EFFECT OF TWINE TYPE AND THE BANANA PINGER ON CATCH RATE WITH SIZES AND SPECIES SELECTIVITY OF GILLNETS WHEN TARGETING COD *(Gadus morhua)*

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ABSTRACT

The study focuses on the selectivity of gillnets by comparing the effect of netting materials (monofilament and multifilament), sound acoustics (Banana Pinger) and four different mesh sizes (152 mm, 178 mm, 203 mm, 229 mm) on catch rates. The data were collected as part of an Icelandic gillnet survey conducted in April 2017 for stock assessment of cod. A total of 22 species were sampled, four species were further analysed for using different mesh sizes. The study showed that the monofilament nets were more effective with slightly higher catch rates in cod and other round fishes while the multifilament gillnets were effective for the flatfish. The effect of sound acoustics indicated low significant difference in the catch rates of cod. The 152 mm and 178 mm mesh sizes had the highest catch rates for cod with length ranging from 60 – 90 cm. A study like this can serve as a tool for species selectivity by choosing the correct mesh sizes to maximise and control catches of the targeted fish by the right choice of gillnets, for sustainable management of fisheries resources.

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1 INTRODUCTION

Fish production in Nigeria holds a very important position in the agricultural sector of the Nigerian economy for providing a cheap source of protein, food security and providing a source of foreign exchange, especially in coastal states. Fish production contributed to 0.5% of national gross domestic product in 2015 and contributes about 40% of the animal protein intake of an average Nigerian (FAO, 2018). In the same year, the total fish production in Nigeria was estimated at 1,027,000 tons, towards which marine catches contributed 36%, inland waters catch contributed 33% and aquaculture 31% (FAO, 2018). It was a major source of income, in 2014 for more than 700,000 people who were engaged directly in inland fisheries (21% women).

Nigeria is the highest consumer of fish and fishery products in Africa with total fish imports amounting to about 1.2 billion USD and exports valued at 284 390 million USD in 2013 (FAO, 2018). The Artisanal small-scale fishers operating in the coastal, inshore creeks of the Niger Delta, lagoons, inland rivers and lakes contributes more than 80 % of the total domestic production in the country (FAO, 2018). Development of the fisheries sector in Nigeria has become of utmost importance, both to ensure adequate food at affordable prices and to maintain a source of economic and social progress for the rural poor. However, the fishery faces challenges which pose a threat to the biodiversity and sustainability of the marine resources (Ssentongo *et* al.,1983).

1.1 Problem statement

Most fisheries in Nigeria are poorly managed and one of the main causes is lack of scientific data to understand the situation of the Nigerian fisheries. Application of appropriate management measures is limited due in part to lack of information on gear types used in coastal areas in the fisheries (Nwosu *et al.,* 2011). For instance, the artisanal fisheries are unrestricted (open access), with increasing numbers of artisanal fishermen actively engaged and using unregulated mesh sizes and illegal fishing methods to catch fish all year round. These uncontrolled fishing pressures have resulted in overexploitation of the target species and longer fishing hours in the fishing areas.

Bycatch is also another notable issue affecting world fisheries management today (Hall, Alverson, & Metuzals, 2000). The catch of cetaceans and sea mammals is a major problem for conservationists all over the world, most especially in the gillnet fisheries. The problem of bycatch of endangered species can also bring closure and restrictions to a particular fishery. In Mexico, the government imposed a permanent ban on gillnet fisheries as a way to protect the Vaquita porpoise's population from extinction (Jaramillo-Legorreta et al., 2017). In Nigeria, incidental catch of dolphins and West African Manatee (*Trichechus senegalensis*is) has been reported. This low production species is killed accidentally in gillnets intended for sharks. The species is found in Nigerian waters exploited by poachers for their meat, skin, oil, and bones (Powell & Kouadio, 2008) Unfortunately, the lack of mesh size regulation and law enforcement enables poachers to escape from punishment (Powell & Kouadio, 2008). Hence the need to devise methods of selective fishing, by recommending a way to reduce the number of non-target species caught in a fishing gear by using the right mesh sizes for every fish species. To mitigate the problems of overfishing and bycatches, knowledge of the size-selectivity of gillnets is crucial to fisheries management to ensure biodiversity and maximise sustainable yield.

1.2 Research Objectives

Acknowledging the problems in the Nigerian gillnet fisheries, the aim of this project is to gain a better understating of the impact gillnets may have on target species and stocks. For that reason, the objectives are:

- To analyse the selectivity of gillnets using cod catch data from gillnet fisheries in Iceland
- To compare the effects of different mesh sizes on different fish species
- To analyse the effect different netting material has on catch and catch composition
- To analyse the effects of sound acoustics on catch composition

2 LITERATURE REVIEW

2.1 Fisheries in Nigeria

Nigeria has an extensive coastline of approximately 900 km and an Exclusive Economic Zone (EEZ) of about 217,313 km² (SeaAroundUs, 2007) (Figure 1). The annual total fish demand for Nigeria, based on the 2014 population estimate of 180 million, is 3.32 million metric tons (Fishery Committee for the West African Gulf of Guinea, 2016). The domestic fish production from aquaculture, artisanal and industrial fisheries for 2014 is just over one million tons. From these estimates, the artisanal sector contributes more than 82% of the total domestic fish production (Faturoti, 2010). The country operates a multispecies fishery along the coastline and narrow continental shelves which contributes to most of the marine fish catch, while its EEZ is fully exploited in the Tuna fisheries and other related pelagic fisheries. There are two major types of capture fisheries in Nigeria, artisanal small-scale fisheries and industrial fisheries (FAO, 2018).

Figure 1: Map of Nigeria showing the coastal areas (Global Affairs Canada, n.d.)

2.2 Fisheries management in Nigeria

A number of decrees were put into effect by the Nigeria Government between the year 1971 – 1992 to control marine fisheries exploitation and maintain a maximum sustainable yield of fisheries resources in the country.

2.2.1 The 1971 and 1972 Sea Fisheries Decrees

This law entails licensing and registration of fishing boats operating in the coastal waters. Trawlers are expected to have information on the maximum sustainable yield of exploited fish stock and the yearly quota for each trawler. The 1971 decree also prohibited the use of explosives and poisons in catching fish. Restrictions on fishing trawlers fishing within 2 Nm of the continental shelf. This was done to prevent the fishing trawlers from competing with the small-scale artisanal canoe fisheries. In 1992 the 2 Nm restriction was later extended to 5 Nm. This decree also made restrictions on the codend of trawl nets used in the industrial fisheries. The minimum mesh size of 76mm is used for exploiting the finfishes while a codend mesh size of 44mm is stipulated for catching shrimps. This law later included the restriction on dumping of bycatch of fish by shrimp trawlers.

2.2.2 The 1992 Sea Fisheries Decree

Both the 1991 and 1992 decrees were made to provide future regulations on the areas to be prohibited for fishing aside from the Lagos-West fishing grounds and put appropriate regulation on mesh sizes used and sizes of fish to be captured.

