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GILLNET SELECTIVITY OF *SALMO TRUTTA* L. FROM TWO LAKES IN ICELAND AS A REFERENCE FOR PRACTICAL APPLICATION ON LAKE KAINJI FISHERIES

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ABSTRACT

This study demonstrates the selectivity pattern of brown trout (*Salmo trutta*) from ten gillnets forming series of mesh sizes 12, 16.5, 18.5, 21.5, 25, 30, 35, 40, 50 and 60 mm (half mesh). Data collected between 1994 and 2014 from Lakes Hraunsfjarðarvatn and Baulárvallavatn in Iceland was used for this study. The ratios of fish lengths to the mesh sizes were used on the selection model. Five types of models were fitted to the data from the mesh sizes: normal location, normal spread, lognormal, bi-normal, and bi-lognormal. The bi-normal model gave the best fit of the data with the lowest deviance (601.339). The study showed fish length increase with increased mesh size but a decrease in number of catch. Majority of the fish in these lakes are immature, size groups 13-37 cm caught in mesh sizes 33 mm and 43mm. Mesh sizes could be added to the net series to ensure coverage of more class sizes. This type of study can serve as a basis for recommending the mesh sizes of gillnet that best suits the fish stock, hence better management of the fishery.

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1 INTRODUCTION

Gillnets are passive gears, commonly used for fishing, especially in shallow waters, such as lakes, rivers, floodplains, reservoirs and streams (Ita 1993), as well as commercial fishery at sea (Cochrane 2002). Usually, these nets are set vertically in the water to cover the surface, midwater, and even bottom in order to catch fish. The choice of the mesh sizes by fishermen is usually to catch certain sizes of fish or due to existing regulations on the fisheries in the area. The most commonly material used to make gillnets is nylon. It can be monofilament or multifilament depending on the type of material used for construction (CRC 2013). It is widely used by artisanal fishers in developing countries (Oginni *et al*. 2006), and for research purposes. The net is relatively inexpensive to construct and maintain, and easy to operate.

In Nigeria, gillnet is known to be the oldest and dominant fishing gear used by small-scale artisanal fishers in inland waters (Emmanuel and Chukwu 2010). Lake Kainji is one of the most important lakes because of the dependence for fish, electricity generation, and domestic purposes. The dominance of this gear on the lake has also been reported (Abiodun and Niworu 2004). Between 1994 and 2001, about 43% of the gear used on the lake was gillnets, while cast nets, drift nets, beach seines, longlines and traps accounting for the remaining percentaged (Abiodun 2002). Gillnets are the most common fishing gears in use for catching the most commercial value fish on Lake Kainji. The lake contributes 6,000 metric tons of fish annually to domestic consumption, which is valued at US$ 3.30 million (Neiland and Bene 2008). It also creates employment, income, and food for over 300 riparian communities within and around the basin (Omojowo *et al*. 2010).

Gillnets are known to be selective to length of fish (Cat and Yuksel 2014), where one mesh size is only highly selective of a small interval of fish length and therefore not fishing smaller or larger fish in the same rate. Knowledge of size-selectivity is, therefore, important in fisheries management to understand developments of the fish stocks. It helps to make the right choice of net mesh size to suit the available fish population (Emmanuel *et al*. 2008). With the right choice of net mesh size it can allow fish to attain sexual maturity and reproduce before capture. Additionally, it contributes to accurate catch data interpretation for better understating of population structure, and effects of fishing on the exploited stock (McAuley *et al*. 2007). This type of scientific information is needed in order to assist fisheries managers and other stake holders in making right decision for forming better fisheries management policies.

Gillnet survey on Lake Kainji started in the late 1960 (Abiodun 2003). The aim was to determine the trend of fish population change and the effects on the fisheries as a measure for management (Ita 1978). Data from the surveys only centre on assessing species composition, abundance, and estimating annual fish yields. Data collection later stopped due to financial constraints until the intervention of the German Technical Aid (GTZ) in the 1990 (Abiodun 2003). Immediately the project ended, there has been inconsistency of data collection from gillnetting and commercial landings. Even with the few available once, there is limited information or no study on mesh size selection of gillnet on commercial value species on the lake, and even other inland water bodies in the country. In addition, length frequency data from such gear is only used to estimate population parameters of fish, such as, growth pattern, condition factor, among others. This also limit the understanding of gillnetting impact on the fishery, thus, difficult to arrive at better scientific advice for management of the resources.

The use of gillnet has also become a threat to fish stock on Lake Kainji, because fishers are using higher rate of smaller meshes not minding the negative effects on the fisheries (BFS 1998). Small sizes or mainly juveniles of commercial value fish are caught. Also, the preponderance of small fishes in the landings/catches of fishers is a danger signal that nets with to small mesh sizes are in use, which can affect recruitment. This may be attributed to lack of knowledge on net selectivity and management on use of gillnets, as a way to enlighten fishers on the right mesh sizes to use for target fish. It is, therefore, imperative to understand the selectivity of the nets for better management of the lake fisheries.

On series of premise, the present study tends to: (i) Evaluate the selectivity pattern of fish species over the gillnet meshes. (ii) Estimate length distributions on the basis of selectivity pattern. (iii) Determine relative fish abundance over time in nets using data on brown trout from two waters in Iceland. The knowledge gained from this study will be applied for estimating gillnet selectivity on Lake Kainji, and other water bodies in Nigeria. This will help to make recommendation on the appropriate gillnet mesh sizes for commercial value fish in other to utilize the fisheries resources in a sustainable manner.

2 LITERATURE REVIEW

2.1 Kainji Lake

Nigeria is located in the tropics on the western region of African. The country is with a vast expanse of water bodies, which are classified as freshwater, brackish water and marine. Kainji Lake (Figure 1) is one of the important freshwater bodies in the country. It is the largest man-made lake in Nigeria (Ayeni and Mdaihli 1996). It was created when a dam was made across River Niger for the purpose of generating electricity, and the construction was completed in August 1968. The lake lies between latitudes 9^o 50′ and 10^o55′ N, and longitudes 4^o 25′- 4^o 45′ E. It has a maximum length of 134 km (north to south) with maximum width of 24.1 km (west to east). The mean and maximum depth are 11 and 60 m respectively, surface area of 1270 km^2, a volume of 13.97 km^3 (Bwala *et al*. 2010). The lake has a catchment area of $1.6x10^6$ km^2, and annual draw down of the water level of 10-11 m (BFS 1998). There are two distinct hydrological cycle on the lake. The white flood is between May and October. The rains cause flood that comes with silt and clay sediments making the water to very turbid. This gives a white colour, hence the name. As the water flows, it loses water and silt through evaporation and infiltration. The water becomes clear and, therefore called Black flood (Mbagwu *et al*. 2002).

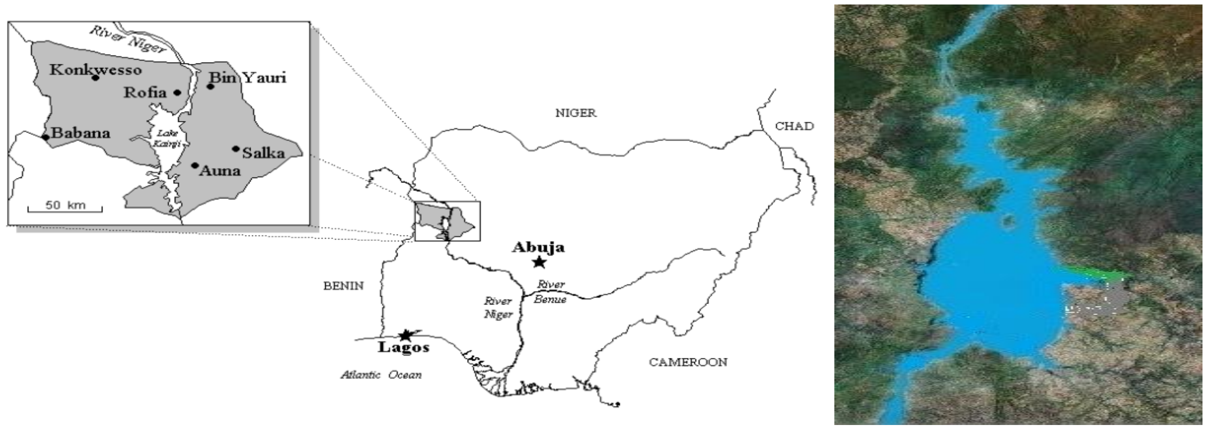

Figure 1: Location of Kainji Lake in Nigeria.

2.2 Gillnets

Gillnet is an important fishing tool modified and constructed in a way to catch target fish, and reduce by-catch (NMFS and ASMFC 2013). In addition, gillnet has advantage over other gears because it can be used in areas with difficult bottom, require less manpower and equipment to operate compared with other fishing gears, which also allows for wider use. It always consists of different mesh sizes with the same length and depth set as a gang (Dan-kishiya *et al*. 2012). It can be set at the surface, middle or bottom of water, depending on the behavior of the target fish, and remaining in a fixed position with the help of sinkers and floats for hours, in most cases over night. Gillnet can catch fish with similar body size depending on the mesh size used, and target species (Karakulak and Erk 2008).

