**International Journal of Fisheries and Aquatic Research**
**ISSN: 2456-7248; Impact Factor: RJIF 5.44**
**Received: 11-08-2020; Accepted: 26-08-2020; Published: 12-09-2020**
**www.fishjournals.com**
**Volume 5; Issue 4; 2020; Page No. 13-22**

# Predictive models for codend size selectivity for the arioma bondi silver-rag driftfish (*Ariommatidae*) in the Cameroonian bottom trawl fisheries: Effects of mesh size on the size selection

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**Abstract**
Ariomma bondi, the silver-rag driftfish is an abundant species distributed in Cameroonian territorial waters. It constitutes an important demersal species because of its considerable and unexploited potential. Some of the demersal fish populations in Cameroonian waters have been heavily exploited and fishing effort may be above optimum levels for many species. In this context, the exploitation of the potential of arioma bondi will increase national fish production which is still in deficit, but to provide sustainable exploitation, resource management is clearly required. Therefore, the evaluation of trawl codends which are going to be used in this fishery and the potential improvements to their selectivity are of prime importance. This study investigated the selectivity parameters and a selective mesh size for bottom trawls used to target arioma bondi in Cameroonian maritime fisheries. The semi-empirical models was used to define selective properties of codend. These properties are determined using the experimental and theoretical methods of assessing the parameters of the selectivity curve, and by plotting the curve. Selection parameters were obtained by fitting a logistic equation using a maximum likelihood method. Codend selectivity was estimated using 24 diamond mesh sizes ranged from 40 to 88 mm. The fish length of the silver-rag driftfish ranged from 140 mm to 310 mm with the average of 225 mm. The results showed that the mesh size of 58 mm was the selective mesh size of the bottom trawl codends used to capture arioma bondi in Cameroonian fisheries, which will ensure sustainable exploitation of this resource.

**Keywords:** selectivity parameters, mesh size, cameroonian territorial waters, selectivity models, ariomma bondi

## 1. Introduction

Fishery resources are the main source of animal protein in the diet of the Cameroonian population and contribute significantly to the total supply of animal protein. It is a preferred protein source for most Cameroonians and the national average consumption of fish was estimated at 15.4 kg per person in 2013 [1]. Indeed, Fishing is very active in the country and represents an important sector from both a socio-economic and food point of view. It is organized around four branches which are industrial fishing, artisanal maritime fishing, inland fishing and aquaculture [2].The national production remains modest and oscillates around 180,000 tons/year, including 93,000 tons for artisanal fishing, 75,000 tons for inland fishing, 8,000 tons for industrial fishing and 1,000 tons for the aquaculture. However, fish production is not able to meet the demand of fish in the country because the national demand is estimated at approximately 400,000 tons/year [3]. Therefore, the Cameroonian government import approximately 220,000 tons of fish each year, which constitutes a significant escape of capital, estimated around 100 billion FCFA/year [4]. In order to ensure food security in the country and maintain the economic growth, Cameroon needs to considerably increase its fish production, especially by aquaculture development with technical assistance to fish farmers. Such a technical assistance can come from countries such as China, Indonesia, and Egypt with proven aquaculture expertise and experience [5]. Most of the marine and inland fishery resources targeted in Cameroun are either overexploited or in the process of overexploitation. Indeed, some of the demersal fish populations in Cameroonian waters have been heavily exploited and fishing effort may be higher than optimal levels for many species. Thus, there is a downward trend in fish catches due to overfishing, intensive fishing pressure, repeated and confined use of fishing grounds in a particular area, especially in the use of non-selective fishing gears [5-10]. However, several acoustic surveys carried out by FAO in 2004, 2005, 2006 and 2007 from the research vessel Fridjoff Nansen in the Gulf of Guinea revealed the presence in Cameroonian territorial waters of abundant fishery resources of the Ariomidae family, in particular the ariomma bondi species, located at depths varying from 100 to 500 m, the potential exploitation of which could provide an estimated production of around 300,000 tonnes / year [11]. Thereby, the production of this species will not only fill the deficit, but may also generate surpluses for export to neighboring countries. In this context, efforts must be reoriented towards the exploitation of these stocks in order to increase fish production. Many studies related to the selective properties of trawl trawls have been carried out, so far they are still being improved [12-14].

Over the past decades, the scientific community has worked to reduce bycatch and juvenile mortality by increasing the selectivity of trawls, which of them mostly have focused on the modification of the mesh size and the codend configuration [15-16]. Thus, the selective properties of codend are characterized by the selectivity curve S (*l*) and its parameters such as the selectivity coefficient, selectivity range and the fraction of fish not subject to the selective action of the net [17]. During these last years, various methods relating to the study of the selective properties of the codend have been used, namely the covered codend method, alternate or parallel haul method, methods using special selective devices, etc [18]. The complexity of the experimental studies on the selective properties of codend as well as the difficulties linked to the explanation of the results make their use somewhat difficult. Due to the complexity of the fish selection process, theoretical research gives an orientative assessment of the selective properties of codend, while experimental studies which are expensive, partial in nature and do not explain many features of the selective action of trawl codends [19-22].

