FISHERIES TRAINING PROGRAMME

P.O. Box 1390, Skulagata 4
120 Reykjavik, Iceland

Final Project 2003

EFFECT OF MESH SIZE AND TWINE TYPE ON GILLNET SELECTIVITY OF COD *(GADUS MORHUA)* IN ICELANDIC COASTAL WATERS

Jorge Raul Faife
Institute for the Development of Small-Scale Fisheries (IDPPE)
j.faife@idppe.org

Supervisor
Haraldur Arnar Einarsson
Marine Research Institute (MRI)
haraldur@hafro.is

ABSTRACT

This report focuses on the selectivity of four mesh sizes of gillnets (6", 7", 8" and 9") and two type of twine (monofilament and multifilament) on cod (*Gadus morhua)* conducted in two different areas in Icelandic waters. The data were collected in April 2001 as part of a spawning net survey of cod but not for examining selectivity. In this study a comparison of relative selectivity of mesh size and netting material was made for these nets in each area. The selection curves were estimated indirectly by using the Gamma model. This study has concluded that monofilament gillnets catch better than multifilament. The mean lengths of cod increased with mesh size of gillnet but the difference of netting material did not affect selection range. However the selection was affected by size distribution and abundance of cod. This approach emphasises that the process of catch such as wedging, snagging, and entangling should be considered in gillnet selectivity studies because it has been demonstrated that small mesh size of gillnet can catch large fish and large mesh size can catch small fish.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Gillnet as a fishing gear

Gillnet is one of the oldest types of fishing gear and is widely used to harvest diverse marine species (Sainsbury 1996). Gillnets are classified as a passive gear, consisting of a large wall of netting which can be set at or below the surface on the sea bed, or any depth in between (Munprasit *et al.* 1986). Its construction can be single, double or triple (trammel net) netting. Depending on the operation, a gillnet can be drifting, fixed or encircling. Fish caught in gillnets are usually gilled, but can be wedged, snagged or entangled (Hovgård 1996a, Hovgård 1996b, Hovgård and Lassen 2000). Nets have usually been set and hauled by hand. However, the use of a net hauler is now very common and sometimes a power block can also be used. Modern nets are made of synthetic fibres such as polyamide and can be monofilament or multifilament or a combination of both in the case of more than one panel.

The importance of gillnets in the modern fishing industry is relevantly modest in terms of catch compared with towed gears such as trawls and seines (Hovgård and Lassen 2000). But the gillnets, at least those with a single netting, are, in general, considered as having a high degree of selectivity, in terms of fish species, as well as the size of the fish, which directly depends on the size of the mesh. However incidental catch of a number of endangered species such as turtles, sharks, marine mammals or seabirds, in certain areas is a matter of growing concern. Research is being carried out, aiming to reduce this risk (ICES 2000).

Technologically, gillnets are simple, easy to mend, require little in the way of on board equipment and are relatively cheap to purchase. They may be set in areas with difficult bottom conditions, as are often found around coral reefs, in coastal rocky areas or in fresh water bodies where towed gears cannot be used (Hovgard and Lassen 2000).

For the above-mentioned reasons, many developing countries including Mozambique are encouraging the use of passive gears such as gillnets, hooks and traps in small scale fisheries.

This paper focuses on the effect of four mesh sizes of gillnets (6”, 7”, 8” and 9”) and two types of twine (monofilament and multifilament) in the selectivity of cod conducted in two different areas of Icelandic waters. The data were collected for spawning surveys of cod but not for the selectivity studies. In this study a comparison was made of relative selectivity of mesh sizes. A comparison is also made on the selectivity of cod between these areas.

1.2 Fisheries in Mozambique

Mozambique, Mauritania, Senegal, Madagascar, Namibia, Ghana, Seychelles are African countries for which the fisheries sector contributes over 5% to the total Gross Domestic Product (GDP) or to foreign currency (FAO 1996). Mozambique has around 2,700 Km of coastline and the fisheries sector represents an integral part of the national economy. However the continental shelf is alternatively narrow and very wide, up to 90 nautical miles at the Sofala Bank. The primary productivity is relatively high due to currents and numerous rivers bringing considerable amounts of sediments and nutrients. The fresh water fisheries are linked with Lake Malawi/Niassa and Cahora Bassa dam, and the numerous rivers that cross the country (SADC 2003).

Figure 1: Map of Mozambique fishing locations.

A large number of commercially important species inhabit coastal waters and are caught by artisanal and industrial fisheries. According to SADC reports, shrimp represents 85% of the total fish exports in value. The average catches of shrimp in the lasts 5 years were estimated at 9,000 tons/year (DNAP 2003).

Shrimp stocks in Mozambique area fully exploited (Bage 2001) but other species such as small pelagics and demersals species are under-exploited and the catches could be doubled (MoF 1994).

Fisheries in Mozambique are divided into industrial, semi-industrial and artisanal fisheries. The industrial fleet consists of 160 vessels, 50% of which are shrimp trawlers and other 50% long liners for tuna, which operate for short periods each year according to the dynamics of species and hand liners for the rocky fish (DNAP 2003). The semi-industrial fleet consist of 200 boats mostly fishing Kapente (cyprinidae) in the Cahora Bassa dam and 35% fishing shrimp in the Maputo Bay and Sofala Bank. The product from industrial and semi-industrial fisheries is for export.

There are 70,000 artisanal fishers with a fleet of 13,920 boats and canoes (IDPPE 2002), of which only 3% are motorised. The sub sector is organised in about 800 fishing centres of which more than 653 are scattered along the coast. The main fishing gears used in artisanal fisheries are beach seines 30%, hand lines 40%, gillnets and traps 25%. Purse seine and surrounding nets such as chilimila nets are also used in certain areas of Mozambican waters (IDPPE 1999).

IDPPE and promotion of artisanal fishery in Mozambique

Artisanal fishery in Mozambique is a highly ranked activity in the absorption of local labour force and provision of aquatic protein products to the local population (Lopes and

Gervasio 2000). The Institute for the Development of Small-Scale Fisheries (IDPPE) was established by the government to, in collaboration with the artisanal fishermen, implement the policies and strategies set by government. The policies and strategies are designed to improve the harvest and market facilities, building capacity including training and management of fishing resource (MoF 1994).