Fish is caught by gillnets in the following ways: Wedged - when fish is held around the body by the net mesh; tangled -fish is held by spines, barbels, teeth or other structures without the body going through the mesh; snagged - this is when fish is held behind the eye by the net mesh; gilled - this is the most common way of fish catch with the net. The mesh is behind the operculum or gills cover, hence the name gillnet (Hovgard and Lassen 2000).

Gillnets are commonly used for research apart from commercial purpose. Data collected from this gear is used to study fish population and yield estimates. For instance**,** Bobori and Salvarina (2010)**,** and Dan-kishiya *et al*. (2012) used catches from this passive gear on Lake Doirani and Lower Usuma Reservoir to estimate fish abundance and composition. Because of the different mesh sizes, groups and sizes of different fish species are selected, which may portray the true population of fish stock.

2.3 Selectivity pattern of gillnet

Selectivity can be defined as the ability of the net to retain certain percentage of fish sizes or lengths that comes in contact with it (Hamley 1975).
There are 3 phases or assumptions by which the chances of gillnet selecting fish to catch is based upon:

a. The probability that fish will be caught has to coincide with space and time of fishing gear usage.
b. The probability that fish available for the fishing gear to catch at that particular location.
c. The probability that fish caught in the fishing gear is retained.
These also depend on the distribution and behavior of fish in the aquatic environment, and the characteristics of the fishing gear.

The chances of fish catch and retention depends on the morphology, length or girth, and behavior of the fish (Potter and Pawson 1991). Fish with lesser girth than circumference of one mesh size easily swims through the net, while those bigger than the mesh may escape. There is higher tendency to catch larger fish than smaller ones because they are more active (Henderson and Wong 1991). The swimming speed increase with fish size, therefore larger fish usually migrate longer distance than small fish, that increase the probability of the larger fish to be encountering the net (Irwin *et al*. 2008).

Fishing power of gear is the ability of a particular gear in retaining fish that comes in contact with it. This shows the efficiency of the gear in catching fish, especially at optimal length. It is important to note this, because most of the selectivity estimation methods include assumption that mesh sizes have similar fishing power (Hovgård and Lassen 2000). Factor that may influenced fishing power include twine thickness. For instance, Holst *et al*. (2002) compared gears with different twine, and reported thin twine to be efficient in catching more fish than thick ones. Nevertheless, further assumption suggested that twine thickness of fishing gear is proportional to mesh size.

Meshes with more elastic twine can stretch if fish struggles, and will catch larger fish, and also a wide selection range (Thomas 2015). Thinner twine increases the stretchability and flexibility of net mesh. Therefore, thinner twine is less visible, stretches easily, and will catch more fish especially larger ones (Hamley 1975). Similarly, hanging ratio and rigging affect net structure, which also affected selectivity and the efficiency of fishing (Thomas 2015). The opening of mesh size depends on the setting of net; same mesh size can have different hanging ratio, which will influence fish catch (Holst *et al*. 2002). Additionally, fishes with narrow and wide bodies require smaller and larger hanging ratios, respectively (Gabis *et al*. 2012). Regardless of these factors, size selectivity of gillnet is important in fisheries, and has been applied by several scientists as a way of giving advice for better management of fish stocks. For instance, it is used to manage the fisheries of three freshwater systems of Greece (Petriki *et al*. 2014). The right choice of mesh size will be establish for commercial value fish and help to control the catches of targeted fish by standardizing gillnet length, also reduce by-catch (Cat and Yuksel 2014). Understanding size-selection is important because it describes the length distribution of catches, and population structure of the water body (Carol and Garcia-Berthou 2007).

2.4 Estimation of selectivity

There are two methods of estimating selectivity, direct and indirect. The direct approach is mostly used in small water bodies, where the population of fish is known. Fish are marked, released, recaptured, and used for such estimates. The indirect approach is commonly used because its application covers larger water bodies. This involves the use of gear to sample or catch fish in a given water body where the total population of fish is unknown. Selectivity estimate is based on the distribution of fish class across the different mesh sizes of the gear. Since it is difficult to know exactly the total number of fish, especially in larger water bodies, selection is based on catches of the gillnet (Hovgard and Lassen 2000). There are also assumptions in this regard. The most important is the principle of geometric similarity, which states that "selectivity depends on fish morphology relative to that of the net mesh". This implies that mesh size and body form determines the retention of fish in net, especially at optimal length. Above and below this length, the chance of retaining fish usually decreases (Clay 1981). In addition, net meshes are efficient for the length class of fish they catch (Naesje *et al*. 2004).

A number of distributions are commonly used as models for estimating selectivity using indirect methods. This involves the manipulations of selection equations of these models to obtain curves for estimating selectivity (Carol and Garcia-Berthou 2007). This includes models like normal, lognormal, gamma, and bi-normal distributions, which are used to derive functions from probability distributions. The indirect estimates are classified into two groups: Type-A curve, which shows the chances of fish catch in a particular net has to do with the size of fish, while type-B curve shows the chances of catching a particular fish size has to do with the type and size of the net. Therefore, catches of each mesh size for a given group-size of fish are comparable to selectivity of the net (Helser *et al*. 1998).

Selectivity is shown by a curve that fit to points representing the ratio of fish retained by the gear against the fish length. This involves fitting models to length data, and estimating length-frequencies from survey data (Clay 1981) and (Punt *et al*. in press). The curves are plotted against the ratio of mesh size or fish length. Gillnets show normal curves, known as bell-shaped or symmetrical curves. Two-peak selection curves will represent the sum of two bell-shape distributions. Normal and gamma curves show moderate skewness, and often lead to similar selection curves (Hovgard and Lassen 2000). The common way of describing gillnet size-selection is using selection curves. This shows the percentage of a given fish size in the population that the gear retains during fishing operation. It helps to interpret catch data accurately, and give a better understanding of the status of the fisheries. In practice, the most appropriate form of selectivity curve for a given data set is determined, which is guided by some assumptions; If the size of fish is relative to the mesh size, the curves will have the same shape throughout the meshes; the way fish is caught and retained by the gear determine the shape of the curves (Hovgard and Lassen 2000). The normal location curve is bell-shape and symmetrical, showing regular or same form of curves without being skewed throughout the mesh sizes. Normal spread and gamma depicts an irregular shape of the curves skewed to the left side (negative distribution). The bi-normal shows moderate skewed shape, which shift to the right with over 20% retention ability across the net meshes. Also, the width of the meshes increase as the mesh size of net also increases, forming a tail. The bi-lognormal also skewed to the right, width of the mesh increase with mesh size increase, and forming an irregular tail. This is achievable by parameterization of the selection curves from these models using the following equations (Miller 2010) below:

Equation 1: Normal location

$$\exp\left(-\frac{(l-km)^2}{2\sigma^2}\right) \text{--} (1)$$

Where;
l = length of fish in mesh size (cm)
k = selection parameter or constant
m= mesh size (mm)
σ = standard deviation

Equation 2: Normal spread

$$\exp\left(-\frac{(l-k_1 m)^2}{2k_2^2 m^2}\right) \text{--} (2)$$

Where;
l = length of fish in mesh size (cm)
k_1 and k_2^2 = selection parameters or constant
m= mesh size of gillnet (mm)

Equation 3: Lognormal

$$\frac{m_i}{l.m_1}\exp\left\{\mu-\frac{\sigma^2}{2}-\frac{[log(l)-\mu-log\left({}^{m_i}/_{m_1}\right)]^2}{2\sigma^2}\right\} \text{----------------------------------}(3)$$

Where:
l = length of fish in mesh size (cm)
μ = modal point
m_1 = number of mesh size of gillnet
m_i =mesh size of individual net (mm)
σ = standard deviation

Equation 4: Gamma

$$\left[\frac{l}{(\alpha-1).k.m}\right]^{\alpha-1}.\exp\left(\alpha-1-\frac{l}{k.m}\right) \text{--} (4)$$

Where;
l = length of fish in mesh size (cm)
α = estimated during curves fitting
k =selection parameter
m = mesh size of net

Equation 5: Bi-normal

$$\exp\left\{-\frac{(l-\sigma_1.m)^2}{2k_1^2.m^2}\right\}+\mu\exp\left\{-\frac{(l-\sigma_2.m)^2}{2.k_2^2}\right\} \text{-----------------------------------} (5)$$

Where;
l = length of fish in mesh size (cm)
μ = modal point
m_i =mesh size of individual net (mm)
σ = standard deviation
$k_1^2$and k_2^2 = selection parameter

Equation 6: Bi-lognormal

$$\frac{m_i}{l.m_1}\exp\left(\mu-\frac{\sigma^2}{2}-\frac{(log(l)-\mu-log\left({}^{m_i}/{}_{m_1}\right))^2}{2k_2^2\sigma^2}\right)+b\,\frac{m_i}{l.m_1}\exp\left(\mu-\frac{\sigma^2}{2}-\frac{(log(l)-\mu-log({}^{m_i}/{}_{m_1}))^2}{2k_2^2\sigma^2}\right) \text{-------(6)}$$

Where;
l = length of fish in mesh size (cm)
μ = modal point
m_i = mesh size of individual net (mm)
σ = standard deviation
k_2^2 = selection parameter

2.5 Application of selectivity estimation

The use and application of models to produce selectivity curves is a vital tool for fisheries management. It helps to identify the best form and shape of selection pattern for a given set of data. These models are based on assumptions tailored toward achieving the desired goals or objectives. In applying these models, it is important to understand the function of selectivity (age or length) to be used.