2.3 Fishing gears and craft in Nigeria

2.3.1 The Small-scale fishing gears

The Nigerian fishing gears can be divided into small-scale and large-scale fishing gears. The small-scale gears are widely used to exploit a wide variety of fish species by the artisanal fisherman. The most common fishing gears used in the exploitation of the multispecies stocks are set gillnets, beach seines, large meshed shark drift nets, hooks on longline/handlines, purse seine and stow nets. The small-scale sector basically has three types of crafts namely

- Dug-out canoe
- Plank canoe
- Half dug-out canoe or Ghana canoe

The plank canoe is further divided into motorised and non-motorised plank canoe (Ssentongo *et al*.,1983)

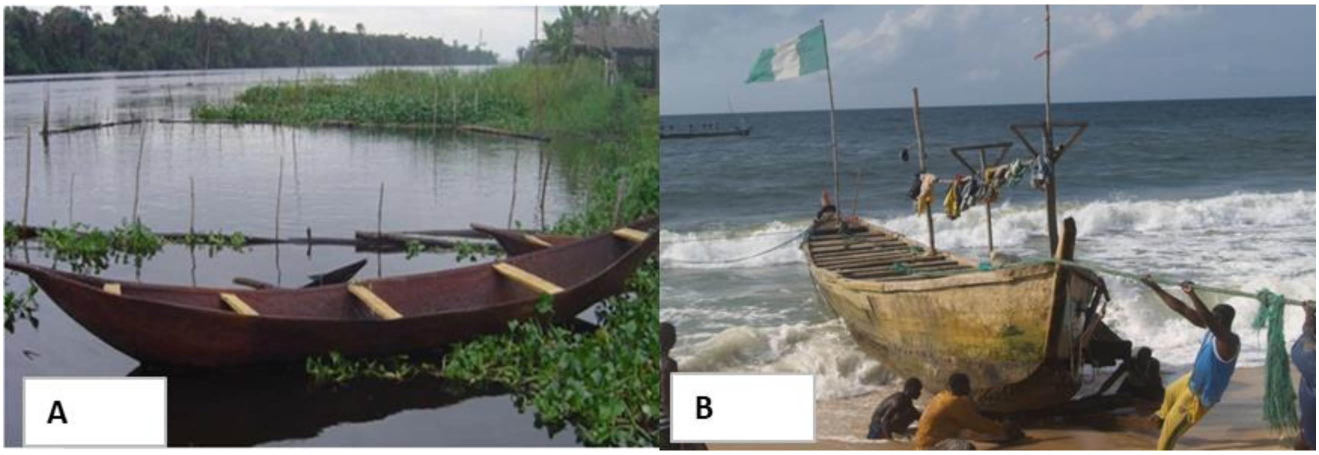

Figure 2: (A) Dugout canoe. (B) Ghana type canoe

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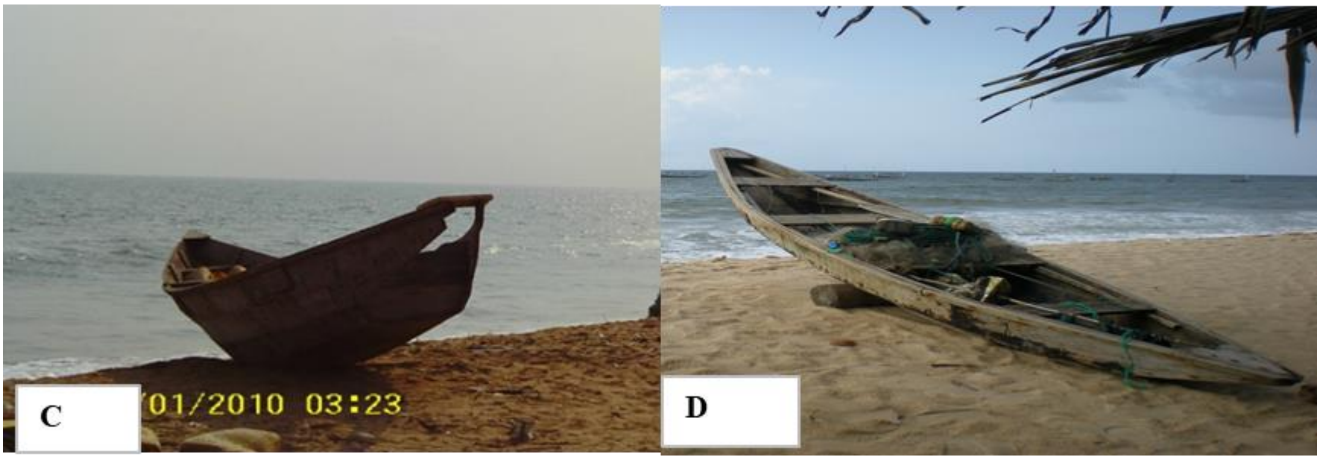


Figure 3: (C) Motorised planked canoe (D) non-motorised planked canoe (Ssentongo, Ukpe, & Ajayi, 1983)

2.3.2 Large-scale fishing gears and craft

The large-scale fishing gears dominate the industrial sector. They are more unconventional and expensive. They are operated by large fishing vessels and shrimpers (Ssentongo, Ukpe, & Ajayi, 1983). The trawlers (Fig.4) operate mainly in the narrow continental shelf up to a maximum of 50 m depths for finfish and shellfish. On most fishing trips, each vessel requires up to 75 – 100 metric tons of automotive gas oil (AGO) which covers over 75% of operational costs.

The industrial fishery is capital intensive and utilises large fishing vessels ranging from 9 to 25 m in length. The majority of the vessels in Nigeria are rigged with twin trawls with otter doors to allow better opening of the mouth of the net while trawling (Leone, n.d.). These trawling vessels are mandated to attach Turtle Excluder Devices (TEDs) and Bycatch Reduction devices to their fishing gears for the conservation of marine mammals and juvenile fishes (Leone, n.d.). The otter trawl net (Fig.5) is constructed of Polyethylene (PE) netting materials with a twine thickness of R1500 tex with 44 -77 mm stretched mesh size (Ssentongo, Ukpe, & Ajayi, 1983), (Fig.5). This sector has been overcapitalised with increasing numbers of vessels, more advanced fishing gears and technology such as sonars and fish finders.