Since its establishment, IDPPE in partnership with fishermen has tested different types of fishing methods at various fishing centers with the main purpose to diversify fishing techniques and management. The main goals are to promote the appropriate technologies of offshore artisanal fisheries and reduce the concentration of beach seines along the coast and in estuaries.

The IDPPE has, with participation of the fishermen, conducted experimental fishing programmes of different passive gears such as gillnets, traps and longlines. Fishermen have largely adopted these fishing gears. For example, driftnets, which were formerly used only to catch small sardines today catch other species of fish with the introduction of nets with bigger meshes in the Nampula and Zambezia provinces. Bottom set gillnets which were used only in some villages to catch big sharks for shark fins are now the major gear used to catch high quality fish like grouper and sea bream. Successful trials in the use of trammel nets for shrimp harvesting have been carried out but still not adopted by fishermen due to the lack of adequate fishing gears material in the local market to make new nets (Bage 2001).

To respond to recent increasing needs for resource management for sustainable artisanal fisheries, selectivity studies are becoming important. These tools can also help to evaluate the effects of catch and mortalities associated with selective fishing methods and techniques and the differences in selectivity between traditional and new technologies or approaches.

2 SELECTION PROCESS AND SELECTIVITY

In the late 1940s and 1950s, there were major advances in technology of great importance to both the fishing industry and fishing technology research. Echo-sounders and net-sounders were developed for use on vessels and fishing gear; underwater photography was pioneered providing a vital tool for fish behaviour studies. These technological advances generated a new dynamism in research and development. There was a gradual recognition that the fish capture process could now be studied as a scientific discipline and fishing gear design might not be so much a 'black art', but more a science. (ICES 2000).

The selectivity of fishing gear studies started during the 1950s. It concentrated mainly on mobile gears, but also on set nets and traps. The difference in selectivity of codends made of natural and new synthetic materials was studied exhaustively as was the relation with mesh size. The selectivity of a range of species was investigated including haddock, cod, redfish, whiting, dab, plaice, herring, lobsters, and crabs. This prolific period of work was driven by international collaboration with major selectivity exercises being undertaken in the North Sea and the Arctic (ICES 2000).

Practically, selectivity of fishing gear can be defined as the proportion of fish available to the gear in a given size or age group that is retained by the gear (Hunte and Mahon 2001, Fridman 1986). Fishing science is often based on theory of probability, i.e. the availability of fish to the gear depends on the catchability of gear, the selectivity and fishing power and effort deployed (Hovgärd and Lassen 2000). Therefore the selectivity of fishing gear can be defined as "any process that gives rise to the differences in probability of capture among the members of exploitable body of fish" (Holst *et al.*1998). This approach is often examined by means of a graph, which relates the probability of capture to fish size (King 1995). In estimating selectivity of fishing gears two main methods are used, namely: direct methods when the abundance per size is known and indirect methods that do not require such information. Therefore indirect methods require only size information from several different mesh sizes fished simultaneously.

Gillnets are commonly used in selectivity studies to estimate the abundance and size structure of fish populations. Various indirect methods are used for estimating selectivity of gill nets. Most studies on selectivity are based on Baranov's "Principle of Geometrical Similarity", which states that selection depends on the geometry of the fish and the meshes. The selectivity will be the same for any combination of fish length and mesh size for which ratio is constant and all the mesh sizes will be equally efficient. However, this principle does not hold true if the catch processes of gillnet are varying (Hanse et al. 1997; Hovgärd 1996; Hovgärd and Lassen 2000).

Gillnets are considered highly size selective and most fish caught often deviate less than 20% from the optimal fish length (Hovgärd 1996). However, gillnet selectivity can be affected by many factors such as gear parameters, parameters related to the fish, operation during fishing process, environmental parameters, etc (Holst *et al.* 1998).

2.1 Behaviour of cod (*Gadus morhua*)

The Atlantic cod (*Gadus morhua.)* is a demersal fish (FAO 2003). However it may become pelagic, when feeding or spawning. The presence of cod usually depends on prey distribution and temperature.

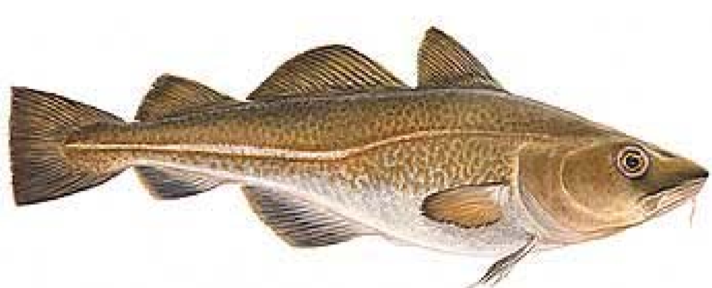

Figure 2: Cod (Gadus Marhua).

Larger cod are found in colder waters in most areas (0-5°C). It lives in waters of wide range of salinity from nearly fresh to full oceanic water, and in temperatures from nearly freezing to 20 ºC.

This species is widely distributed in a variety of habitats from the shoreline to well down the continental shelf, to depths over 600 m, but is mostly found within the continental shelf areas from 150-200 m. Cod is gregarious during the day; forming compact schools that swim between 30 and 80 m above the bottom, and scatter at night (FAO 2003).

This is one of the world's most fecund fish, with an average production of 1 million eggs per female. The sex ratio is nearly 1:1, with a slight predominance of females. The maximum range of temperature for spawning is from below 0°C to about 1 2°C, with most spawning taking place over the lower half of this range (FAO/SIDP 2003).

The growth rate is rather high; females grow slightly faster than males. It also varies from one area to another: for example, it is known that fish from the English Channel and the North Sea grow faster than those living at higher latitudes. Three year -old fish have average length of 56 cm (males) and 59 cm (females); 5 year olds, 81 cm (males) and 85 cm (females). The species lives up to 20 years and can grown up to 130 cm. The Atlantic cod is an omnivorous species. Larvae and post larvae feed on plankton, juveniles mainly on invertebrates, and older fish on invertebrates and fish, including young cod (FAO/SIDP 2003).