The simplest way to compare selectivity of gillnet is by using the length distribution data from mesh sizes, which is easy to collect. It is, therefore, important to know how to interpret the curves resulting from such data to get the require information. This information together with life history of the fish gives clear understanding of the fisheries, hence better management advice. There are three ideas to this regard: The length composition of catch in the net is a reflection of both mature and immature individuals (Myers and Mertz 1998), the catch should have more individuals that have attained reasonable or optimal length, and protection of mature individuals based on the length composition of the catch is also vital (Berkeley *et al*. 2004).

Studies on gillnet selectivity have been conducted on many freshwater fishes. Brown trout (*Salmo trutta*) selectivity was estimated by Borgstrom and Plahte (1992), Jensen (1995), and Jensen and Hesthagen (1996) using the direct estimation method for selectivity. (Miller and Holst 1997), used indirect method with normal, lognormal, and gamma models to estimate selectivity of sockeye salmon on Fraser River on the assumption that fishing effort is equal for all meshes. Lognormal gave the best fit. Similar models were also used on seven cyprinids and pike perch (*Sander lucioperca*), where the normal scale model gave the best fit due to lowest deviation of the curve, which was the best spread of the data (Carol and Garcia-Berthou 2007). While normal scale model gave the best fit for *Capoeta trutta* (Cat and Yuksel 2014) lognormal model on the other hand gave the best fit for *Luciobarbus escoinus* in estimating selectivity (Yuksel *et al*. 2014). In estimating the selectivity of pink salmon (*Oncorhynchus gorbushia*), the bi-normal model gave the best fit (Fujimori and Tokai 2001). Similarly, bi-normal and lognormal models were reported as the best fits for *Caranx sexfasciatus* and *Caranx tille*, respectivley (Balasubramanian *et al*. 2010). In an Ethiopian tropical reservoir, (Hailu 2014) reported that lognormal gave the best plot for *Oreochromis niloticus*.

3 MATERIAL AND METHODS

3.1 Description of study area

The study was done on Lakes Hraunsfjarðarvatn and Baulárvallavatn, which are located on the Snæfellsnes peninsula in the western part of Iceland (Figure 2). Hraunsfjarðarvatn used to be 2.52 km^2 and at 206.7 m above sea level, but after the construction of dam the water level increase by 3.5 m. The average depth of the water was 39.2 m with maximum depth of 84.0 m (Rist 1971), which change to an average depth of 42.7 m with maximum depth of 87.5 m. River running from the lake is known as Vatnsá, and has a small dam causing the higher water level in Hraunfjarðarvatn. The river Vatnsá runs down to the other lake, Baulárvallavatn.

Baulárvallavatn is 1.58 km^2 in area, and at 193.1 m above sea level. It has an average depth of 17.7 m and maximum depth of 47.0 m (Rist 1971). The river running from Baulárvallavatn is named Straumfjarðará, where the main dam is built for the power station.

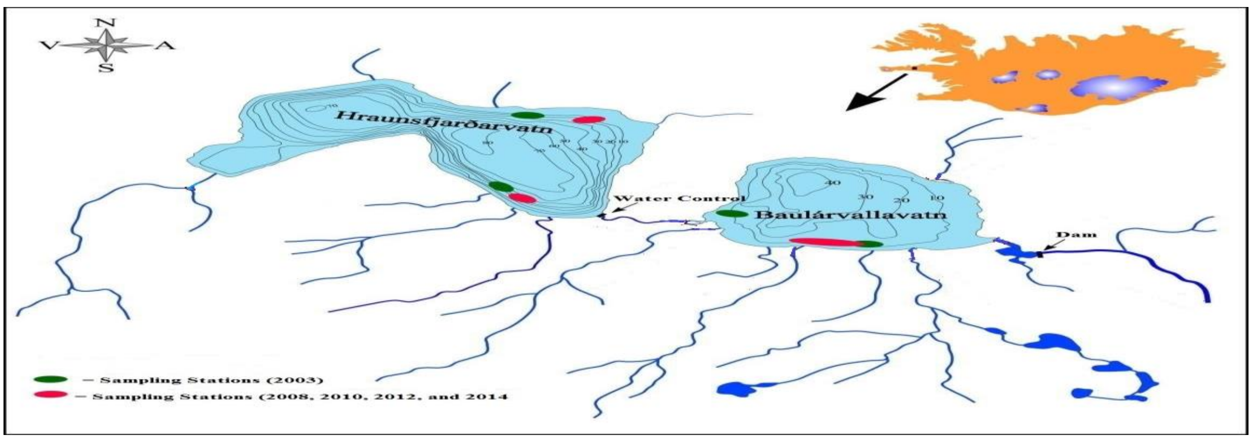

Figure 2: Gillnet sampling areas on Hraunafjarðarvatn and Baulárvallavatn (Report on trout stock 2012).

3.2 Data collection

The construction of the dam named Múlavirkjun using water from river Straumfjarðará started in 2005. For this reason a research was conducted to monitor the state of brown trout from the two lakes above the dam (Table 1). Standardized net series comprise of 12-16.5-18.5-21.5-25-30-35-40-46-50, and 60 mm of half meshes were used for sampling. The twine thickness of 12, 16.5, 18.5, 21.5, 25, 30, and 35 mm is 0.17 mm, while for 40, 46, 50, and 60 mm is 0.24 mm. The hanging ratio of the net was 0.5 (50%). Each net is 30 m in length and 1.5 m in depth. The nets were set in the afternoon and hauled next morning, allowing for soaking time of 15 hours in all cases. The water depths where nets were placed were approximately 1.0-2.5 m. This standard net series are believed to have equal fishing power (Hamley 1975, Jensen 1995). The same locations were sampled each year. In 1994 and 2003 samples were collected in summer, while 2003, 2008, 2010, 2012, and 2014 were collected in autumn.

Two stations at the north and southern part of Hraunfjarðarvatn Lake were sampled, while one location was sampled on the southern part of Baulárvallavatn Lake. In all the years (1994, 2003, 2008, 2010, 2012 and 2014), fish catch for the two lakes was also recorded. Fish was measured for length and weight separately from every mesh size. The length was measured to standard length with 1mm accuracy and the weight to 2g accuracy. Sexual maturity of individual sample was determined and classified according to (Dahl 1943).

Table 1: Sampling scheme of Lakes Hraunsfðarvatn and Baulárvallavatn.

Lake	No. of station	Year	Day	No. of net set
Hraunfjarðarvatn	2	2003	02/07	11
	2	2008	30/09	11
	2	2010	17/09	11
	2	2012	20/09	11
	2	2014	19/09	11
Baulárvallavatn	1	1994	01/08	11
	1	2003	02/07	11
	1	2008	30/09	11
	1	2010	17/09	11
	1	2012	20/09	11
	1	2014	19/09	11

3.3 Study species

Brown trout (*Salmo trutta*) is widely distributed in Europe, West Asia, and North Africa. It has been introduced into water ways on almost every continent, except Antarctica (Ryan 2015). Brown trout is found in freshwater of Iceland, and can also be anadromous (IMFA 2015). This means they live part of their lives in both freshwater and seas (Ryan 2015). The body is compressed in the middle, and tapers at the tail region. The snout is round, and mouth is large equip with teeth. It has preference for temperature of 18-23 ^{o}C, and cold oxygenated upland water (IUCN 2010). The juveniles and adults prefer shallow and deeper waters, respectively, especially while feeding (Ryan, 2015). It can grow up to 100 cm in length with 35-50 cm being common in freshwater (IMFA 2015). Females spawn in part of freshwater that is shallow, and cover with sand and fine gravel (IUCN 2010). The larva (12 mm long) remains buried in sand until it is about 25 mm when it comes out and begin to feed. At juvenile stage, it begins to show territoriality (IUCN 2010). The spawning period is late autumn (November-December). It is a carnivorous fish, and believed to feed at dusk or early part of the night (Ryan 2015). Males attain sexual maturity at age 2, while the female at 3 years (NCCMA 2015). Brown trout is caught throughout the year in Iceland. It is abundant in the southern region, and commonly used for sport fishing (IMFA 2015).

Figure 3: Brown trout (*Salmo trutta*) (Adam *et al*. 2008).

3.4 Statistical analysis

The data used for the analysis is from a 6-year (1994, 2003, 2008, 2010, 2012, and 2014) survey conducted by the Institute of Freshwater Fisheries. The years 1994 and 2003 are not included (Table 2) because of lack of information on the net mesh sizes.

Table 2: Fish catch on Lakes Baulárvallavtn and Hraunsfjarðarvatn.

Year	Baulárvallavatn	Hraunsfjarðarvatn	Total
2008	96	141	237
2010	82	100	182
2012	89	78	167
2014	104	104	208
Total	**275**	**423**	**794**

The length-weight relationship was calculated using the generalized linear model (GLM). This shows the relationship between two variables by finding the best line that fits through the points or data when making a plot. This was done to describe the relationship between the length and weight of fish in order to check the suitability of the data set for achieving the set objectives of the study.