Figure 4: Typical inshore trawler used in Nigerian inshore fisheries (FleetMon, 2017)

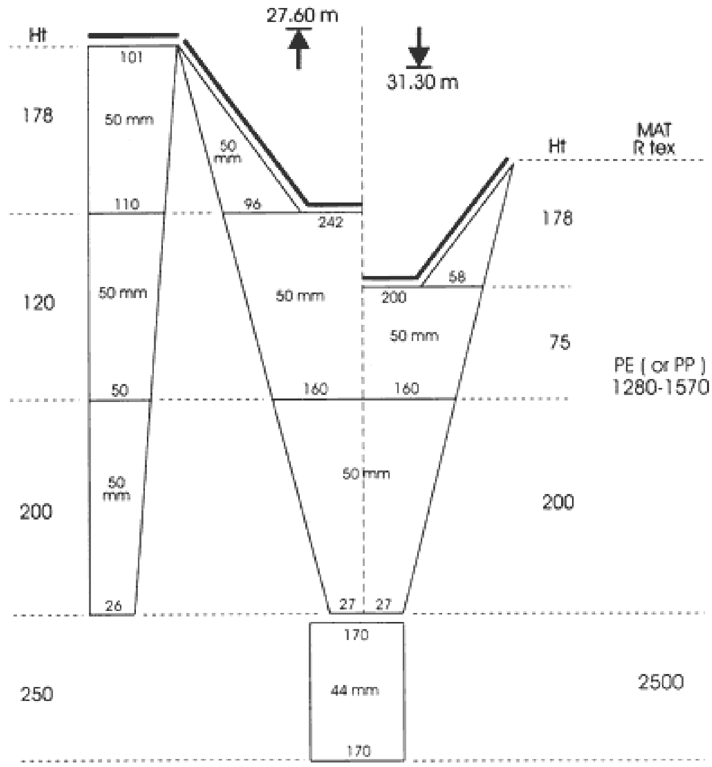


Figure 5: shrimp trawl

2.4 Gillnets

Gillnets are a simple wall of netting kept erect in a water column using floats and sinkers (Fig.6). Globally, the gillnet is one of the most significant fishing gears for harvesting a variety of species in the sea and in freshwater (Hovgard & Lassen, 2000). They are efficient, relatively inexpensive and capable of catching a higher number of commercially important species (Jayasinghe, 2017). Nevertheless, gillnets have limited species selectivity and occasionally catch non-target species, for example, birds, cetaceans, turtles, and sharks. Gillnets are considered a highly size selective fishing gear and commonly used by many fish biologists in stock assessment studies. Gillnets are more receptive to bumpy fishing grounds than most other fishing gears and they can be operated at any water depth. Depending on the method of application, gillnets can be classified as drift gillnets, set gillnets and encircling gillnets. Drift gillnets are operated in surface layers and allowed to drift with the current, either separately or with the boat to which it is tethered. Set gillnets are most common in the Nigerian waters, they are fixed to the bottom of the water by means of anchors of ballast while encircling nets are operated in surface layers in coastal areas.

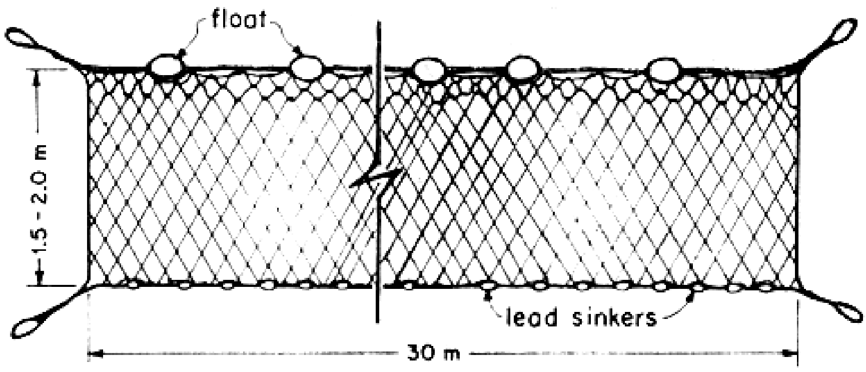


Figure 6. A typical gillnet design (Instructables, 2016) with floats and lead sinkers. The floats are used at the top of the net while lead sinkers are attached at the bottom of the net to allow the net to suspend vertically in the water.

2.4.1 Gillnet Netting Material

Gillnets are made from simple netting materials which consist of monofilament and multifilament or a combination of both. The monofilament gillnets are made from a single filament, they are usually thin and invisible to fish in the water while the multifilament nets are coarse and relatively stronger than the monofilament nets. The multifilament gillnets are less flexible but relatively stronger than the monofilament gillnets. Several experiments have been conducted on the reaction of species to fishing gears in clear water. Most results showed that the visibility of the netting material is an important factor in determining its efficiency (Faife, 2003). The materials with low visibility give no contrast to the background as seen in synthetic monofilaments (Faife, 2003). There are other properties of the material reported that can affect the catching efficiency of the fishing net such as the softness of the net, diameter, elasticity and breaking strength (Faife, 2003). The softest nets yield the highest catch because the soft nets are poor reflectors of pressure waves and they provoke fewer reactions from the lateral lines of the fish than stiff or coarse nets (Faife, 2003). Other studies, such as studies on Marbled sole (*Pleuronectes yokohamae)* in Korea, showed that the catches of monofilament net gillnet had an average 1.4 times more efficiency than the multifilament gill net (Kim *et al*., 2011).

2.4.2 Sound Acoustics in gillnet fisheries

Sound acoustics are simple devices attached to gillnets used to deter marine mammals from coming into contact with fishing gears. To mitigate the problem of incidental catches in gillnets, several types of gear modification, including the use of acoustic devices (pingers) on nets, were invented to warn marine mammals of their presence when fishing (Doyle, Dale, Choi, & City, 2012). Several studies on the effect of sound acoustics has been carried out in commercial fisheries by comparing the catch rates in nets with and without pingers by ensuring all other parameters of the nets (e.g. length, mesh size, depth, hanging ratio) remain constant (Dawson, Northridge, Waples, & Read, 2013). One study estimated that the annual bycatch of marine mammals attributed to gillnets was more than 6,000 animals between 1990 and 1999 (Read, 2008). The accidental catch of West African Manatte (*Trichechus senegalensis*) in gillnet fisheries in Nigeria poses a threat to the sustainability of this species.

The use of sound acoustics (a.k.a pingers) in the gillnets have shown to be a highly effective approach in reducing the bycatch of harbour porpoises, and the pinger had no effect on the target species catches. This study strongly believes it can be applied to other gillnet fisheries (Larsen & Eigaard, 2014). The effect of pingers on fish clupeids (*Clupeidae*), cod (*Gardus morhua*) and chinook salmon (Oncorhynchus tshawytscha) in pens and tanks has also been investigated, only one study suggested a reduction in the catch rate of target species. In Sweden, a pinger trial on gillnets was conducted and the result showed that the detection rate of cetacean including whales, dolphins, and porpoises were reduced by 100% (Fishtek Marine, n.d.). The study (Tom, Ruth, Richard, & Nick, 2012) also reported a reduction in bycatch of harbour porpoise (*Phocoena phocoena*) in nets with acoustic pingers.

2.4.3 Selectivity of gillnets

Studies on selectivity have been performed since the early 50s. Practically, the 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. In gear technology, the availability of fish to the gear depends on the catchability of gear, which entails the selectivity, fishing power and effort deployed (Hovgard & Lassen, 2000). The selection process gives rise to differences in the probability of capture among members of the exploited body of fish. In fact, the catch process can be divided into three phases.