The fish is caught all around Iceland throughout the year, but the greatest catches are taken in March/April and again in June/July. Spawning takes place in late winter and early spring. Tagging experiment results show that migration of mature cod during spawning often occurs in large numbers from West to East Greenland and to some extent, to the spawning area of the South and Southwest coast of Iceland (ICES 2003, ICES 1998) The nursery areas are in the nutrient-rich waters off the Northwest coast, where the warm Gulf Stream of the Atlantic meets the cold Polar stream, and also along the North and East coasts. The main catching methods are by bottom trawls, long-line fishing, gillnets, and jigging. The most common age at catch is 4-7 years, and the weight is 2-5 kg. (4-10 lbs.), but larger fish are also caught (Icelandic ® USA Inc 2003).

According to Icelandic regulations for cod, the minimum mesh size for gillnets is currently 5½ inches (140 mm). However, a study took place in 2000 and fishermen recommended increasing the mesh size to 6 inches (152 mm) for the Northern Gulf (Sentinel Fisheries Programs 2003). Since 2004, the upper limit of mesh size for cod is 8 inches (Ministry of Fisheries of Iceland 2002).

3 MATERIAL AND METHOD

3.1 Operational and fishing procedures

This study is based on gillnet records which were collected from two different areas in coastal Icelandic’s waters in April 2001, during the spawning season of cod. Area 1 was conducted in parallel 65º 20’N to 64º 50’ N and 23º 08’ W to 24º 22’W during 9 days and in 57 stations by cruiser NOR1 – 2001. Area 5 was conducted in parallel 64º 07’N to 63º 50’N and 15º 42’W to 16º 22’W during two days and in 17 stations by cruiser NSO1-2001. The figure below shows the location of the two areas and stations that the trials were done.

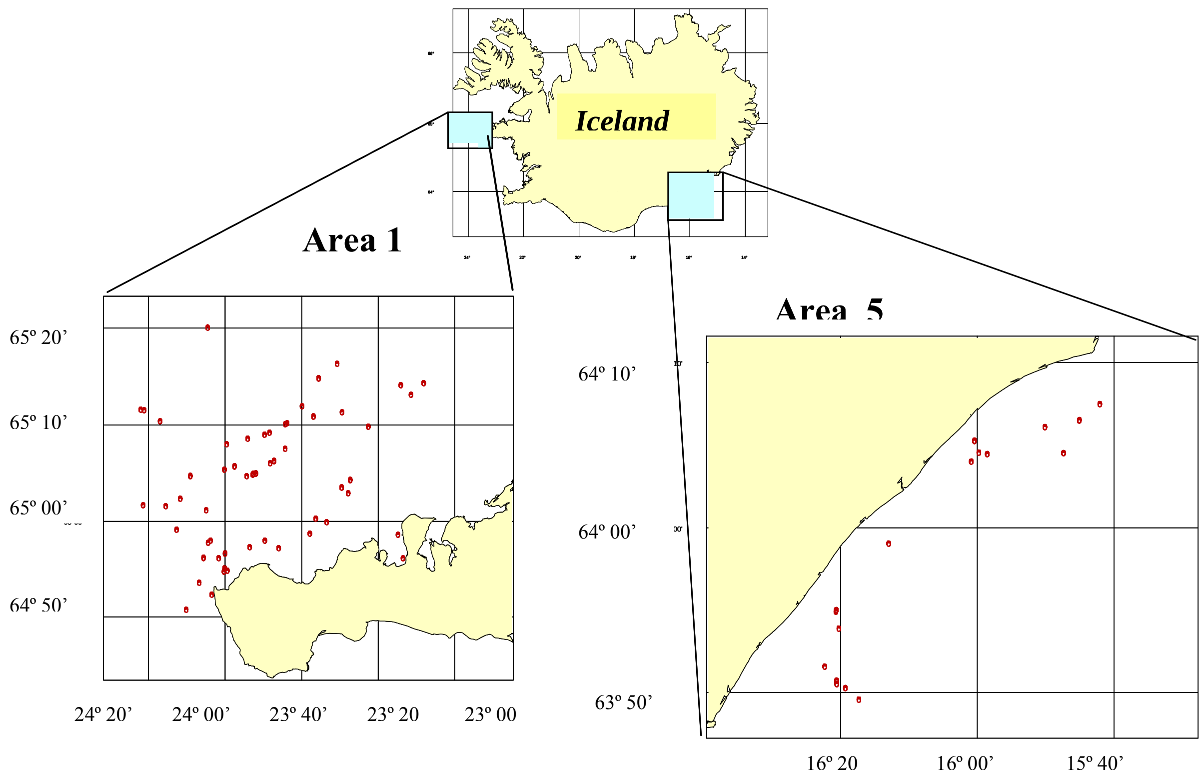

Figure 3: Station locations of Icelandic spring ground-fish surveys in cruiser NOR1-2001 and NSO1-2001.

Twelve polyamide gillnets, of which six were monofilament and six multifilament, with a combination of four different mesh sizes (6", 7", 8" and 9") were tied together to form a chain. The 12 nets with four different meshes were designed to be 55 m in length and reach 2 m depth. The diameter of the twine was 0.70 mm to 0.85 mm for monofilament and 1.5/8 to 1.5/12 for multifilament. The hanging ratio of gillnets was 0.5 and was almost equal for all nets. Gillnets were set in shallow waters at the end of the day and collected the next morning. Table 1 below shows how the net were set.

Table 1: Fixing scheme of 6 monofilament and 6 multifilament gillnets during cruiser NOR1-2001 and NSO1-2001. Mesh size in inches.

Net number	1	2	3	4	5	6	7	8	9	10	11	12
Mesh size	6"	7"	8"	9"	6"	7"	8"	9"	9"	8"	7"	6"
Twine type	mono	Mono	multi	multi	mono	mono	multi	multi	mono	mono	multi	multi

The comparison of selectivity was done on the different twines of net and meshes size in two areas, assuming that the other gear parameters, such as vertical slack, flotation and weights are equal in construction. The main environmental parameters of two areas are represented in Table 2.

Table 2: Main physical characteristics of area 1 and area 5.