Stages of maturity was estimated based on the method by Dahl (1943) considering stage 4 and above as mature fish, while less than stage 4 as immature. At the mature stages, the gonads are fully developed; the fish is about to spawn, spawning or have spawned. Information on maturity was collected only from sub-samples in each year (Table 3). Therefore, it was not the whole data collected that was used for maturity determination.

Table 3: Data for maturity determination.

Sex/year	Male	Female
2008	43	38
2010	46	59
2012	54	47
2014	43	57
Total	**186**	**201**

Selectivity pattern calculation was based on data of fish measured at fork length collected from gillnets series with 12 mm, 16.5 mm, 18.5 mm, 21.5 mm, 25 mm, 30 mm, 35 mm, 40 mm, 46 mm, 50 mm, and 60 mm knot-knot or bar length of mesh sizes sometimes called halfmesh (Figure 4). The indirect method is used for this study because fish population in the aquatic environment is not known. The raw data was examined carefully to check for errors or abnormalities before proceeding with further analysis. The minimum and maximum fork length values where determined and group into class intervals of 1mm accuracy. This is further transformed into a single length count. This is based on the assumption that all mesh sizes have the same efficiency and effort during sampling.

This was done to minimize residual sum of squares, and also reduce deviation using solver in Microsoft Excel. The optimal length of each mesh size was then estimated using the equation below:

Equation 7: Normal model

$$\exp\left(-\frac{(l-km)^2}{2\sigma^2}\right) \quad (7)$$

This was done to minimize residual sum of squares, and also reduce deviation using solver in Microsoft Excel. The optimal length of each mesh size was then estimated using the equation below:

Equation 8: Optimal length

Op*l* = k x m -- (8)

Where;
k = selection parameter or constant
m = mesh size of each net

The normal location, normal spread, lognormal, bi-normal, and bi-lognormal models were used to fit the length distribution data from the net. Selection range was estimated for each net mesh as the length where 25 % of the fish was retained. A single selection curve (master curve), which is the combination of curves of all the mesh sizes was obtained from the 6-year data from these lakes. This was then used to calculate the estimated length distributions of each year, and then compared with observed length frequencies of the fish. This was done using the gillnet functions package for R (index of/~Miller/Selectware/R/gillnets) according to (Miller 2010) and Microsoft Excel.

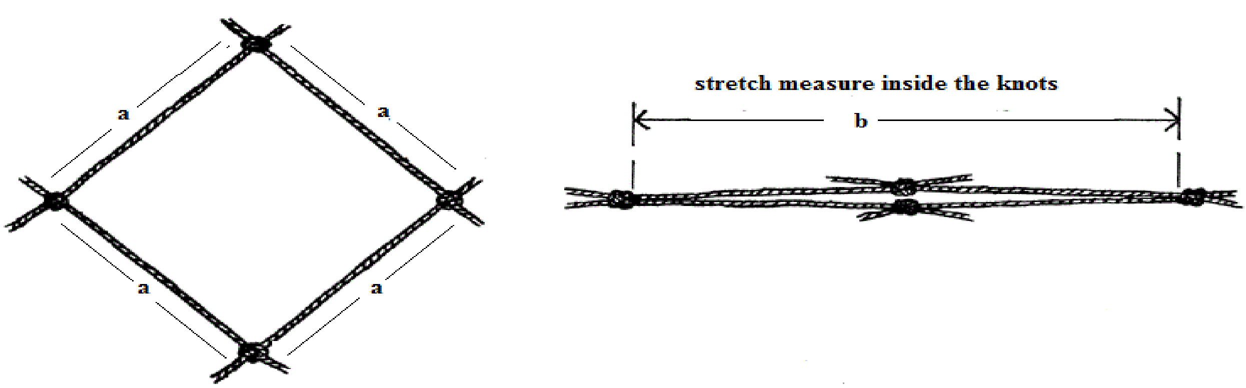

Figure 4: Mesh measurements; (a) knot to knot and bar length (b) stretch mesh (*www.cdlib.org 2015*).

4 RESULTS

There was a decrease in catch on the gillnet with increase in mesh size across the years on Lake Baulárvallavatn with the exception of mesh size 12 mm (Table 4). Majority of the catch was in 16.5 mm, 18.5 mm, 21.5 mm, and 25 mm meshes, where 16.5 mm and 25 mm had the highest and lowest catch, respectively.

Table 4: Number of fish in mesh sizes (mm) on Lake Baulárvallavatn**.**

Mesh size/ Year	**12**	**16.5**	**18.5**	**21.5**	**25**	**30**	**35**	**40**	**46**	**50**	**60**	**Total**
2008	-	23	10	12	19	12	8	6	6	-	-	96
2010	9	25	12	9	7	3	6	3	3	3	2	82
2012	2	28	25	20	6	1	4	-	1	2	-	89
2014	3	32	26	14	19	2	4	2	2	-	-	104
Total	**14**	**108**	**73**	**55**	**51**	**18**	**22**	**11**	**12**	**5**	**2**	**371**
Mean	**4.67**	**27.0**	**18.25**	**13.75**	**12.75**	**4.50**	**5.50**	**3.67**	**3.0**	**1.25**	**0.5**	**92.75**

There was decrease in catch on the gill net with increase in mesh size across the years on Lake Hraunsfjarðarvatn (Table 5), with the exception of mesh sizes 12 mm and 21.5 mm. Majority of the catch was in 16.5 mm, 18.5 mm, 21.5 mm, and 25 mm meshes, where 21.5 mm and 25 mm had the highest and lowest catch, respectively.

Table 5: Number of fish in mesh sizes (mm) on Lake Hraunsfjarðarvatn.

Mesh size/ Year	**12**	**16.5**	**18.5**	**21.5**	**25**	**30**	**35**	**40**	**46**	**50**	**60**	**Total**
2008	2	28	16	52	11	10	14	3	2	3	-	141
2010		20	11	30	19	5	6	5	3	-	1	100
2012	7	6	26	9	17	5	2	6	-	-	-	78
2014	-	26	16	23	15	9	7	6	2	-	-	104
Total	**9**	**80**	**69**	**114**	**62**	**29**	**29**	**20**	**7**	**3**	**1**	**440**
Mean	**2.25**	**20.0**	**17.3**	**28.5**	**16.0**	**7.0**	**7.0**	**5.0**	**2.0**	**1.0**	**0.0**	**105.75**

The mean length distribution of fish increases on the net meshes in Lake Baulárvallavatn across the years on the overall (Table 6). The highest and lowest lengths were on mesh sizes 60 mm, and 12 mm, respectively.

Table 6: Fish mean length on Lake Baulárvallavatn.

Mesh size/ Year	**12**	**16.5**	**18.5**	**21.5**	**25**	**30**	**35**	**40**	**46**	**50**	**60**	**Total**
2008	-	21.2	22.2	25.3	30.1	30.3	27.7	37.2	39.8	-	-	27.4
2010	10.9	16.9	22.7	27.1	25.4	37.5	27.3	31.1	38.2	31.7	48.3	23.0
2012	23.4	16.5	18.2	21.5	23.1	15.5	33.9	-	40.6	40.4	-	20.3
2014	14.8	17.8	20.8	25.9	26.6	28.0	35.2	42.45	37.8	-	-	22.9
Weighted mean	**13.5**	**18.0**	**20.4**	**24.4**	**27.3**	**30.4**	**30.1**	**36.5**	**39.1**	**35.2**	**48.3**	**23.5**

The mean length distribution of fish increases on the net meshes in Lake Hraunsfjarðarvatn across the years on the overall (Table 7). Also the highest and lowest lengths were on mesh sizes 46 mm, and 12 mm, respectively.

Table 7: Fish mean length on Lake Hraunsfjarðarvatn.

Mesh size /Year	**12**	**16.5**	**18.5**	**21.5**	**25**	**30**	**35**	**40**	**46**	**50**	**60**	**Total mean**
2008	15.9	17.27	21.04	24.11	24.92	29.87	26.11	38.07	42.2	38.53	-	23.82
2010	-	17.22	22.75	23.99	28.02	25.12	21.58	35.42	36.07	-	21.3	24.08
2012	16.06	19.25	20.21	27.21	26.95	26.62	28.05	35.97	-	-	-	23.87
2014	-	19.88	22.12	22.54	27.92	28.4	30.43	29.20	40.95	-	-	24.36
Weighted mean	**16.02**	**18.25**	**21.25**	**24.01**	**27.15**	**28.03**	**26.35**	**34.12**	**39.21**	**38.53**	**21.3**	**24.03**

Majority of the fish caught on the nets regardless of the sex are immature, and are between the lengths 10-39 cm (Table 8). There are few mature fish between the lengths 40-59 cm, though with more mature females than males.

Table 8: Maturity of brown trout according to sex and length group.

Sex/length (cm)	**Male**		**Female**	
	Immature	**Mature**	**Immature**	**Mature**
10 -19	61	1	64	0
20 -29	74	1	66	0
30 -39	30	2	42	9
40 -49	7	10	5	14
50 -59	0	0	0	1
Total	**172**	**14**	**177**	**24**

The length-weight plot fitted with generalized linear model (Figure 5) shows the relationship between the length and weight parameters of the fish on these lakes. The growth is isometric (b value =3.06); Brown trout from these lakes have similar growth pattern, hence, similar body morphology. The blue and red points were the plotted data from Lakes Baulárvallavan and Hraunsfjarðarvatn, respectively.