- The probability of fish retained in the net specific to characteristics of the fishing gear
- Vulnerability of the fish to the net behavioural pattern
- Fish distribution

Generally, the mesh size of gillnets is uniform in size and shape; hence it catches fish of similar sizes. Fish species which are smaller in size will be able to pass through the net while those too large to push their head through the mesh are unlikely to get wedged or gilled to the net, thereby escaping. This gives selectivity to medium-sized fishes. The body length distributions of fish in the different gillnet mesh sizes are the simplest way to express and compare selectivity of gillnets of different mesh sizes. This makes it possible to control species selectivity with mesh sizes. For management purposes, it is preferable to calculate the gillnet selection curve, which is an expression of the probability of capturing a certain size group of fish in a specific gillnet mesh size (Kheng & Phen, 2008). The selectivity of a gillnet is affected by so many factors which include the mesh size, visibility of the twine, hanging coefficient, netting material, fish morphology, mesh thickness, the colour of the twine, mesh thickness and method of fishing (M. Shahul Hameed, 2008).

Gillnets are considered highly selective fishing gears, and for that reason, they are widely used as a research tool to estimate stock abundance. The selection curve shows the size selection of a particular fish species and its proportion of the population which is caught and retained in a fishing gear (Hovgard & Lassen, 2000). Gillnet selectivity studies are achieved by fishing, using several gillnets of differing mesh sizes to control the catchability of fishes when the fish size increases (Hovgard & Lassen, 2000). To fully understand the selectivity of a gillnet, it is also important to note the catch processes involved when the fish comes into contact with the net. According to Baranov (1948) there are four ways by which the fish can be caught in a gill net (Fig.8):

- Snagged - the fish is held to the netting at the head region
- Gilled - the fish is caught immediately behind the gill cover
- Wedged - the fish is caught around the body somewhere behind the gill cover
- Entangled: - the fish is wrapped in the netting, held by pockets of netting by the teeth, fins, spines or other projections.

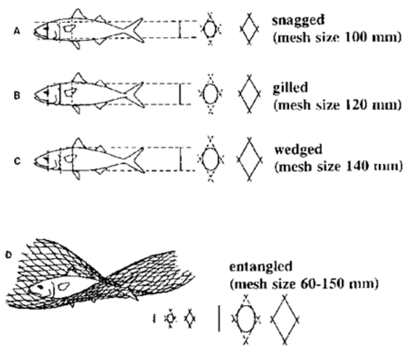


Figure 7: In the figure, mesh size is given in different sizes showing the different catch processes of a fish (Baranov, Theory and assessment of fishing gear, 1948).

2.4.4 Estimation of Gillnet selectivity

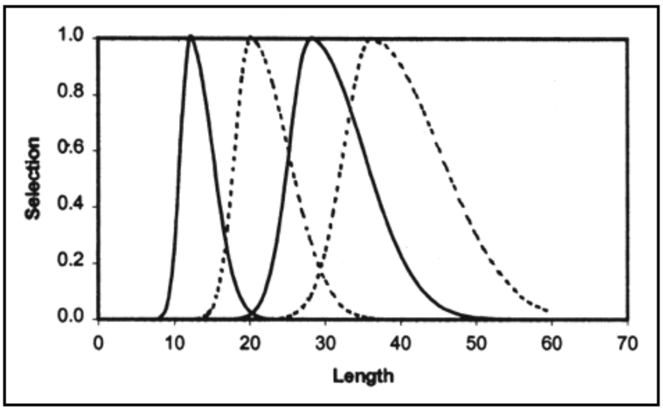
To estimate the selectivity in gillnets, two popular approaches for estimating stock abundance have been used. The direct method is used where the fish population of a stock is known. An example is the trawl codend with cover while the indirect method is used where the fish population is unknown (Hovgard & Lassen, 2000). The direct method is a more reliable way of determining gillnet selectivity, but this method is generally expensive and arduous to conduct as the whole size composition of the population must be known. On the other hand, the indirect method is mostly used to estimate gillnet selectivity. The indirect method requires no knowledge of the fish population size composition and it utilities easily available data with simple calculations (Hovgard & Lassen, 2000). In general, indirect estimates of gillnet selectivity are obtained by comparing the observed catch frequencies across several meshes (Millar RB, 1997).

A useful assumption for describing gillnet selectivity is the principle of geometric similarity (Baranov, Theory and assessment of fishing gear, 1948). This concept is by no means compulsory, but it gives a convenient simplification of the selection process. Baranov (1948) reasoned that the catch process of gillnets is a function of fish size and mesh size only, representing selectivity(s) as a function of mesh size (m) and fish size (z) i.e.

$$s(z, m) = s(kz, km)$$

where k is any constant

The principle implies that when the selection is expressed as a function of fish size and mesh size, the fish size is normalised with the mesh size, then the selection curves from different mesh sizes will have precisely the similar shape. (Fig. 9). Selection curves are grouped as sigmoid, bell-shaped and two peaked curves. A typical gillnet selection curve is also bell-shaped or two-peaked. The two-peaked selection curves are naturally represented by the sum of two bell-shaped distribution. The bell-shaped selection curve is described by its mode, width, height, and shape. The mode corresponds to the optimum length of fish caught, the width to the selection range, the height describes how efficiently the mesh catches fish of the optimum length, and the shape varies according to several characteristics of net and fish (Hamley, 1964). The bell-shaped selectivity curves are often denoted by functions derived from probability distribution from statistics, such as normal, log-normal or gamma distribution functions. Using these expressions implies that the estimation of the selection of large fish is predisposed by the catches of small individuals and vice-versa.



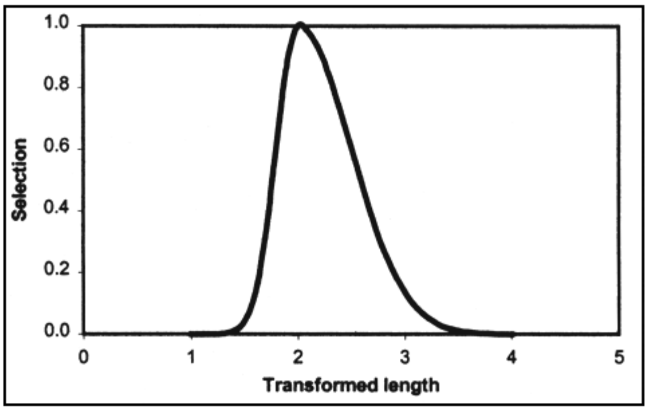


Figure 8: Principle of Geometric similarity (Baranov, 1948). The upper image displays the mesh selection for four different mesh sizes. The lower image displays a master curve. The master curve is represented when the normalised selection curve is plotted against a normalised fish size.

2.5 Target Species

For this study, cod (Fig.10) is the main target species and the trial was conducted in areas known to have abundant stock. This species is a semi-demersal fish; however, it may become pelagic when feeding and spawning. The presence of cod in an area is usually dependent on prey distribution and temperature.