	Min depth	Max depth	Min Surf. Temp.	Max. Surf. Temp	Min wind speed	Max. Wind speed	Min. Water Transparency	Max. water transparency
Area 1	14 m	308 m	.-2ºC	6,3ºC	9 m/s	37 m/s	9 m	11 m
Area 5	39 m	95 m	2.9ºC	7.6º C	9 m/s	13 m/s s	2.5 m; 9.5 m; 18 m	

In area 1, 12,645 cod were caught of which 7,700 were measured. In area 5, 7,354 cod were caught of which 2,843 were measured.

Two similar vessels were used for this survey, both using gill-netter with an over all length of about 35 m and 7 m beam. The power of the main engine was 486 Kw/660 HP.

3.2 Estimation procedures

In this study, catch from gillnets with same mesh size and type of netting material are considered on an average basis i.e. have been standardised to unite effort (Fujimori and Tokai 2001). The virtual number (v. number) of analysed fish was determined by the ratio factor (R. factor) between the number of fish measured and number of fish counted by the following equation:

Equation 1: Virtual number of fish

$$R_{factor} = (N_{measured} + N_{counted}) / N_{measured}$$

The grouped mean lengths ($\bar{x}$) and standard deviation (SD) were calculated by using the following equations:

Equation 2: Grouped mean

$$\overline{X} = \sum_{cell} \frac{(\text{midpoint}x\text{Frenquency})}{\text{TotaFrequence}}$$

Equation 3: Standard deviation

$$SD = \sum_{i=1} \sqrt{\frac{Tl^2 xfrequence}{n} - \overline{X}^2}$$

Where TL is the total length of cod.

Because of the large number of samples in this study, a Z-test was used to compare the means of length of cod in each mesh size (Bhattacharyya and Johnson. 1977).

Equation 4: Z-test formula

$$\overline{X}_1 - \overline{X}_2 \pm Z_{\alpha/2}\sqrt{\frac{SD_1^{\ 2}}{n_1} + \frac{SD_2^{\ 2}}{n_2}} =$$

Where: X means size o fish $Z_{\alpha/2}$ is the upper $_{\alpha/2}$ point of N(0,1) *SD* Standard deviations *n* sample size.

The gillnet selectivity model has been estimated indirectly, that is, that all nets are fished simultaneously with equal effort. This means that all nets have an equal chance of encountering fish and also that the gillnet efficiency of each mesh size is equal. In contrast, a direct estimation requires knowledge of real size structure of the population (Hansen *et al.*1997).

Because distinct catch processes of gillnet are unknown in this study, the curve selection was estimated by using the gamma model.

Equation 5: Gamma model

$$S(m_j, l) = \left(\frac{l}{(\alpha - 1)km_j}\right)^{\alpha - 1} \exp\left(\alpha - 1 - \frac{l}{km_j}\right)$$

Where l n size of fish in size (length).

m_j mesh size of j gillnet in Cm, α and k are selection parameters

l length of fish in Cm

Equation 6: Optimal length

$$Opl = (\alpha - 1)km$$

4 RESULTS

4.1 Length distributions

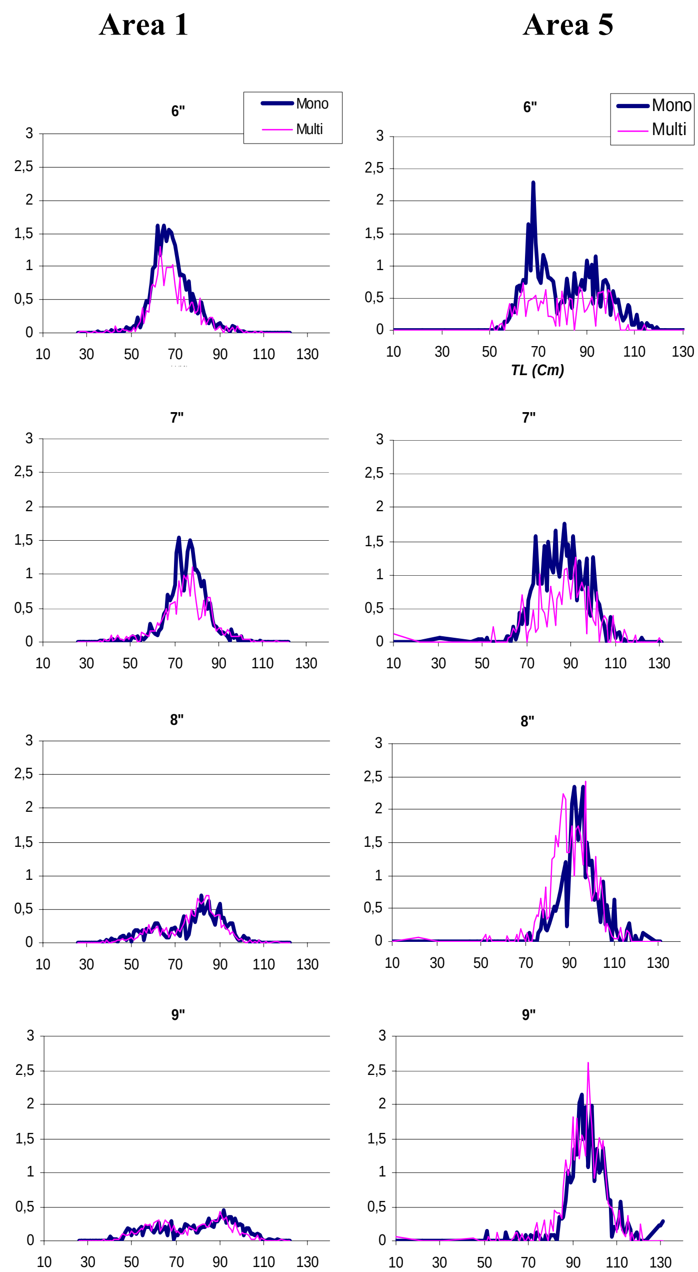

Figure 4: Length frequency distribution of cod for 4 mesh sizes and two material types.