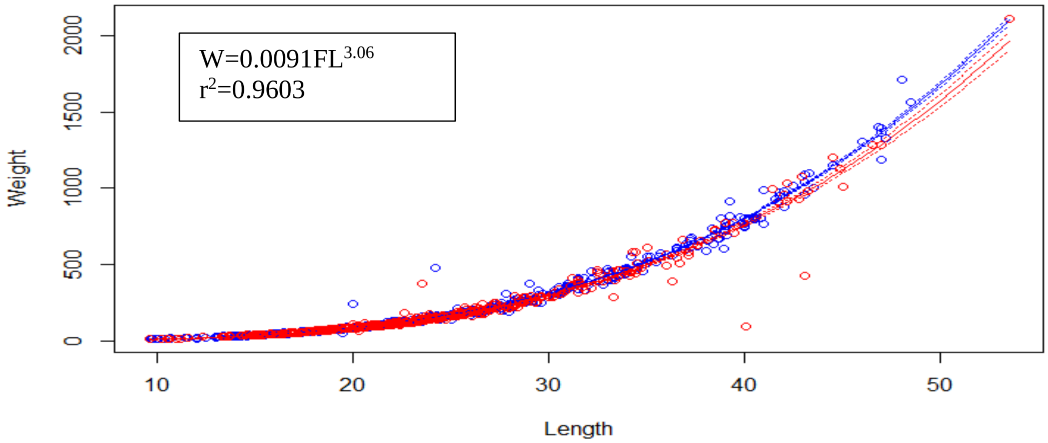

Figure 5: Length-weight relationship of brown trout on Baulárvallavan and Hraunsfjarðarvatn.

The relative selectivity curve shows probability of each net mesh size to retain a particular length or size of brown trout encountering it. The selection range at 50% (straight line) shows a pattern of increase across the mesh sizes (that is, 12-60 mm) (Figure 6). At optimal length, there is high chance of catching small fish in mesh size 12 than in 60 mm.

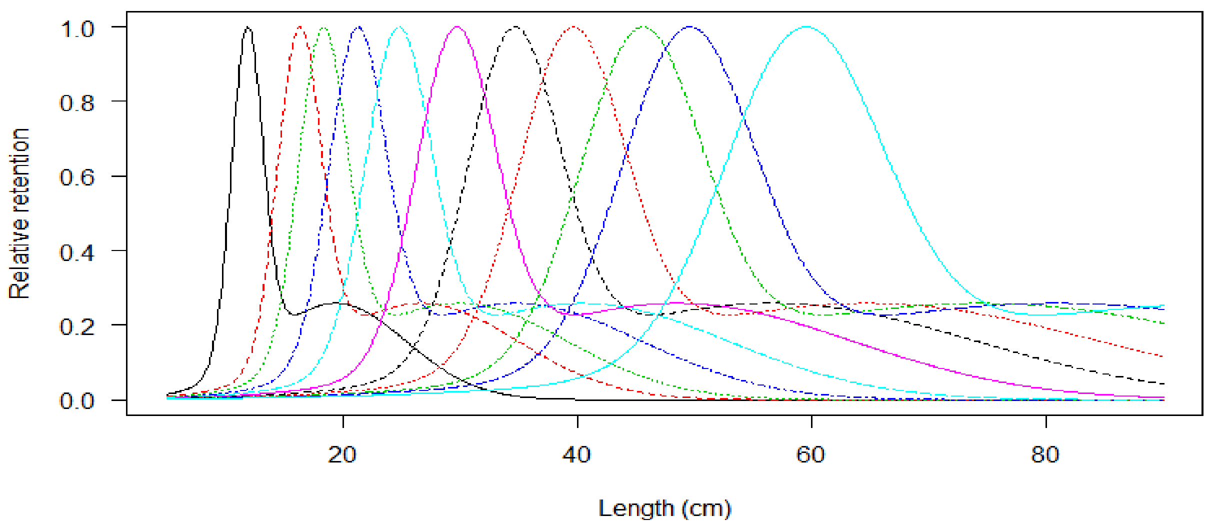

Figure 6: Relative selectivity curve of the mesh sizes for the bi-normal model.

The residual plot shows the fitting of the catches represented on mesh sizes (Figure 7). There was no visible bias or lack of fit of this model. There are few fish on the smallest and largest mesh sizes with over-representation of 28-40 cm size classes in meshes 21.5 and 25 mm. There was under-representation of fish on the smallest mesh size (12 mm) than 16.5 mm in the gillnet series.

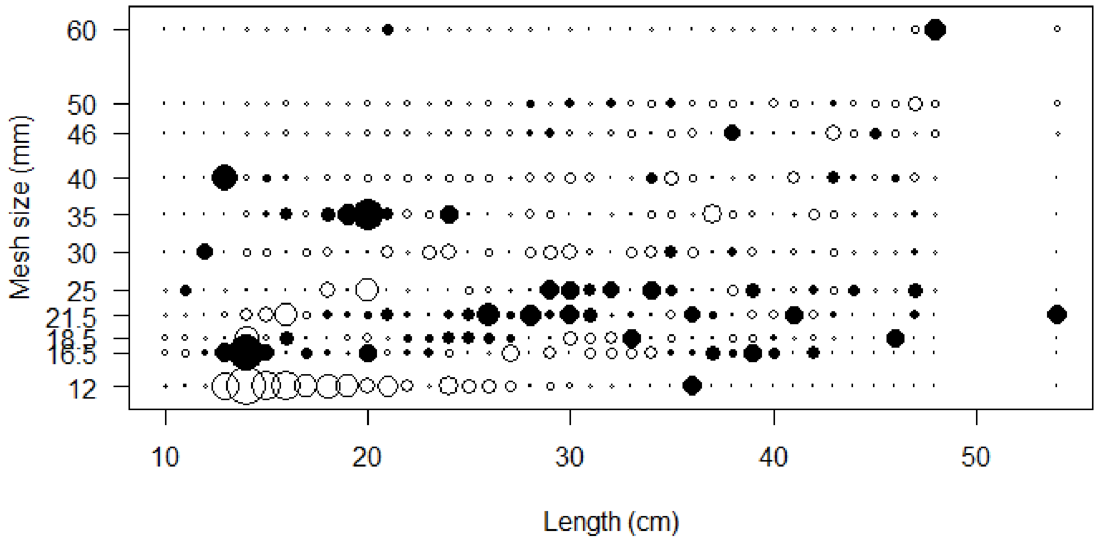

Figure 7: Residual plot of bi-normal model of mesh sizes (white and black dots represent positive and negative residual values, respectively).

The selectivity models (normal location, normal spread, lognormal, bi-normal and bi-lognormal) were fitted to the gillnet data of brown trout (Table 9). Bi-normal model gave the best fit because of the lowest deviance, hence, was used for this study to the estimate selectivity of gillnet.

Table 9: Point estimates of mesh selection parameters for the models.

Model	**normal location**	**normal spread**	**lognormal**	**bi-normal**	**bi-lognormal**
Parameter	k, $\boldsymbol{\sigma}$	k_1, k_2	μ, $\boldsymbol{\sigma}$	k_1, k_2, $\boldsymbol{\sigma}$	k_1,k_2, $\boldsymbol{\sigma}$,μ
Mode (mesh 1)	13.151	14.804	13.1876	11.859	13.183
Mode (mesh 2)	-	-	-	19.414	69.726
Std (mesh 1)	9.012	3.923	4.538	1.347	4.532
Std (mesh 2)	-	-	-	6.003	5.827
deviance	880.607	952.033	783.709	601.339	783.709
D.o.f	398.00	398.00	398.00	395.00	395.00

The selection range at 25 % of fish retention increases across the mesh sizes. At optimal length, this range also follow similar trend (Table 10). Though there was fluctuation in the catch across the meshes, but on the overall there was decrease in the catches as the mesh sizes of the net increases. Similarly, there was a wide gap between mesh sizes 12 and 16.5 mm in the selection range compared with other meshes.

Table 10: Optimal length distribution of fish in the net series.

Mesh size	Catch (%)	Optimal length	Selection range
12	2.9	11.9	5.0
16.5	23.7	16.4	13.9
18.5	17.9	18.4	17.4
21.5	21.3	21.3	19.8
25	14.2	24.8	23.0
30	5.9	29.8	27.2
35	6.4	34.7	32.2
40	3.9	39.7	37.1
46	2.4	45.7	42.6
50	1.0	49.6	47.6
60	0.4	59.6	54.3

The master curve shows the length distributions of fish retained by the gillnet series for the four years' data on these lakes (Figure 8). Majority of catch sizes represented are within the length range of 20-65 cm.