Figure 9: North Atlantic cod *(Gadus morhua)* (Iceland Pelagic, 2013)

The Atlantic cod is the most important marine resource in Icelandic waters. Cod are fast growing species, highly fecund and greedy feeders. Common size of cod in the catch is in the range of 55 to 90 cm. Cod can grow quite large; the largest individual measured in Icelandic waters was 186 cm long, and 17 years old (Iceland Responsible Fisheries, n.d.).

Total catch of Icelandic cod in Icelandic waters in 2015 was 228,000 tonnes as compared to 221,000 tonnes in 2014. According to the 20% harvest control rule applied by the Icelandic fisheries management authorities, the TAC (total allowable catch) for the quota year 2016/2017 is 244,000 tonnes (Iceland Responsible Fisheries, n.d.). In recent years the Icelandic cod stock has been growing considerably and it is expected that the TAC in coming years will gradually increase. The cod is caught all around Iceland, mostly at depths of 100-250 m and ocean temperatures of 4-7 °C. The most important fishing grounds are off the southwestern coast, off the West Fjords, and off the southeastern coast. Fishing is driven by market condition and managed according to season and properties of the fish which can differ between fishing grounds and season (Iceland Responsible Fisheries, n.d.).

3 METHODOLOGY

3.1 Operational and fishing procedures

This study was based on gillnet records which were collected from three different fishing areas in coastal Icelandic waters in April 2017. These three areas; (Fig.11) Hofn, Skagastrond, and Snaefellsnes have a total of 42, 56, and 42 stations respectively. The specimen included the main target, which is cod and other species including haddock, plaice, dab, saithe etc. (Table 3). A comparative fishing experiment was conducted with monofilament and multifilament gillnets at those three different fishing areas in Iceland. As the number of gillnets (Table 2) was unequal (two 152 mm and 178 mm monofilament, one 203 mm and 229 mm monofilament, one 152 mm and 178 mm multifilament and two 203mm and 229 mm multifilament), fish numbers were extrapolated to simulate equal fishing effort.

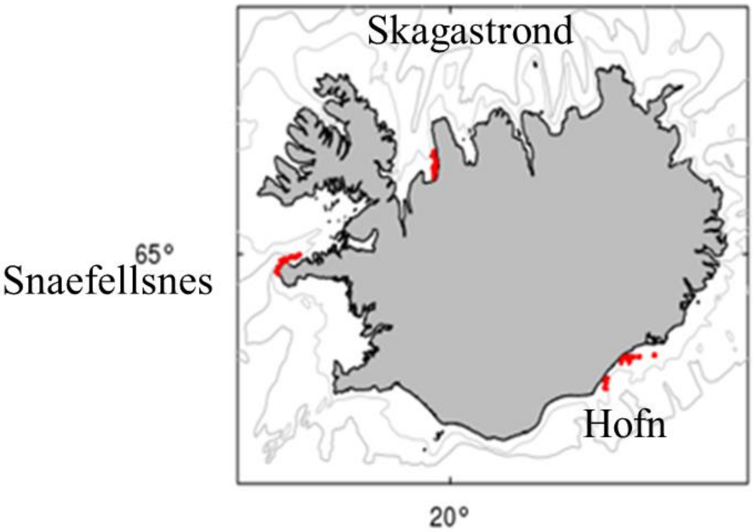


Figure 10: Map of Icelandic Spring Demersal-fish Surveys in all three areas. Red dots indicate the experimental sites for the gillnet.

The net configuration consisted of twelve polyamide gillnets, six were monofilament and six multifilament, with a combination of four different mesh sizes 152 mm, 178 mm, 203 mm, and 229 mm (6”, 7”, 8” and 9” inches) were tied together to form a net panel. The 12 nets with four different meshes were designed to be 55 m in length and reach 2 m depth. 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. The comparison of selectivity was done on the different netting materials of the net and meshes size in three areas, assuming that the other gear parameters, such as vertical slack, flotation and weights are equal in construction.

Table 1: Fishing scheme of 6 monofilament and 6 multifilament gillnets in the three fishing areas. Mesh size in millimetres (mm)

Net no.	1	2	3	4	5	6	7	8	9	10	11	12
Mesh size	152	178	203	229	152	178	203	229	229	201	178	152
Net type	Mono	Mono	Multi	Multi	Mono	Mono	Multi	Multi	Mono	Mono	Multi	Multi

3.2 Application of "pinger"

For this study, a comparative experiment was conducted with set gillnets with the acoustic device attached to investigate the effect of sound acoustics (Fig.7) on the target species catches. The pingers were set up in stations in pairs. One fleet of net (station) with pingers and the other without pingers. The distance between fleets was always more than two nautical miles to ensure the pinger would not have an effect on the other fleet that did not have pingers. Each pinger-fleet had a total of five pingers with 250 m spacing between each. However, for this study, we didn't analyse the data from the possibilities of pairs, we simply pulled the data without considering the effect of pairs (see discussion).

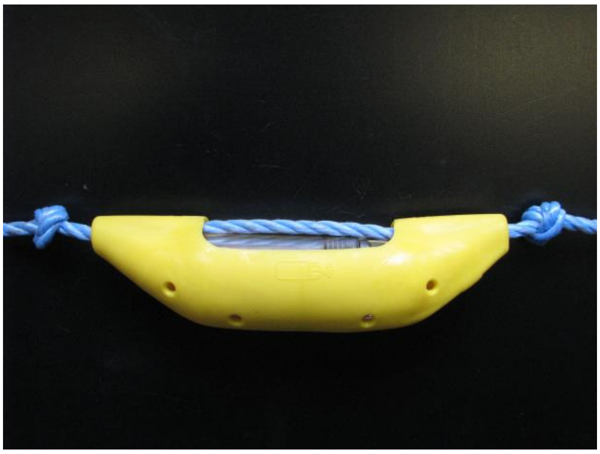


Figure 11: A Sound acoustic device (a.k.a. Banana Pinger) (Fish site, 2013)

3.3 Statistical Analysis

The data analysis calculation is based on the measurement of the length of the fish. The fishes sorted by mesh sizes weighed and the total length was measured to the nearest centimetre. Each fish was counted and classified according to the three fishing areas. The length distribution and catch rates for parameter were estimated. Comparative studies were carried out on the monofilament/multifilament and between gillnets with pinger/no pinger. One-way ANOVA tests were carried out in excel to compare the mean values of the variables. Analysis of selection patterns was done by fitting a normal curve to the size distributions, and selectivity of the gillnet series was calculated. Five different types of selection expressions were fitted to the catch of all mesh sizes: Normal (common spread), Normal, Lognormal, Bi-normal, and Bi-lognormal. Following the analysis by Millar & Holst (1997) each selection curve was fitted under the assumption that the meshes are equal in efficiency. The best fit was based on the model with the lowest deviance (Karakulak & Erk, 2008; Millar & Holst, 1997). Species and size selectivity curves for the different mesh sizes was extrapolated in R package using Millar & Holst (1997) gillnet script.