In area 1 (Western Iceland), the distribution in 6” and 7” gillnets was unimodal i.e. one peak and catches were relatively higher in the monofilament nets (Figure 4). Catches in the two the large mesh nets were considerably low and bimodal. The average catch overall was lowest in the 9” monofilament. The average length of cod increase was from 6” to 9”.

In area 5 (South Eastern Iceland) catches in the 6” nets were bimodal, but unimodal for the 7”, 8” and 9” meshes. In general, large fish were caught in all mesh sizes in area 5. As in area 1, catches in monofilament nets were considerably higher in two small meshes. Catch rates tended to increase with mesh size in area 5, but decreased in area 1 (Figure 4). The type of twine has little influence on the length distribution, but more on catchability, with more fish being caught in monofilaments gillnets.

Comparison of the two areas

Figure 4 shows that in area 1 the length frequency is narrow and unimodel in small mesh size gillnets and disperse and bimodal in large mesh size. In contrast, in area 5 the length frequency is narrow and unimodal in large mesh size and disperse in small mesh size. It shows that the best selection of gillnet were in two small mesh sizes in area 1 and in two large mesh sizes in area 5. The catch rates for all mesh sizes were higher in area 5 than area 1 and the value of mean length of cod were relatively higher in area 5 than in area 1 (Figure 5).

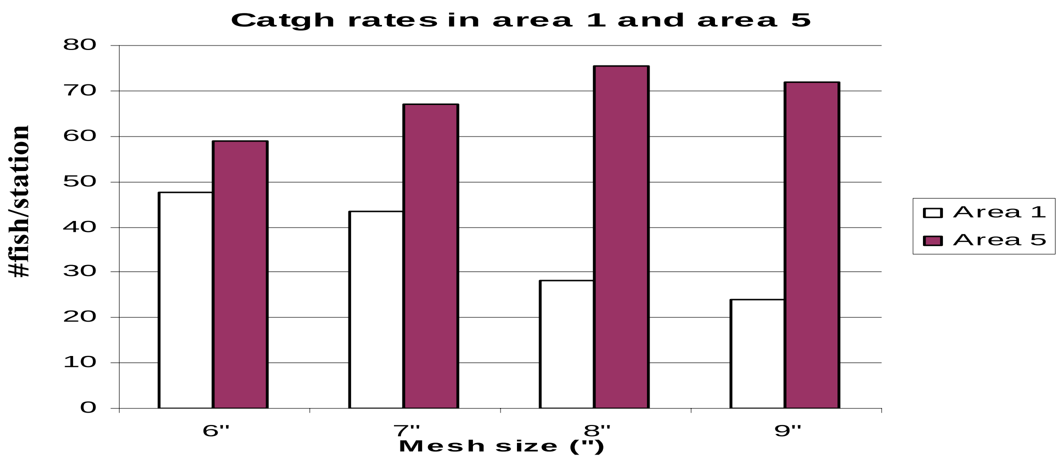

Figure 5: Average catch rates of cod per station for 4 mesh sizes in area 1 and area 5.

4.2 Estimation procedures

Calculations of grouped mean length, variance, standard deviation and P value are presented in Table 3.

In area 1 the catchabilty of gillnets decreases with increased mesh size. Mean lengths of cod increased with mesh size and standard deviation increased too. The monofilament gillnets had higher catch rates than multifilament. Differences in mean length between monofilament and multifilament in 6”,7” and 8” gillnets is not significant at the level P=0.001 (Table 3). However, in 9” mesh size gillnet the difference between monofilament and multifilament means is significant at level P=0.1is significant.

In area 5 the catchability of gillnet did not change much with increasing mesh size. Standard deviations are lower in gillnets with large mesh sizes than small sizes and the lowest was in 8”. The small mesh monofilament gillnets caught better than small mesh multifilament, but in large mesh size gillnets the catch was almost the same. The comparison of means length in gillnets with same mesh size shows that multifilament in 6” and 7”gillnets is not significant at level P=0.001, (Table 3). However, in 8” and 9” the difference between monofilament and multifilament means is significant at level P=0.1.

Comparison between the two areas

In both sampling areas the mean lengths of cod increased with larger mesh size and the transformed mean length (λ=length/mesh-size = l/m) decreased with the mesh size of gillnets increasing.

Table 3: Statistical results estimated from data of effect of mesh size and twine type on selectivity for area 1 and area 5 where Mn is monofilament gillnet with n inch mesh size and Mnn is multifilament gillnet with n inch mesh size.

		M6	M66	M7	M77	M8	M88	M9	M99
Area1	Station	57	57	57	57	57	57	57	57
	Total of fish	1596	1115	1395	1087	808	799	701	660
	Mean	68.5	68.5	75.6	75.1	77.2	77.8	79.4	76.1
	SD	9.21	10.23	9.19	11.31	14.46	13.08	17.19	16.35
Area 5	Station	17	17	17	17	17	17	17	17
	Total of fish	608	319	654	400	528	657	535	602
	Mean	80.87	80.0	86.0	86.9	94.5	90.7	97.2	95.2
	SD	14.3	14.3	11.0	13.1	8.1	9.6	10.2	10.1

Table 4: Transformed length (λ) which represents relation between lengths of cod and mesh size where Mn is monofilament gillnet with n inch mesh size and Mnn is multifilament gillnet with n inch mesh size.

	M6	M66	M7	M77	M8	M88	M9	M99
Area1	4.5	4.5	4.3	4.2	3.8	3.8	3.5	3.3
Area5	5.3	5.3	4.8	4.9	4.7	4.5	4.3	4.2

4.3 Fitting model

The gillnet selection curve estimation has been fitted for both area 1 and area 2 by using the gamma model. The value of α, k and Optimal Length were calculated for each gillnets in each area.

The results from the gamma model shows that in area 1 all gillnets are selective for certain range of fish size. The small mesh size catches small fish and the large mesh size catches large fish. Gillnets with largest mesh size (8" and 9") are less selective than small mesh size gillnets. The selection of monofilament and multifilament are similar in small mesh size gillnets. The distinctions of selection between the two types of twine appear gradually with increasing mesh size. Table 7 and 8 (in the appendix) show the optimal lengths for each gillnet.