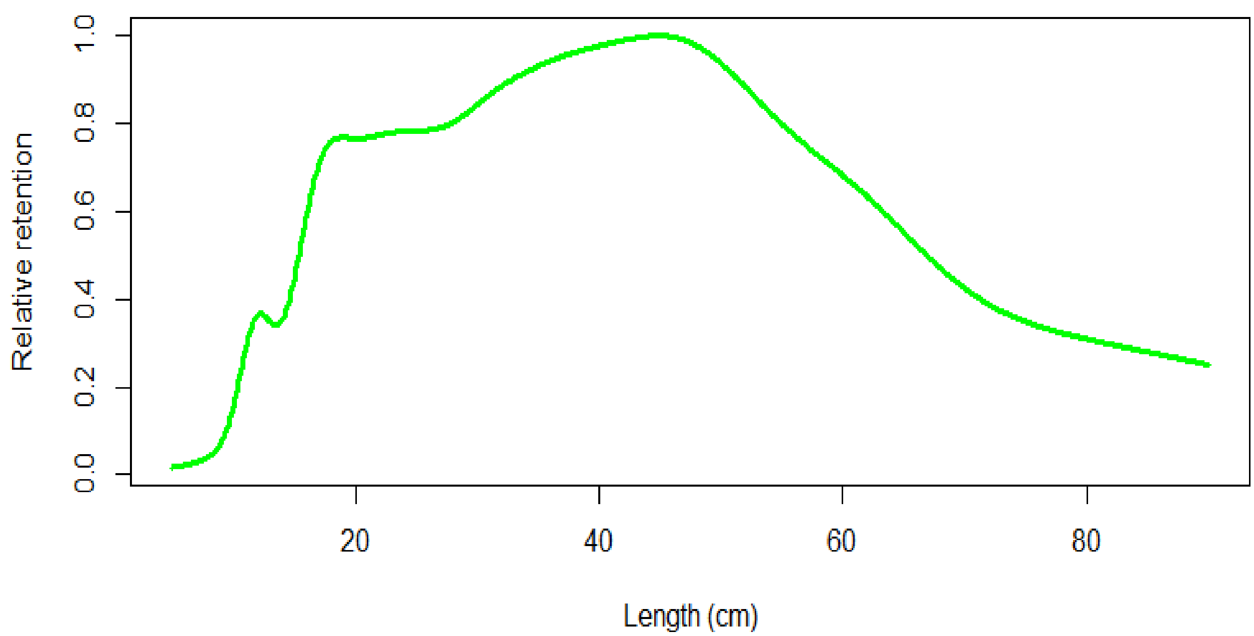

Figure 8: Master curve of mesh sizes for the years (2008, 2010, 2012, and 2014).

The frequency of fish caught in the mesh sizes (blue bars) known as the observed and from the master curve (red bars) shows the estimated length distributions (Figure 9) of fish in the fleet of this net series of the 6-year data from the lakes.

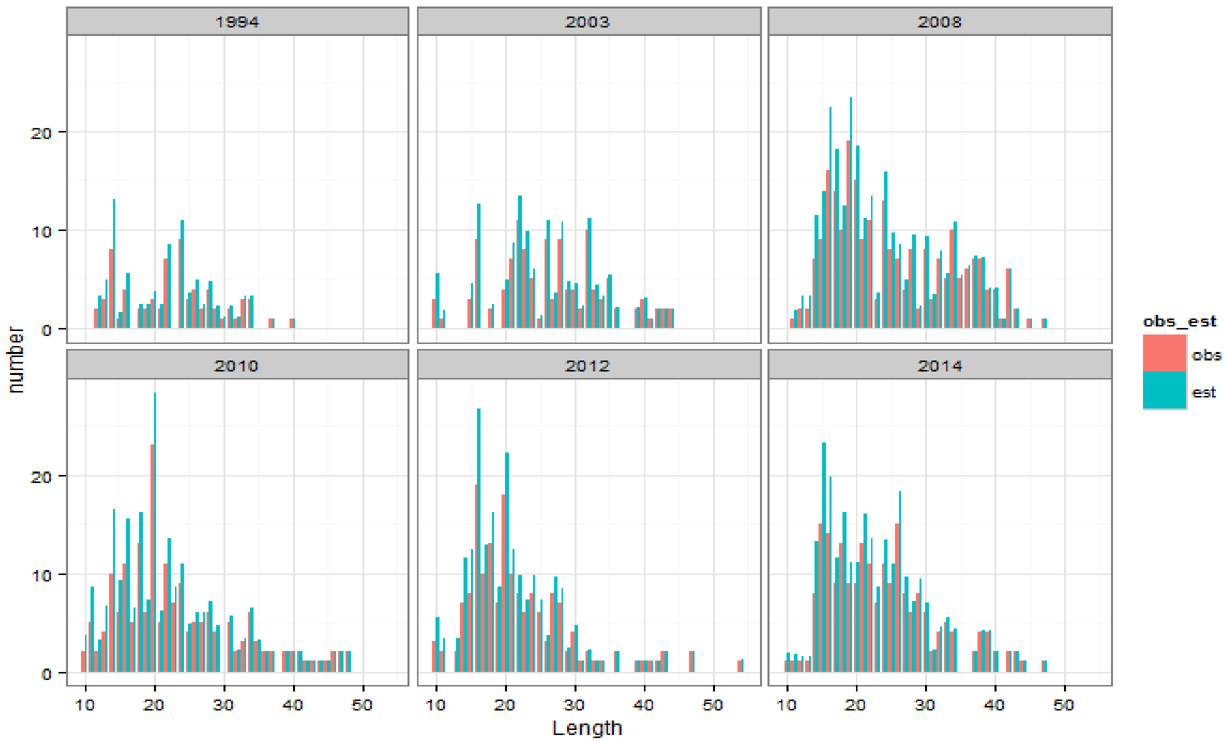

Figure 9: Observed length frequency and estimated length distribution from the master curve.

5 DISCUSSION

The study tends to show the selectivity patterns of individual mesh sizes of gillnet on the fisheries of Lakes Baulárvallavatn and Hraunsfjarðarvatn in Iceland from the catch data of brown trout. It also shows the length distribution, catch variation on the mesh sizes, and the estimated size distribution of fish population on the lakes. This is important from the stock assessment point of view because it gives a better understanding of status of the stock. In addition, it can serve as a reference point in the choice of mesh size that is appropriate for the fisheries. This will help to avoid the catch of juveniles or immature fish, as well as controlling the catch of targeted fish species with the net.

In this study, there is general decrease in the number of fish retained by the gear in most of the years as the mesh size increases, which varies from 30 to 35 mm, and 21.5 mm on Lakes Baulárvallavatn and Hraunsfjarðarvatn, respectively (Tables 3 and 4). While the mean catch value of Lake Baulárvallavatn shows mesh 16.5 mm with most of the catch, on Lake Hraunsfjarðarvatn mesh size 21.5 mm is the most effective. The lowest catches from the smallest and biggest meshes observed could be attributed to the probability of fish encountering the nets, and the difference in sizes of stock population in these lakes.

Mean length of fish caught by gillnet in the lakes increase with increase in mesh size (Tables 5 and 6). This follows the assumption of Baranov on the principle of geometric similarity, that gillnet will catch fish depending on the size in relation to the mesh size. There is variation of catch size from 50 mm mesh, and 35 mm, 50 to 60 mm on Baulárvallavatn and Hraunsfjarðarvatn, respectively. The variation in these values recorded could be due to the sizes of fish available in the area, and the number of fish retained by the mesh sizes during encounter. There is also possibility that high rate of fish catch in the population is by wedging and entangling.

The length-weight plot of brown trout from these lakes have shown a strong relationship between these parameters. This is important because it helps to evaluate fish stock body form from the same or different environment. The value of *b*, which determines the growth pattern is 3.06 (Figure 5). This shows that the body form maintains a constant proportion to the length of the fish. The growth coefficient is also high (r^2=0.96), which indicate that the length is significantly related to the weight of the fish. The morphology of the fish shows that they are from the same population stock, because there is connection between these lakes. In addition, the confidence interval of the data from these lakes did not differ significantly after plotting and fitting using least square method. Therefore, combining the data from these lakes for selectivity study is appropriate.

Knowing the length interval where fish chance of growing from immature to mature is a valuable information to estimate the spawning stock of the lakes. Nevertheless, with the knowledge of the effect of the selectivity of the sampling tool, deeper understanding of the spawning stock situation is eminent. This can be explained on the basis of individual, cohort or group. Table 8 shows the maturity situation of fish from the population stock in these lakes. Brown trout in these lakes start to mature at about 39 cm length, and become fully mature at about 40 cm. At this stage, it is expected that the fish start spawning for the first time. It can be seen that more of the fish caught have not fully attain maturity in these lakes during the period of sampling. In a river in France, 36.9 cm FL has been reported as size at maturity (Maisse *et al*. 1991) of brown trout. In Iceland at subarctic River Laxá, landlocked brown trout had 35.4 cm FL, as maturity size, which is underestimated due to the sampling period (Steingrímsson and Gíslason 2002). This shows that the brown trout in these lakes mature at a larger size, which could be due to difference in environmental conditions, such as food availability, and physico-chemical parameters.

The length distribution of fish caught by the net, and the relative selectivity curve are shown (Figure 6). While the catches reflect the length distribution of fish that could be the most abundant in these lakes, the selectivity curves show the estimates of retention probabilities for both mesh and fish lengths. The probability of a mesh size to retain fish increase with the length of the fish. It means selectivity of the net increase with increase mesh and fish size. This is also similar to the observation made by (Rudstam *et al*. 1984), but contrary to the findings of Borgstrom and Plahte (1992). This could be due to the property of the net and fish behavior. Length selection also depends on fish morphology, net mesh size, and hanging ratio, then all selectivity curves will be similar.

