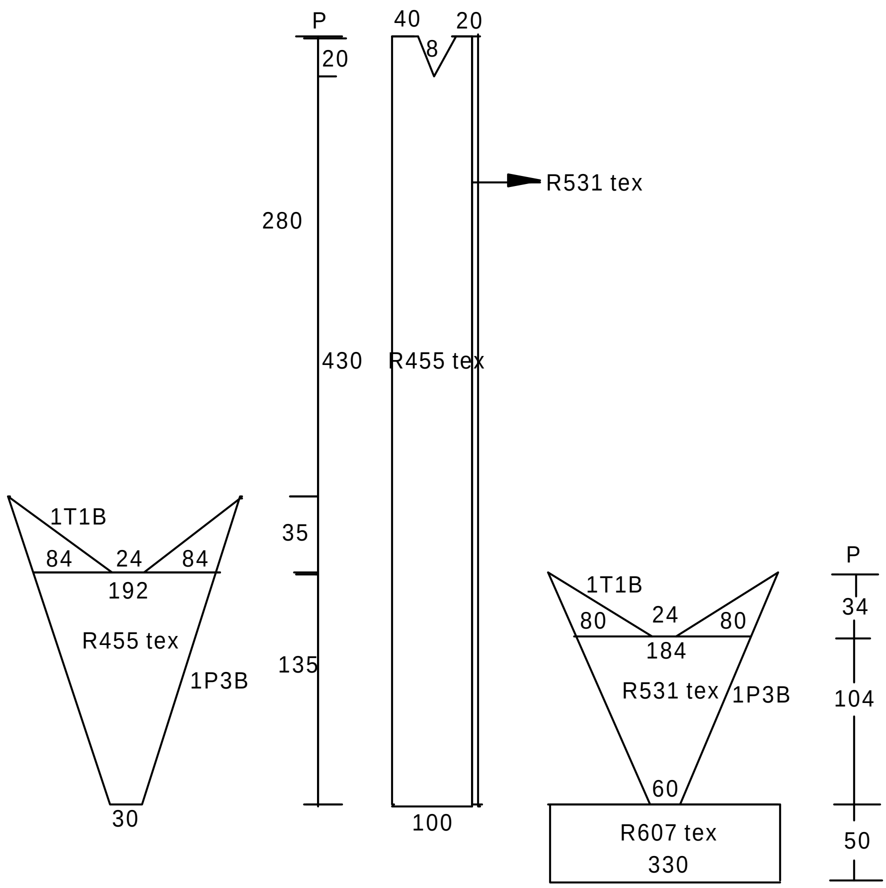

Figure 10: Short belly Icelandic small shrimp trawl used before 1967.