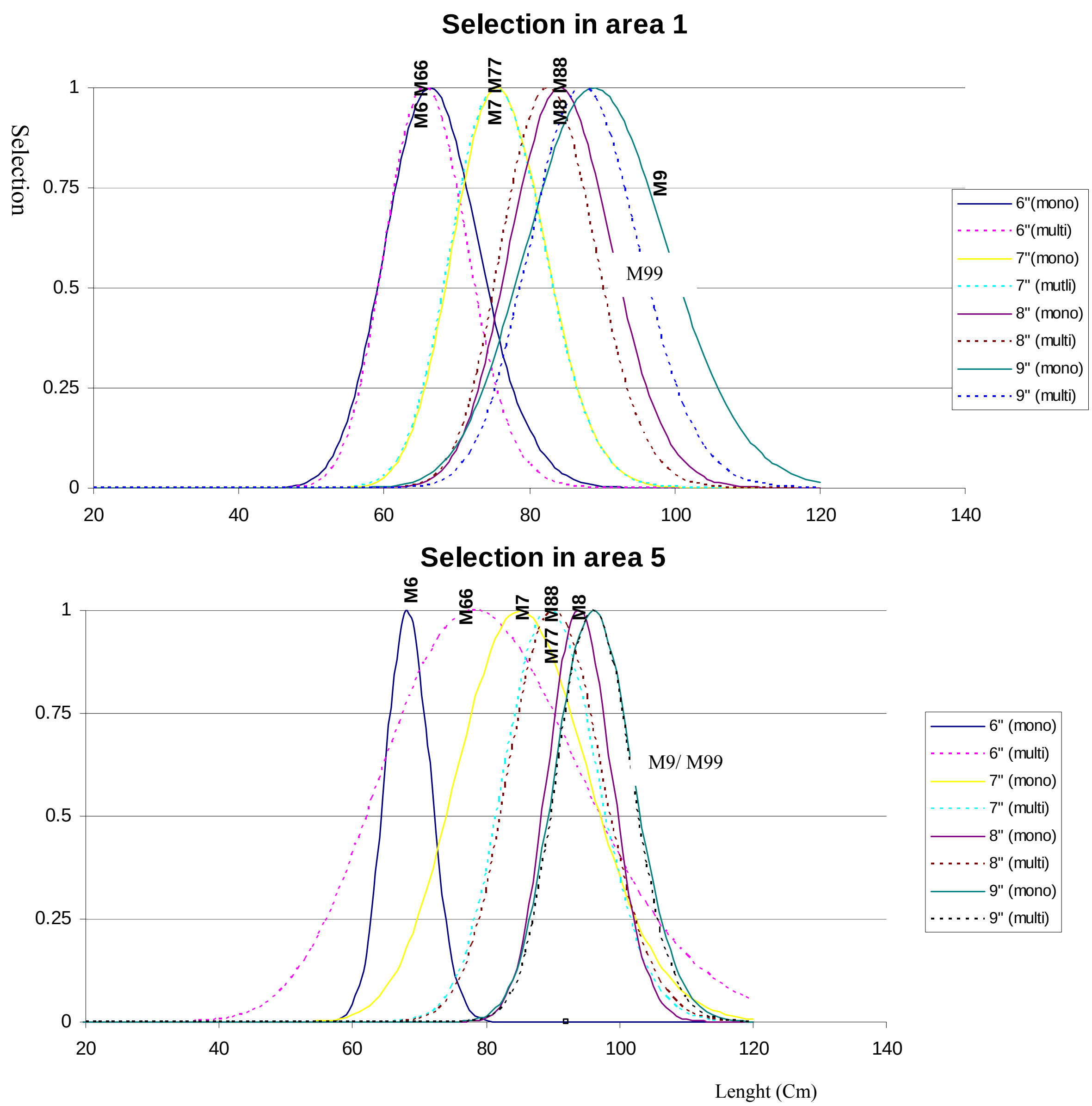

Figure 6: Estimation of selection of gillnets by Gamma model in area 1 and area 5 X cod Length Y proportion.

In general, in area 5, all gillnets are selective in a certain range. The range of selectivity of gillnets increase with increasing mesh size, except in smallest mesh size gillnets (6"), where the multifilament gillnet have very large range of selectivity. The selection of monofilament and multifilament are different in small mesh size gillnets but the difference disappear with increasing mesh size.

The estimation of selection S∈[0.75; 1.00] where this represents 50% of total catches from the model shows that the range length of cod is similar for all gillnets with same mesh size and this range increases with mesh size in area 1.But in area 5 the variation of mean length is not linear (Table 6).

Table 5: Length range of cod in area 1 and area 5, where S∈[0.75; 1.00] which represents 50%of total catch. The value was estimated by graphical interpolations.

	Gillnet	M6	M66	M7	M77	M8	M88	M9	M99
Area 1	Optimal length	66.5	65.7	75.7	75.5	84.1	82.5	88.9	87.3
	Selection range (Cm)	8.6	8.5	9.5	9.4	10.5	9.5	14.6	11.3
Area 5	Optimal length	68.19	78.24	85.06	89.47	93.93	90.14	96.07	96.08
	Selection range (Cm)	4.7	22.4	14.9	10.5	7.3	10.6	9.0	8.4

5 DISCUSSION

The catch rates (number of fish/station) obtained from eight different types of gillnets tested, shows that area 5 had the best catch number and size of fish than in area 1. It's, probably, because the relative abundance was higher in area 5 than in area 1. The difference of relative abundance between area1 and area 5 can be supported by migration of mature cod during spawning season to the South of Iceland where the temperature of the waters are relatively warmer (ICES 2003, ICES 1998).

Because the range of size distribution was different between these two areas, that is in area 5 there was larger range of size distribution of fish than in area 1, the catch rates of the gillnets, decrease with increasing the mesh size in area 1. In area 5 the catch rates did not change much by increasing the mesh size, see Figure 4.

The average size of fish in the two areas was different, that is in area 1 they were smaller than in area 5. It demonstrates clearly that fish in area 5 were larger than in area 1.