Fish capture in nets according to Hamley (1975) describe a normal curve and also total selectivity from sum of all the curves. This shows a moderate skewness of the curves (Figure 6). Gillnet selectivity curves according to Hamley (1975) may approach the normal curves when most of the fish are gilled or wedged. High rate of the fish catch might be by wedging, and gilling in these lakes during the period of study. While in smaller mesh sizes fish is gilled, wedged, and even entangled, larger mesh sizes, snag and at times entangle fish because of the net margin that becomes wider. In addition, this can be on the basis of the morphology of brown trout. The heights of the selectivity curves of mesh sizes according to (Hamley 1975) portrays the efficiency of the meshes in fish catch at the optimal length. This may not be true in most situation because fish can be wedge, entangle or gill by the net. In this study the assumption is that the ability of the net to catch fish is constant in all the net meshes. The height increases progressively across the mesh sizes. Size groups 13-37 cm of brown trout is mostly represented across the net, with few bigger fish (> 37 cm). It can be assume that the size groups 13-37 cm are dominant in these lakes. The residual plot from the selectivity curves also shows that the model best fit the data (Figure 7). The under and over representation (represented by white and black dots, respectively) of fish in the smallest and other bigger mesh sizes could be due size distributions in the lakes.

The bi-normal model was found to give the best fit of the selectivity curve of the catch data than the other four models (Table 9). In other words, the curves from the bi-normal model gave the best descriptions of the catch data. This is because it gave the least deviance (601.339), thereby keeping the residual sum of squares at minimal level. Also, the standard deviations from this model is the lowest (1.347, 6.003). These values show the spread between one mesh size and the other. This increase as the mesh size increases, which is an indication that fish were caught in different ways - wedged and gilled. This is supported by the assumption that fish catch depends on fish morphology and net meshes. Several studies have shown that bi-normal model give the best fit for different fish species (Fujimori and Tokai 2001, Balasubramanian *et al*. 2010).

Based on the bi-normal model used to fit the data, the modal length for the gillnet selection increases across the mesh sizes (Table 10), in length distribution of catches. The wide gap in the selection range of mesh size 12 mm could be due to the few fish in the optimum selection of the net. The optimal length and the selection range or estimated length shows that majority of the catch from these lakes are from mesh sizes of 16.5 mm and 21.5 mm.

The efficiency of fishing gear is the ability to catch and retain a giving class size of fish. The master curve (Figure 8) give a summary of fish size the net has ability to retain, if the fishing power is the same across the mesh sizes. The net series has >50% chances of catching and retaining fish of lengths 20-65 cm from the lakes over these years. From stock assessment point of view gillnet series should be in a way that more fish lengths will be represented. This will give better estimates of the state of the stock. Fish of length less than 15.5cm have <50% retention probability of the net series, but if extra net would be added to the net, like 14 mm, better coverage would be for the smallest length groups of the trout.

The master curve can also be used to estimate the length distributions of fish from data of unknown mesh sizes (1994 and 2003), if the fishing power of the net is the same. The different years show the number of fish of a given length the net would have retained during the fishing process (Figure 9). In other words, it shows how the stock was exploited by the fishing gear in these years on the lakes. For instance, in 2014, majority of the fish of about 15cm length encountering the net were not retained, while those around 30 cm and above were retained.

5.1 Application of this study on Lake Kainji fishery

Gillnets are frequently used by many scientists to estimate selectivity, and size distribution of fish. Apart from that, gillnets are also used to determine fish abundance, and distribution in water bodies, including inland fisheries - lakes, reservoir, rivers, and floodplains.

This kind of study is worthwhile in giving relevant advice on how stock population can be managed in a sustainable manner. It has shown the range of fish sizes found in these lakes, and the right net mesh to catch the required size of fish, avoiding immature or juveniles. If this study is replicated on Lake Kainji, it will contribute greatly to the management of the fishery.

An experiment on gillnet selectivity to evaluate the current state of the stock will be carried out on the lake. Relevant information, which include mesh sizes, species type, stages of maturity, length and weigh will be collected. This information will be analyzed for length distributions, length-weight relationships, size selection, and species selection using the indirect method. It is hope that the results would be used as basis for recommending allowable mesh sizes of gillnet for the fishery. Hence forth, data from survey (fishers catch and experimental gill netting) on Kainji Lake, and possibly other inland water bodies, will also include gillnet selectivity evaluation.

It will be of great importance, if recommendation from this type of study is reviewed in the fisheries edicts and regulations both at the state and federal levels. The impact may be slow or gradual, but at the long run it will greately improve the fishery.

6 CONCLUSION

This study shows that there are small, medium to large sizes of brown trout in Lakes Baulárvallavatn and Hraunsfjarðarvatn, with more of intermediate size, fewer small and larger sizes. While the number of fish catch decrease with mesh size increase, the length of fish on the other hand, increase with increase mesh size. The spread of fish catch along the net meshes obey the principle of geometric similarity, that size of fish retained by the net depends also on the mesh size. Majority of the fish caught by the nets have not fully attain maturity with the dominant size groups of 20-29 cm for both sexes. Bi-normal model gave the best interpretation of the catch data of these lakes. The class group that are mature base on the selection range are within the mesh sizes of 46-60 mm. The right mesh size that will be used to catch brown trout in these lakes can also be good to catch other species of fish with similar body form or morphology.

It is also important to note that, if a wider range of length distributions need to be represented, more meshes especially smaller ones (<12 mm) need to be included in the series, and closing the gap in the bigger mesh sizes (i.e. 55 mm). This could reveal more class or size distribution of the fish stock.

Selectivity studies can give a better guide to how fish stock is exploited by fishing gear. This can be seen when different mesh sizes of the net is used. The more the mesh sizes the better the length classes be represented. From this study it can be said that information on gillnets selectivity can give valuably understanding of how to manage commercial fishery where net fishery are practiced. This type of study is relevant in the management of any fishery. Data of gill netting and also fishers catch on Lake Kanji over the years would be needed to do similar estimation in order to understand how the fishery was exploited over the years. There is also need to improve on data collection, especially from gillnets because doing this will give better evaluation of the fishery.

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LIST OF REFERENCES

Abiodun, J. A. (2002). *Fisheries Statistic Bulletin of Kainji Lake, Nigeria.* Nigerian-German Kainji Lake Fisheries Promotion Project Technical Report Series 2.

Abiodun, J. A. (2003). Evaluation of fisheries catch trend on Lake Kainji in Nigeria, 1995-2001. *Journal of Applied Science and Environmental Management* 7(2): 9-13.

Abiodun, J. A., & Niworu, A. M. (2004). *Fisheries Statistical Bulletin of Kainji Lake, Nigeria.* Kainji Lake Resource Management and conservation Unit Technical Report Series 23.

Adam, P., James, C., & Speas, C. (2008). *Brown trout (Salmo trutta) species and conservation assessment.* [February 2015] <http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5199817.pdf>

Ayeni, J. S., & Mdaihli, M. (1996). *Identification of non-fishing income opportunities around Kainji Lake.* New Bussa: Nigerian-German Kainji Lake Fisheries Promotion Project.

Balasubramanian, A., Meenakumari, B., Boopendranath, M. R., Pravin, P., & Erzini, K. (2010). Mesh selectivity of drift gillnet for *Caranx sexfasciatus* and *Caranx tille* (Electronic version). *Fishery Technology* 47 (2): 111-120.

Berkeley, S. A., Hixon, M. A., Larson, R. J., & Love, M. S. (2004). Fisheries sustainability via protection of age structure and spatial distribution distribution of fish populations. *Fisheries* 29: 23-32.

Bobori, D. C., & Salvarina, I. (2010). Seasonal variation of fish abundnace and biomass in gillnet catches of an East Mediterranean Lake: Lake Doirani (Electronic version). *Journal of Environmental Biology* 31: 995-1000.

Borgstrom, R., & Plahte, E. (1992). Gillnet selectivity and a model for capture probabilities for a stunted trout (*Salmo trutta*) population (Electronic version). *Canadian Journal of Fisheries and Aquatic Sciences* 49: 1546-1554.

Bulletin Fisheries Statistics (1998). *Fisheries Statistical Bulletin, Kainji Lake, Northen Nigeria.* Nigerian-German (GTZ) Kainji Lake Fisheries Promotion Project.

Bwala, R. L., Sule, A. M., Yem, I. Y., Ndakotsu, S., & Adedeji, R. (2010). Indigenous fish indentification methods in Lakes Kainji and Jebba, Nigeria. *African Journal of General Agriculture* 6: 105-114.

Carol, J., & Garcia-Berthou, E. (2007). Gillnet selectivity and its relationship with body shape for eight freshwater fish species (Electronic version). *Applied Ichthyology* 23: 654-660. doi:10.1111/j.1439-0426

Cat, A. E., & Yuksel, F. (2014). Multi-monofilament gillnet selectivity for *Capoeta trutta* (Heckel,

1843) in Keban Dam Lake, Elazig, Turkey. (P. D. Lawn, Ed.) *Youth Science Magazine* 2: 15-26.