4 RESULTS

The survey recorded a total of 26 species, including dab, haddock, saithe, plaice, harbour porpoise, and lumpfish. The main target species (cod) recorded the highest number of catch in all mesh sizes (152mm, 178mm, 203mm and 229mm) and in all three fishing areas (Hofn, Snaefellsnes, Skagastrond). There were catches of sea mammal (harbour porpoise), round fishes and flat fishes present in the fishing nets, however some of these species where not caught in all areas. For example, harbour porpoise was only caught in Area 3 (Skagastrond). Some species were absent in some mesh sizes for example the white-beaked dolphin was only caught in the 178mm mesh sizes. The target species, cod, recorded the highest catch and catches was observed in all fishing areas and all mesh sizes. There was a total number of 16,545 individual cod in the 152mm mesh size net, a total of 15,798 cod in the 178mm net, a total of 11,785 cod in the 203mm mesh size and a total of 9,127 in the largest mesh size (229mm).

Table 2: Table showing the different species sampled in all mesh sizes and three fishing areas, cod recorded the highest number of fish in all mesh size.

Species	152mm	178mm	203mm	229mm	Total	Area
harbour porpoise *Phocoena phocoena*	2		1	1	4	3
white-beaked dolphin *Lagenorhynchus albirostris*		2			2	3
Atlantic wolffish *Anarhichas lupus*	30	16	8	7	61	1,2,3
Cod *Gadus morhua*	**16545**	**15798**	**11785**	**9127**	**53255**	**1,2,3**
Dab *Limanda limanda*	340	225	64	20	649	1,2,3
Haddock *Melanogrammus aeglefinus*	867	276	122	118	1383	1,2,3
Halibut *Hippoglossus hippoglossus*	9	15	4	2	30	1,2,3
Norway haddock *Sebastes marinus*	11	10	8	1	30	1,2
Herring *Clupae harengus*	8	9	11	5	33	1,2,3
Lemon sole *Pseudopleuronectes americanus*	60	27	6	4	97	1,2,3
Ling *Molva molva*	112	69	43	31	255	1,2,3
Long rough dab *Hippoglossoides plateessoides*	72	27	9	10	118	1,2,3
Lumpfish *Cyclopterus lumpus*	5	10	19	54	88	1,2,3
Monkfish *Rhina squatina*	3	6	8	15	32	1,2
Saithe *Pollachius virens*	549	280	183	141	1153	1,2
Plaice *Pleuronectes platessa*	475	1083	2189	2915	6662	1,2,3
Polar sculpin *Cottunculus microps*		1			1	1
Pollack *Pollachius pollachius*	2				2	1,2
Rabbitfish (rat fish) *Chimaera monstrosa*	9	2	3		14	2
Redfish *Sebastes marinus*	64	79	24	21	188	1,2
Stone king crab *Lithodes maia*			2		2	2
Skate *Raja dipturus batis*				1	1	1
Starry ray, thorny skate *Raja raja asterias*	21	51	87	37	196	1,2,3
Tusk, torsk, cusk *Brosme brosme*	7	4			11	1,2
Whiting *Merlangius merlangus*	19	9	7	12	47	1,2,3
Witch *Glyptocephalus cynoglossus*	3	4		1	8	1,2,3

4.1 Comparison with Netting Material

The catch for the cod in the sample in both the monofilament gillnets and multifilament gillnets in all fishing areas is summarised in Table 5. Table 5 shows the total number of cod caught in mono- and multifilament and it also shows the average number of cod per net (brackets). The catch of the monofilament was always higher in all areas. The was a significant difference between the monofilament and multifilament catches. In total monofilament net catch on average about 12.5% more than the multifilament (p=0.01 see table 4). The length composition of cod is similar in the two netting materials (monofilament and multifilament nets) (Figure 12).

Table 3: Total number of cod in the two-netting material in all three fishing areas

Area	Monofilament: Number of cod (average number per net)	Multifilament Number of cod (average number per net)
Hofn (42 stations)	14604 (57.8)	11849 (47)
Snaefellsnes (42 stations)	17989 (71.4)	16502 (65.5)
Skagastrond (56 stations)	4915 (14.6)	3648 (10.9)

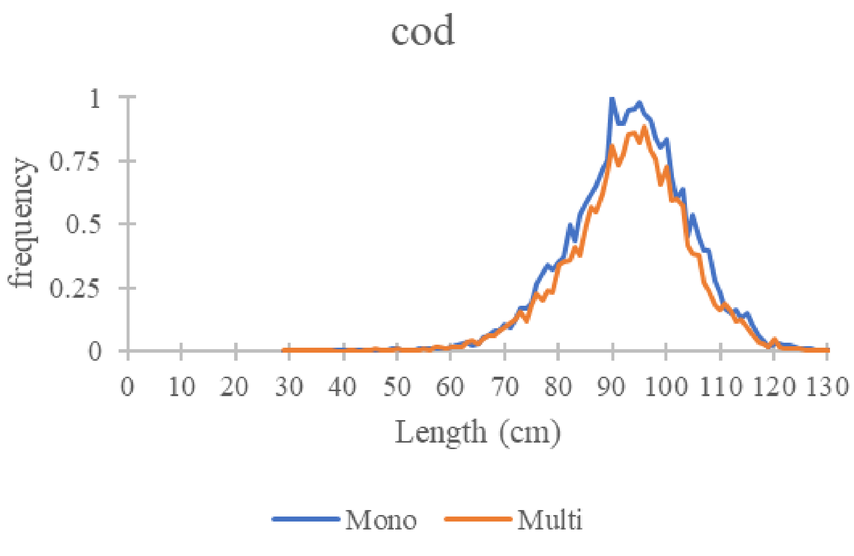


Figure 12: (a) Length frequency distribution of cod in the monofilament and multifilament net

4.2 Comparison nets with and without sound acoustics

The catch rate for the cod composition in the sample in both the nets with pingers and nets without pinger in all fishing areas is summarised in the boxplot below (Fig.13a). The was a modest significant difference between the pinger nets and non-pinger nets catches. (p=0.0468) The length distribution of cod is similar in the two nets (pinger/non-pinger) as shown in (Fig:13b).

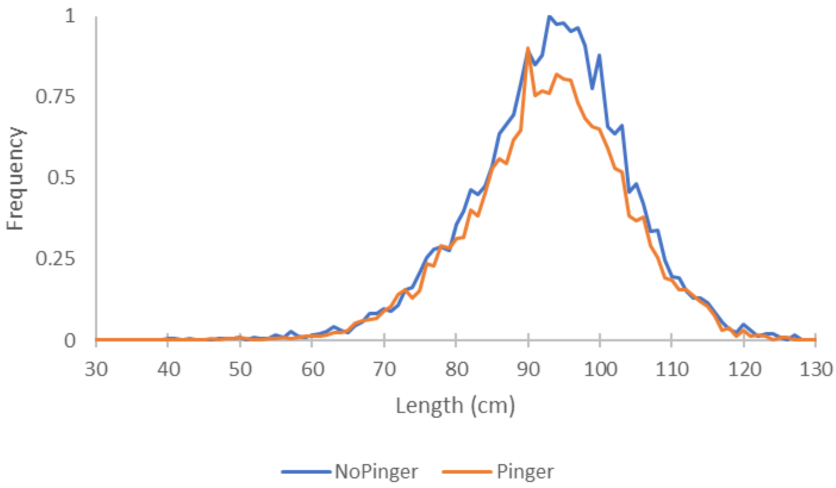


Figure 13: Length frequency distribution of cod in the nets with and without Pinger.