In area 1, small fish were probably entangled in the two largest mesh sizes (8" and 9") and other fish have been gilled or wedged in the two smallest meshes (6" and 7"). Contrarily, in area 5 large fish have been wedged or entangled in small mesh size and the other fish were gilled in large mesh size. That is why the length distribution represented in Figure 4 shows two peaks in the large mesh sizes (8" and 9") in area 1. However, in area 5 the two peaks appear for the two small mesh size nets (6" and 7"). Similar observations have been found by different research conducted on selectivity (Hansen *et al.* 1997; Hovgård 1996a; Holst *et al.* 1998).

Barnov's similarity assumption of gillnet selectivity may not be applicable if all the different catch processes such as gilled, wedged, snagged and entangled are considered. Therefore, a record of selectivity data is very important to account the way and the proportion of different catch processes.

Generally the horizontal hanging of the bottom gillnet is about 0.50m. If a length smaller than 0.50m is used, the net will tend to tangle fish and will capture different sizes and species. If the hanging ratio is greater than 0.50m, the gillnet will tend to gill the fish and will be more selective (FAO 1996; King 1995). On the other hand, if twine is very thick, then the gillnet will tend to tangle. One example is the trammel net for shrimp where the hanging ratio and thickness of the inner panel are minimums; more than 80% of shrimp are entangled. Therefore, to better understand the selectivity of gillnets, studies should be conducted where hanging ratio and diameter of twine are main parameters.

Many studies conducted on selectivity have been done including using the smallest mesh size applied by fishermen (5.5 inches) and have concluded that the different capture process can only be noted by using smaller meshes targeting different sizes of fish. This idea can be refuted in this study because it is clear that small and large mesh size in accordance of abundance and size distribution of each area can catch different ranges of cod by different processes.

The selection curves in this study have been drawn by using the Gamma model, therefore they have been forced to be symmetrical. As shown in the length distribution of cod, in Figure 4, the selection curves should be asymmetric in certain conditions. There are other methods for estimating selection curves, which are possible to use such as normal, and log normal.

However, all mesh sizes of gillnets indicate a high degree of selection in both capture processes This study shows that there is a relationship between mesh size and length range of cod and the deviation of most fish caught by all gillnets (except with 6" multifilament gillnet in area 5) (see Table 7).

In area 5 the curve was not linear because the number of samples recorded was low, particularly in the 6" monofilament.

5.1 Considerations of different type of twine (monofilament and multifilament)

This study has shown that the monofilament gillnets catch better than multifilament. These results indicate that the catch decreases with increasing number of filament and that this may be related to the visibility or friction of materials. Ongoing experiments on Baltic cod suggest that an increase in number of filament in multifilament twine from four to six decreases numbers by about a third (Hovgård *et al.*1999). This follows the findings of a few direct studies on this matter that suggest that a thin twine diameter is better than a thicker one (Hovgård 1996a).

5.2 Rationality on consideration of change the mesh size

Gillnets selectivity show that enlarging the mesh size of the current mesh (5½") in area 5 in the future to catch larger fish can be considered. However as cod is a sexually dimorphic specie i.e. the females grow to a larger size than males increasing the minimum mesh size will remove the protection afforded to the large fish and can result in reduction in reproduction out put of stock.

The consideration of the upper limit of mesh size made recently in the gillnet regulations will provide a good selection of gillnets because they will protect the large females and at the same time the size of cod caught will continue respond the market size.

As the common size of cod at catch is 60 – 90 cm i.e. a weight between 2 and 5 kg, an optimum mesh sizes 6" and 7" could be recommended as this mesh size has the appropriate range for this target group (see Figure 6 area 1). However, as this study was based in data, which have been collected during the spawning season, in order to take such a decision, another similar study will need to be conducted during the fishing season involving smaller mesh size gillnets.

ACKNOWLEDGEMENTS

My thanks to the project director of United Nation University – Fisheries Training Programme Dr. Tumi Tomasson and Deputy Programme Director Mr. Thor Asgeirsson for giving me the opportunity to participate in this programme and their guidance and assistance. I'm also thankful to my supervisor Mr. Haraldur Arnar Einarsson for his valuable assistance with this project. My thanks and appreciation to the MRI group involved in data-collecting for providing the data and Mr. James Begley for his help in statistical calculations**.** My thanks to Mrs. Lárus Pálmasson and Einer Hreinsson for providing information regarding fishing technology and regulation. I'm also thankful to my colleagues and all members of Marine Research Institute for the contribution in this study.

REFERENCES

Bage, H., 2001. Report from a consultancy on Experimental Fishing Program IDPPE Angoche, 6/5-5/6 2001. *Institute for the Development of Small-Scale Fisheries (IDPPE*). Mozambique

Bhattacharyya, G.K. and Johnson, R.A. 1977. *Statistical Concepts and Methods* . University of Wisconsin. Jones & Sons. New Your. ISBN: 0-471-07204-4

Food Agriculture Organization 1996 (FAO 1996). Fish and Aquaculture in Sub-Saharan Africa: Situation and Outlook in 1996. FAO *Fisheries Circular. Nº 922*. Rome, FAO.44p [January 12, 2004] <http://www.fao.org/DOCREP/006/w3839e/w3839e00.HTM>

Food Agriculture Organization 2003 (FAO 2003). *Fisheries Global Information System (FIGIS*. FAO,Rome. [December 14, 2003] <http://www.fao.org/figis/servlet/>

Food Agriculture Organization 2003 (FAO/SIDP 2003) 2003. Species Identification and Data Programme SIDP.FAO, Rome. [December 11 2003] < http://www.fao.org/figis>

Fridman A.L., 1986. *Calculations for fishing gear design* Osney Mead, Oxford

Fujimori, Y., Tokai, T. 2001 Estimation of Gillnet selectivity curve by maximum likelihood method. *Fisheries Science*. Tokyo. 108-8477.

Holst, R., Madsen, N., Moth-Poulsen, T. Campos, A., and Fonseca, P., 1998. Manual For Gillnet Selectivity. *European commission. ConStat. DK*

Hansen, M.J.; Madenjian, C.P., Selgeby.J.H., and Helser,T.E. 1997. Gillnet Selectivity for Lake trout in Lake Superior. *Canadian Journal of fisheries and Aquatic Science* 54, 2483 – 2490.