Clay, D. (1981). A new technique for estimation of gillnet selectivity and re-analysis of data for sevral fish species. *NAFO Science Council Studies*(1): 7-22. [February 2015] <http://archive.nafo.int/open/studies/s1/clay.pdf>

CRC Coastal Resource Center (2013). *Global lessons and information to assist with monofilament gillnet management in Ghana. USAID Intergrated Coastal and Fisheries Governance Program for the Western Region of Ghana, Narragansett.* Graduate School of Oceanography, University of Rhode Island, Coastal Resources Center.

Cochrane, W. G. (2002). *Sampling Techniques* (3rd ed.). New York: John Wiley and Sons.

Dahl, K. (1943). *Orre and Ørret. Studies and Forsøk av Knut Dahl.* Oslo: J. W. Cappelensn Publishers.

Dan-kishiya, A. S., Olatunde, A. A., & Balogun, J. K. (2012). *The status and prospects of Artisanal Fisheries of Lower Usuma Reserviour, Bwari, FCT, Abuja*. *Researcher* 4: 47.

Emmanuel, B. E., Chukwu, L. O., & Azeez, L. O. (2008). Gillnet selectivity and catch rates of pelagic fish in tropical coastal lagoon ecosytem. *African Journal of Biotechnology* 7: 3962-3971.

Emmanuel, B., & Chukwu, L. (2010). Evaluating the selective performance of gillnets used in a tropical low brackish lagoon, South-western Nigeria. *Journal of American Science* 6: 49-52.

Fujimori, Y., & Tokai, T. (2001). Estimation of gillnet selectivity curve by maximum likelihood method. *Fisheries Science* 67(4): 644-654.

Gabis, G., Kelpsaite, L., Parkins, C., & Castro, K. (2012). *Effect of hanging ratio on the catch of Red Sole (Cynoglossus senegalensis), Black Sole (Synaptura cadenati) and Catfish (Arius spp) in The Gambian Bottom Set Gillnet Fishery.* The USAID-BaNafaa project, Coastal Resource Center, URI.

Hailu, M. (2014). Gillnet selectivity and length at maturity of Nile Tilapia (*Oreochromis niloticus* L.) in a tropical reservoir (Amerti:Ethiopia). *Journal of Agricultural Science and Technology* A4: 135-140.

Hamley, J. M. (1975). Review of gillnet selectivity. *Journal of Canadian Board of Fisheries* 11: 1943-1969.

Helser, T. E., Geaghan, J. P., & Condrey, R. E. (1998). Estimating gillnet selectivity using non-linear response surface regression. *Canadian Journal of Fisheries and Aquatic Science* 55(6): 1328-1337.

Henderson, B. A., & Wong, J. L. (1991). A method for estimating gillnet selectivity of Walleye

(*Stizostedion vitreum vitreum*) in multimesh multifilament gillnets in Lake Erie, and its application. *Canadian Journal of Fisheries and Aqautic Science* 48: 2420- 2428.

Holst, R., Wileman, D., & Madsen, N. (2002). The effect of twine thickness on the size selection and fishing power of Baltic cod gillnets. *Fisheries Research* 56: 303-312.

Hovgard, H., & Lassen, H. (2000). *Manual on estimation of selectivity for gillnet and longline gears in abundnace surveys.* Rome: FAO.

Icelandic Ministry of Fisheries & Agriculture (2015). *Information Center of the Icelandic Ministry of Fisheries and Agriculture*. [February 2015] <http://www.fisheries.is/mainspecies/diadromous-fish/brown-trout/.>

International Union for Conservation of Nature (2010). *The Global Invasive Species Database*. Retrieved from The Global Invasive Species Database.

Irwin, B. J., Treska, T. J., Rudstam, L. G., Sullivan, P. J., Jackson, J. R., VanDevalk, A. J., & Forney, J. L. (2008). Estimating Walleye (*Sander vitreus*) density, gera catchability, and mortality using three fishery-independent data sets for Oneida Lake, New York. *Canadian Journal of Fisheries and Aquatic Sciences* 65: 1366-1378. doi:10.113a/F08-062

Ita, E. O. (1978). An analysis of fish distribution on Kainji Lake, Nigeria. *Hydrobiologia* 58: 233 -244.

Ita, E. O. (1993). *Inland Fishery Resources of Nigeria.* Fisheries and Aqauculture. Rome: FAO.

Jensen, J. W. (1995). A direct estimate of gillnet selectivity for brown trout. *Journal of Fish Biology* 46: 857-861. doi:0022-1112/95/050857

Jensen, J. W., & Hesthagen, T. (1996). Direct estimates of the selectivity of a multimesh and a series of single gillnets for brown trout. *Journal of Fish Biology* 49: 33-40. doi:0022-1112/96/070033

Karakulak, F. S., & Erk, H. (2008). Gillnet and trammel net selectivity in the northern Aegean Sea, Turkey. *Scientia Marina* 72: 527-540.

Maisse, G., Mourot, B., Breton, B., Fostier, A., Marcuzzi, O., Le Bail, P. Y., Richard, A. (1991). Sexual maturity in sea trout, *Salmo trutta* L., running up the River Calonne (Normandy, France) at the 'finnock stage' (Electronic version). *Journal of Fish Biology* 39(5): 705-715. doi:http://dx.doi.org/

Mbagwu, I. G., Ladu, B. M., & Amadi, A. O. (2002). Contribution of the seasonal and long term flood patterns of River Niger to the development and control of water hyacinth (*Eichhrnia crassipes*) in Kainji Lake, Nigeria. *Proceedings of the International Conference on water hyacinth.*, (pp. 105-110). New Bussa, Niger State.

McAuley, R. B., Simpfendorfer, C. A., & Wright, L. W. (2007). Gillnet mesh selectivity of the sandbar shark (*Carcharhinus plumbeus*): implications for fisheries management. *Journal of Marine Science* 64: 1702-1709.

Miller, R. (2010). *R functions for trawl and net (or hook) selectivity*. [February 2015] <https://www.stat.auckland.ac.nz/~millar/selectware/code.html.>

Miller, R. B., & Holst, R. (1997). Estimation of gillnet and hook selectivity using log-linear models. *ICES Journal of Marine Science* 54: 471-477. doi:1054-3139/97/040471

Myers, R. A., & Mertz, G. (1998, 02). The limits of exploitation: A precautionary approach. *Ecological Application*s 8: S165-S169.

Naesje, T. F., Hay, J. F., Nickanor, N., Koekenor, J. H., Strand, R., & Thorstad, E. B. (2004). *Fish populations, gillnet catches, and gillnet selectivity in the Kwando River.* NINA Project 27, Trondheim.

National Marine Fisheries Service & Atlantic States Marine Fisheries Commission. (2013). *Workshop on Sea turtle and Atlantic Sturgeon bycatch reduction in gillnet fisheries.*

Neiland, A. E., & Bene, C. (2008). *Tropical river fisheries valuation: background papers to a global synthesis. The worldfish center studies and reviews 1836.* Viper Solution.

North Central Catchment Management Authority. (2015). *Rainbow Trout and Brown Trout (Oncorhynchus mykiss and Salmo trutta) Description and characteristics.* [February 2015] <http://www.vic.waterwatch.org.au/file/inform/Rainbow%20and%20Brown%20Trout.df.>

Oginni, O., Fasakin, E., & Balogun, A. (2006). Gillnet selectivity of Cichlidae *Sarotherodon galilaues* (Linne 1958) in Iwo Reserviour, South-west Nigeria (Electronic version). *Middle East Journal of Scientific Research* 1: 10-15.

Omojowo, F., Olowosegun, T., & Omojowo, T. (2010). Fish production pattern in Kainji Lake Areas. *World Rural Observations* 2: 75-79.

Petriki, O., Erzini, K., Moutopoulos, D. K., & Bobori, D. C. (2014). Gillnet selectivity for freshwater fish species in three lentic systems of Greece. *Ichthyology* 1-12. doi:10.1111/jai.12476

Potter, E. E., & Pawson, M. G. (1991). *Gillnetting. Laboratory Leaflet.* Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research, Lowestoft, 69.

Punt, A. E., Hurtado-Ferro, F., & Whitten, A. R. (in press) (Electronic version). Model selection for selectivity in fisheries stock assessments. *Fisheries Research* (2013), 11.doi:10.1016/j.fishres.2013.06.00

Rudstam, L. G., Magnuson, J. J., & Tonn, W. M. (1984). Size selectivity of passive fishing gear:

A correction for encounter probability applied to gillnets (Electronic version). *Canadian Journal of Fisheries and Aquatic Science* 41: 1252-1255.

Ryan, C. (2015). *'Salmo trutta' (on-line) Animal Diversity*. [February 2015] <http://animaldiversity.org/accounts/*Salmo_trutta*/.>

Steingrímsson, S. O., & Gíslason, G. M. (2002). Body size, diet and growth of landlocked brown trout, *Salmo trutta*, in the subartic River Laxá, north-East Iceland. *Environmental Biology of Fishes* 63: 417-426.

Thomas, S. N. (2015). *Gillnet selectivity*. [February 2015] <http://210.212.228.207//bitstream//handle//123456789//885/Gill%20net%20selectivity.pdf?sequnce=1.>

Yuksel, F., Gunduz, F., & Demirol, F. (2014). Gillnet selectivity for *Luciobarbus esocinus* (Heckel, 1843) in Keban Dam Lake, Elazig, Turkey. *Indian Journal of Fisheries* 61: 108-111.