4.3 Comparison species selectivity with different mesh sizes

The study shows that cod is caught in all mesh sizes with the highest catch rates recoded (average number of fish per net) in the 178 mm, 152 mm mesh sizes, and the catch rate among the four mesh sizes was highly significant (Table 4). For the other species, the 152 mm and 178 mm are most effective for the haddock stock. While the 203 mm and 229 mm mesh sizes are most effective for the plaice stock with fish size range of 35-60 cm. The 152 mm and 178 mm mesh sizes are effective for dab with fish size range of 25-40 cm, and the 152 mm mesh sizes are effective for the saithe with fish size range between 65 – 120 mm (Figure 14).

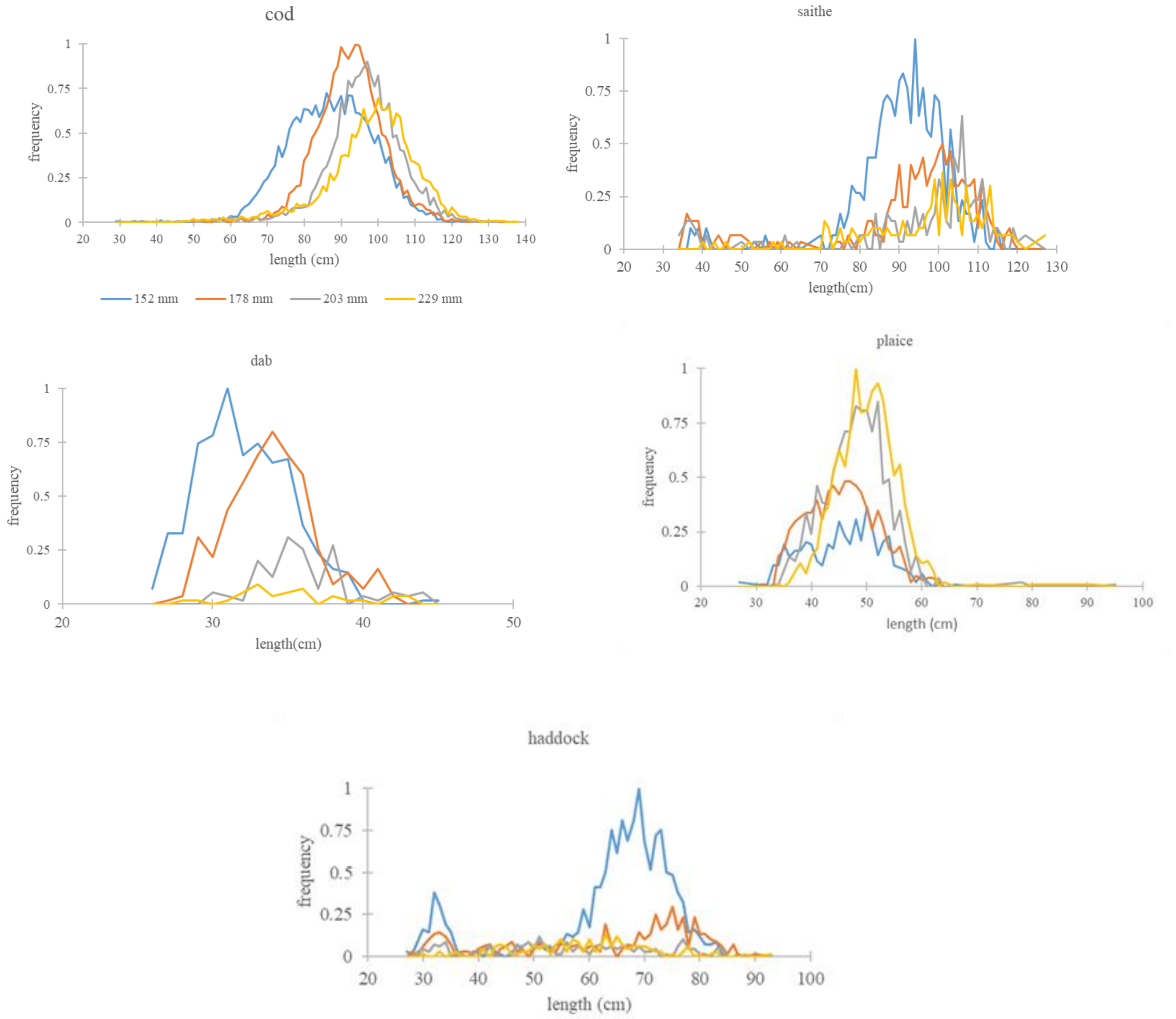


Fig14: Length frequency distribution for cod and four other species; haddock, saithe, dab, and plaice using in all mesh sizes (152 mm, 178 mm, 203 mm and 229 mm)

4.4 Comparison of size selectivity with different mesh sizes

The length distribution for the cod caught in all four mesh sizes summarised in the boxplot in Figure 15. Cod catches was observed in all mesh sizes, the relative length in cod increased with increasing mesh sizes. The 152 mm mesh sizes were most effective in cod sizes ranging from 80-90 cm, 178 mm from 85 cm-95 cm, 203 mm from 90 cm-100 cm, and 229 mm from 95 cm-110 cm fish length.

However, while there were relatively higher catch rates in the smallest mesh sizes, there seem to be weak significant difference in the catch rates of all mesh sizes. The optimum length (cm) for the 152 mm mesh meshes is estimated at 77.3 cm with width of 29.8 cm, the 178 mm mesh sizes had an optimum length of 90.5cm and width of 34.9 cm, the 203 mm mesh size had an optimum length size of 103.3 cm and width of 39.98 cm and the 229 mm mesh size recorded an optimum mesh size of 116 cm and width of 44.8 cm. The selection curve for the cod data is shown using the bi-log model which gave the best fit with the least deviance (Figure 16)

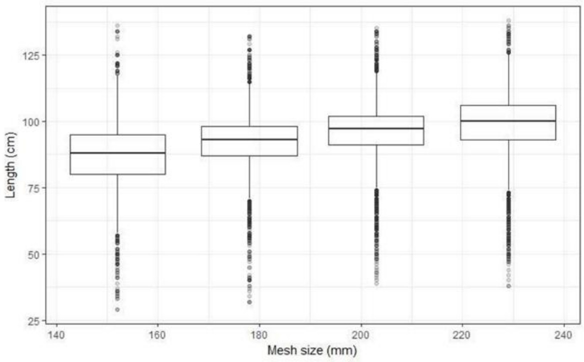


Fig15: Box plot showing length distribution of cod in the four different mesh sizes. The size of the fish increases with the larger mesh sizes.