Hovgård, H. 1996a. A two step approach to estimating selectivity and fishing power of research gillnets used in Greenland waters. *Canadian Journal of fisheries and Aquatic Science* 53-1007-1013.

Hovgård, H. 1996b. Effect of twine diameter on fishing power of experimental gill nets used in Greenland Water. *Canadian Journal of fisheries and Aquatic Science* 53-10014-1017.

Hovgård, H. and Lassen, H., 2000. Manual on estimation of selectivity for gillnet and longline gears in abundance surveys. *FAO Fisheries Technical Paper*. No. 397. Rome

Hovgård, H., Lassen, H., Madsen, N., Poulsen, T. and Wileman, D. 1999. Gillnet Selectivity for North sea Atlantic Cod (Gadus morhua): Model Ambiguity and Data Quality are related. *Canadian Journal of fisheries and Aquatic Science*.56: 1307-1316

Hunte, W and Mahon,R., 2001. Trap mesh selectivity and the management of reef fishes. *Blackwell-Synergy Science Ltd*. 2 .356 - 375

Icelandic ® USA Inc 2003. *Specie Info for Cod*. [December 12, 2003] <http://www.icelandic.com/site/ss-cod.cfm>

Institute for the Development of Small-Scale Fisheries 1999 (IDPPE 1999). *Technology study in Palma District, Cabo Delgado Province*. IDPPE. Survey Report. By Faife. J. and Lansley.J

Institute for the Development of Small-Scale Fisheries 2002 (IDPPE 2002). *National Artisanal Fishery Census of Mozambique*. Maputo. [January 2, 2004] <http://www.idppe.org/estatisticas.htm>

ICES 1998. International Council for the Exploration Sea 1998. *Size specific time and duration of spawning of cod (Gadus morhua) in Icelandic waters* by: Thorsteinsson, V. and Marteinsdottir, G. 1998 .

ICES 2000. International Council for the Exploration Sea 2000. *Improvement Fishing Technology to Catch (or conserve) More Fish: The Evolution of the ICES Fishing Technology and Fish Behaviour Working Group During the Past Century*. By Walsh, S.J., Engas, A. Ferro, R., Fonteyne, R. and Marlen. B.V

ICES 2003. International Council for the Exploration Sea. The cod Stock Complex in Greenland (Nafo Subarea 1 and ICES Subarea XIV) and Icelandic Waters (division VA) *Annual Report*.[December 29, 2003] < http://www.ices.dk/reports/>

Lopes, S and Gervasio, H. 2000. Co-Management of Artisanal fisheries in Mozambique: A Case Study of Kwirikwidge Fishing Centre, Angoche District, Nampula Province. *ICLARM. Fisheries co-management*. Penang. Malaysia. 29 p

King, M, 1995 *Fisheries Biology, assessment and Management.*Oxford: Osney

Ministry of Fisheries of Iceland 2002. *Regulation nr. 365, for cod Gillnets in Iceland* – Regulation of fisheries of Iceland.

Ministry of Fisheries of Mozambique 1994 (MoF 1994). *Fisheries Master Plan*. Centro de Informaçao e Treino. Mozambique(CIT).

Ministry of Fisheries of Mozambique 2002 (MoF 2004). Regulation of Marine Fishery of Mozambique.

Mozambican Directorate of Fisheries Administration 2003 (DNAP 2003). Annual report. *Ministry of fisheries of Mozambique*.

Munprasit. A., Theparoonrat. Y., Sae-ung. S., Soodhom.S., Matunaga.Y., Chokesanguan.B., and Siriraksophon.S. 1989. Southeast Asian Fisheries Development

Center (SEAFDEC). *Fishing Gears and Methods in Southeast Asia: II Malaysia*. . .TD/RES/24. Bangkok: SEAFDEC.

Sentinel Fisheries Programs 2003. *Selectivity study (gillnet)*. Gulf of St. Lawrence Cod Quebec region [December 26, 2003] <www.osl.gc.ca/en/peches-sentinelles>

Sainsbury, J.C. 1996 *Comemercila Fishing Methods*. Oxford: Osney Mead.3rd edition

Southern African Development Community 2000 (SADC 2000). *Marine Fisheries and Resources Sector***.** SADC Windhoek [December 15, 2003]

APPENDIX

Table 6: Comparison between mean lengths of cod for gillnets with same mesh size in different area and in different twine type

Gillnets	Mean length X1	X2	P value	
M6 vs M66	68.5	68.5	0,001	H_0 not rejected
M7 vs M77	75.6	75.1	0,001	H_0 not rejected
M8 vs M88	77.2	77.8	0,001	H_0 not rejected
M9 vs M99	79.4	76.1	0,1	**H_0 rejected**
M6 vs M66	80.9	80.0	0,001	H_0 not rejected
M7 vs M77	86.0	86.9	0,001	H_0 not rejected
M8 vs M88	94.5	90.7	0,1	**H_0 rejected**
M9 vs M99	97.2	95.2	0,1	**H_0 rejected**
M6 vs M6	68.5	80.9	0,1	**H_0 rejected**
M66 vs M66	68.5	80.0	0,1	**H_0 rejected**
M6 vs M6	75.6	86.0	0,1	**H_0 rejected**
M77 vs M77	75.1	86.9	0,1	**H_0 rejected**
M8 vs M8	77.2	94.5	0,1	**H_0 rejected**
M88 vs M88	77.8	90.7	0,1	**H_0 rejected**
M9 vs M9	79.4	97.2	0,1	**H_0 rejected**
M99 vs M99	76.1	95.2	0,1	**H_0 rejected**

Table 7: Results of fitting of Gamma model parameters for estimation of gillnet selectivity in area 1 and area 5, where M*n* are monofilament gillnet with *n* inch mesh size and M*nn* are multifilament gillnet with *n* inch mesh size

		M6	M66	M7	M77	M8	M88	M9	M99
Area 1	α_1	106.86	138.62	146.64	145.77	149.04	174.16	86.18	139.49
	K_1	0.04	0.03	0.03	0.03	0.03	0.02	0.05	0.03
Area 5	α_5	409.05	28.86	75.89	167.17	380.24	166.61	264.56	299.83
	K_5	0.01	0.18	0.06	0.03	0.01	0.03	0.02	0.01