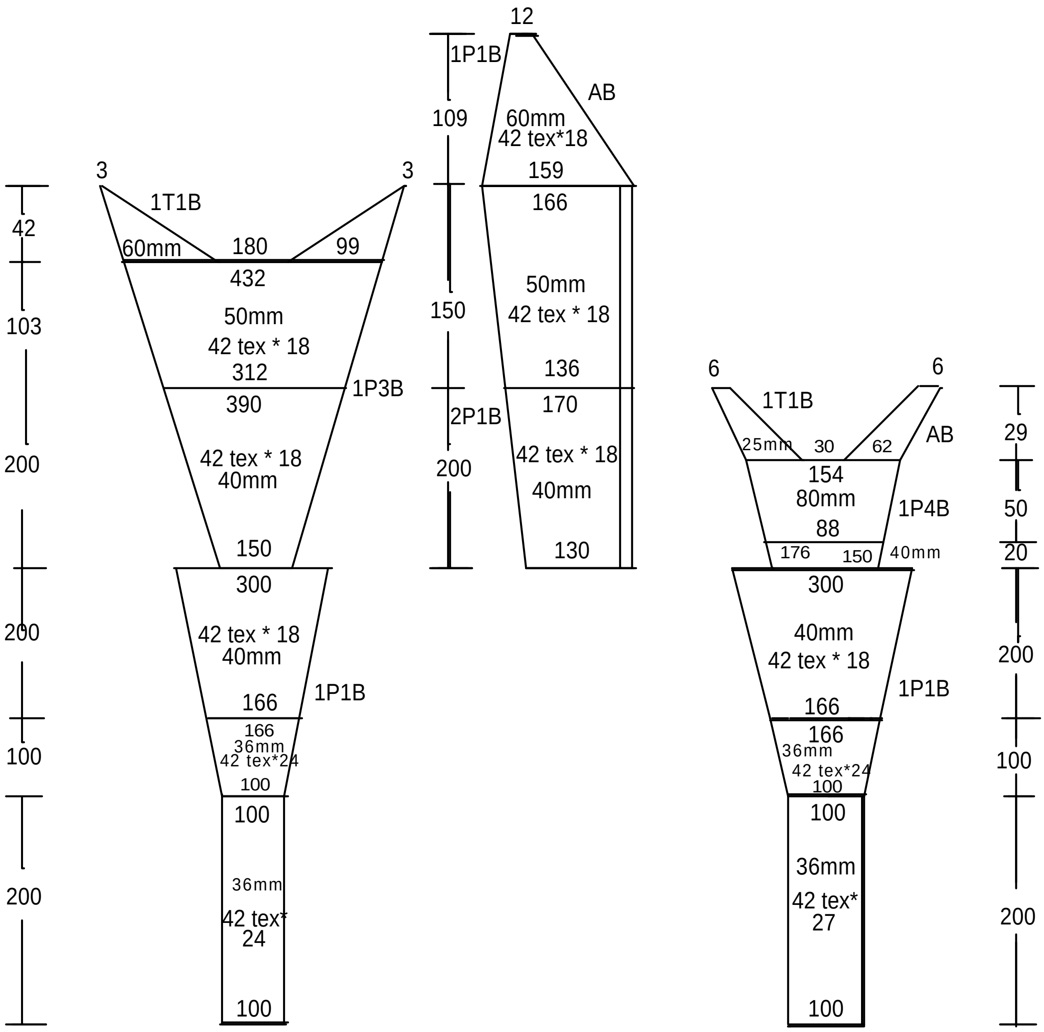

Figure 11: Larger Icelandic shrimp trawl design for big vessels used in the inshore fishery in west Iceland after 1967. Such trawls killed large numbers of small fish that could have yielded 1600 tons of commercially important fish for future use (Thorsteinsson 1992).

9 CONCLUSIONS

Four different fish and small shrimp by-catch reduction devices have been studied here, namely, the Nordmøre grate, grid; enlarged mesh size and square shaped mesh. The square mesh has been found to be appropriate for Gambian fishermen in terms of low cost, efficient selectivity and simplicity. The shape of the diamond meshes of the sections proposed for modification to square meshes need to be changed to an angle of 90º and the meshes mounted through the bars to attain the square shape. Thorsteinsson (1992) revealed from the shrimp trawl survey conducted in the north of Iceland from 1998 that no defects of undersized fish swimming out from the cod-end were detected. Another advantage with the square mesh in shrimp trawls is that less time is required to sort out the shrimp categories from the bulk catch. Similar statements were made by (Broadhurst *et al*. 1996 and 2003).
Enlarged meshes could be a good means reducing by-catch but the Fisheries Regulations on minimum mesh size of the state must be put into consideration. Enlarged meshes could only be effective if the regulations on mesh size were amended and hence enforced accordingly. Otherwise, legal battles between fishermen's associations and Marine Research Institutions are highly probable. The Nordmøre grates and grid might not be applicable in tropical waters considering the species' behaviour and size compared to species found in other parts of the world. Furthermore, additional costs are required which might not be favourable to the average fisherman and the device might not be easy to put into operation by local fishermen in The Gambia.

Mortality of undersized fish due to by-catch from shrimp trawls, stow nets and other shrimp fishing methods operating in the coast and estuaries affects the future stocks of commercially important fish and shrimp resources. The cause is the small mesh sizes employed in the nets. Regulations on mesh size are not strictly enforced in The Gambia especially in the estuary where most fish spawn. However, the illegal smaller mesh sizes of 17-20 mm at cod-ends of stow nets as well as diamond shaped meshes are affecting the fish and shrimp resources in the estuary. Drift gill nets are less destructive compared to stow nets, yet, capturing some juvenile fish and shrimps. Considering the artisanal sector, which is the main supplier of fish for food to the populace, measures to allow the fishery resources to escape from the nets must be in place, without which the future stocks will be jeopardised and fish may not be affordable to most Gambians in the near future. In the coastal waters where shrimp trawling is practiced, discards of unwanted small sized fish is regular. The Gambian Government is obliged to reduce the number of fishing vessels as a means of safeguarding the fishery resources for future use. Furthermore, the 40 mm minimum mesh size for deep sea shrimp trawls operating in The Gambia waters is required to be increased to 50 mm to merge with coastal shrimp vessels.

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