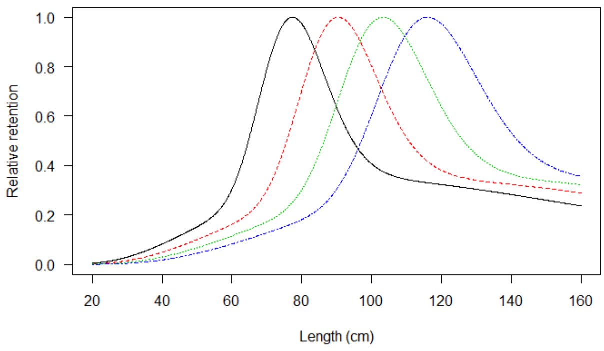


Fig16: The selectivity curve for cod in all four mesh sizes. The Bi-log model here gave the best fit for the cod data. With the least deviance for the cod data.

Table 4: Optimum length and width of cod caught in the four mesh sizes

Mesh sizes (mm)	Optimum length (cm)	Width (cm)
152	77.3	29.8
178	90.5	34.9
203	103.3	39.8
229	116	44.8

Table 5: One-way ANOVA test results showing p values for Mon vs. Multi filament nets, with and without pinger, and catch rate for cod (number of cod per net) among different mesh sizes.

Groups	*Number of nets*	*Average*	*variance*	*Standard deviation*	*P-value*
Monofilament	830	45.19	2024.292	44.99	0.0100
Multifilament	815	39.26	2324.125	48.20	
No Pinger	847	33.989	1233.117	35.12	0.0468
Pinger	798	30.659	1065.184	32.64	
152mm 178mm 203mm 229mm	415 411 405 395	21.82 20.97 18.92 17.07	164.6 161.1 178.9 182.5		0.00000005

5 DISCUSSION

This small trial clearly shows how a well-designed plan for gear research can give valuable information to help management in the fishery sector to regulate their fisheries and ensure responsible and long-term sustainability of the marine resources.

5.1 Netting Materials

While higher catch rates were found to be higher for the monofilament nets than the multifilament net, a one-way ANOVA for the difference in number of cod per net showed significant difference with (P=0.01). The expected catch is about 5 more cods per net if monofilament is in use. As the result shows no large difference in catch rate, the fishermen need to consider other factors, such as durability of the netting materials. The catch difference in species could be attributed to the morphology of the species and the way the fish behaves towards a fishing gear (Baranov,1948). The gillnets with thin twines (monofilament gillnets) showed higher catch rates than nets with more than one filament (multifilament gillnets). The visibility, flexibility and thickness of the net could be the major determinate for the disparity in catch rates of the fishing nets as it was observed that the monofilament nets are less visible to the fish compared to the coarse nets (multifilament nets). The monofilament nets also recoded higher catch rates in most species, especially cod and other round species such as haddock and saithe but observed that the multifilament nets were more effective for dab and plaice (flatfishes). This result supports a similar study which reported that coarse nets entangle flat fishes more effectively than the round fish (Simasiku, Mafwila, & Sitengu, 2017). Another reason for the increase in catch rate in the monofilament gillnet could be that the fish caught at the beginning of the soaking period could have acted as bait to attract more fish to the net area (Kallayil *et al.*, 2003). This study is very important for artisanal fisheries, indicating there would be no gain in catch if the fishermen changed from monofilament to multifilament.

5.2 Pingers

Similarly, while the catch rates were slightly higher for nets without pingers, weak significant difference was found between nets with pingers and nets without pingers (P=0.046). However, results could be biased because the results of the pinger/non-pinger data was not extrapolated in pairs. This was not achieved due to lack of time available for the time consuming demands of the data filtering. No significance difference for bycatch of cetaceans, however the sample size was very small which could lead to results being unreliable. There were only 3 cod per net, fewer in nets where pingers were used with very little difference. Nevertheless, the pinger might have a slight effect on the behavior of the fishes with an effect on total catch rate of the nets, but the fishermen might not notice this difference as it is so small. A similar study was documented on the use of sound acoustics to reduce bycatch of cetaceans in gill nets fisheries, some acoustic trails reported a 50% reduction in the catch of harbour porpoise caught in the net with no significant diffrence in the catch rate of the target species (Erbe & McPherson, 2012). The target species (cod) had a relatively higher catch in nets without sound acoustic (pingers) compared with nets with sound acoustics with equal fishing power controlled, but there was no significant difference when the sampled mean is compared. The difference in catches could be attributed to the way fish respond to sounds, as some fish species are neophobic by nature and they respond to sound differently.

5.3 Species selectivity

The species selectivity data revealed that the 152mm mesh sizes were more effective for the haddock, saithe and dab than the other mesh sizes, the 203 mm and 229 mm mesh sizes showed to be most effective for the plaice (flat fish), this is probably because of the morphological characteristics of the fish. This study can help the fishery manager in determining the appropriate mesh size to harvest a specific species. For instance, let’s assume a multispecies fishery where we have haddock, saithe, dab and plaice in the same fishing ground. To reduce the fishing pressure on the haddock, saithe and dab stock normally caught in the 152mm mesh size, fishermen could be advised to use mesh sizes larger than 152mm to reduce the fishing pressure on those fisheries, but plaice would still be caught up in the net. The study revealed that changes in mesh sizes could be used to improve selectivity of a certain fishery, most especially in a multispecies fishery. This study can serve as a management tool to ensure long-term sustainability of fishery resources.

5.4 Size selectivity of cod

In this study, all mesh sizes were seen to effectivity catch the cod. The length distribution range increased in bigger mesh sizes. This revealed that the size of fish is relative to the mesh size (Baranov, 1948). For example, when small fishes with certain girth come in contact with small mesh sizes, they get easily enmeshed in the small mesh sizes, but small fishes can easily pass through a much larger mesh size while the girth of larger fishes don't get too far into the smaller mesh sizes but get enmeshed in the larger mesh sizes. The common size of cod at catch is 60 – 90 cm, optimum mesh sizes of 152 mm and 178 mm could be suggested as this mesh size has the appropriate range for this target group. This knowledge can serve as a tool to recommend a minimum mesh size for a specific fishery.

6 RECOMMENDATIONS AND CONCLUSION

The variable catch rates in different species with mesh sizes and material, emphasise the need for improved understanding of the behaviour of fish in relation to the use of different netting materials, sound acoustics, and mesh sizes. Although the results of this study follow a similar trend as previous studies, I recommend more controlled data collections from a variation of different fishing gears need to be performed to make collection of length from every fish species in catch from gillnets of different mesh sizes and/or different material, or with use of any devices possibly affecting the fishery, and with many replicates and in different areas and time. Further research also needs to be conducted on the effect of sound acoustics on sea mammals in Nigerian waters. This study will benefit the multispecies fisheries in Nigeria and provide the fisheries managers with a better understanding of the multispecies fisheries and enable better control of the catch rates and sizes of fish to be captured, as well as advising on mesh-size regulations especially in the small scale artisanal fisheries.

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