The experimental methods are very laborious and not very comprehensive since the results are fragmentary and do not allow to generalize [19, 23]. The methods which approach the mesh size of the codend to that of the gillnet by estimating that it is equal to 60-80% of the mesh of the latter give contradictory results due to numerous differences between the working conditions and the characteristics of the gillnet and filter nets but, the gillnet and filter net materials are different [24-25]. Likewise, the methods which determine the mesh size in a trawl codend based on the analysis of the process of entanglement according to the biometric parameters of the fish are certainly more justifiable [26].

However, they do not take into account the size composition of the target shoal, fishing regulation indicators, fishing conditions variable, etc. In addition, it is difficult to determine the mesh size based around the coefficient of allowable fishing mortality using the Baranov-Beverton-Holt equation and their modifications due to the difficulties associated with the use of this equation [27-28]. The methods based on the determination of the loss and the gain when passing from one mesh to another do not use theoretical data in the calculations but rather statistical data, thus increasing the accuracy of the results, while by limiting its field of use [29]. Considering these shortcomings, in this study, the determination of the selective properties of trawl codend is based on the use of semi-empirical models to estimate the selectivity curve. First, these models facilitate a qualitative assessment of the character and degree of influence on the selectivity of the size-composition of the target fish shoal, the biometric characteristics of the fish morphology, deformation of the meshes, quantity of the catch etc firstly [30].

Second, to determine the mesh size at trawl codends which will be necessary to target arioma bondi with bottom trawls in Cameroonian fisheries, this work takes into consideration the method that uses basic selectivity models [31]. Such models without assumptions, link among themselves the size-composition of the target shoal of fish, the selectivity curves of the codend with mesh size, mature fish size, catch of juveniles, escapement of fish via the mesh.

This means is more universal, exact, sticks with all other ways of determination of mesh size and can be associated to them.

## 2. Materials and Methods

### 2.1. Study area and data collection

In this study, the Ariomma bondi, the silver-rag driftfish was used as a material. It is a demersal species belonging to the Ariommatidaea family which is a common and abundant species distributed over Cameroonian and Nigerian territorial waters and located at depths of up to 100 m.

The study was carried out in in the Central Gulf of Guinea (camerouian water) which extending from the border with Equatorial Guinea, south of the Campo River estuary (2°20'N) to the Nigerian border north of Akwayafe River (4°40' N) (Fig.1). The continental shelf area (up to 200 m depth) is about 13 000 -14,000 km2, while the total Exclusive Economic Zone (EEZ) area is around 25,000 km2 [32]. The gear used in the experiments was a typical commercial bottom trawl “Yang I” employed in the area. It was entirely made of knotless polyamide (PA) netting.

Experimental size selection data were collected on board the commercial fishing vessel“Yang I” of the fishing Company ‘‘SIPECAM’’. A total of 245 size composition from the smallest to the largest possible size of the species were obtained and used in this study (Table 1).

**Table 1:** Size composition of Ariomma bondi

| $l_i$ (mm) | 140 | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 | 250 | 260 | 270 | 280 | 290 | 300 | 310 | Σmᵢ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $m_i$ | 2 | 2 | 4 | 6 | 7 | 12 | 20 | 41 | 53 | 40 | 22 | 12 | 8 | 5 | 3 | 3 | 1 | 2 | 245 |

$l_i$ = Lenght size, $m_i$ = number of sample


**Fig 1:** Map of Cameroon coastline and EEZ

### *2.2. Modeling the size selection processes in the codend*

In the present study, the retention of fish

For the codend can be modeled using the following semi-empirical models to assess the selectivity curve and its parameters.

$$S\,(l) = \frac{1-\alpha}{1+\exp\left[\frac{2.2(KA-l)}{D}\right]} + \alpha \quad (1)$$

With

$$K_s = 2\left(\frac{1-\alpha\left(1+\frac{0.1}{K_m}\right)}{1-\alpha}\right)\left(\frac{K_{cor}(1-\varepsilon)}{K_m K_{cor}}\right) \quad (2)$$

$$D_s = \frac{0.2K_{cor}(1+\epsilon)}{(1-\alpha)K_m^2 K_{com}} \quad (3)$$

Where *S(l)* is the function of the selectivity curve, $K_s$ is the selectivity coefficient, $D_s$ is the selectivity range, A is the internal mesh size, $K_m$ is the coefficient of the fish body, $K_{com}$ is the coefficient which takes into consideration the deformation of the fish body during its passage in the mesh, $K_{cor}$ is the coefficient that corresponds to the working mesh shape and the mesh form at the maximum cross section of fish's body. $\varepsilon$ is the relative work lengthening of the mesh. *l* is the fish length, and α is the proportion of fish not affected by the selective effect of the mesh. The quantity α, which is the proportion of fish not affected by the selective effect of the mesh can be determine using Eq.4:

$$\alpha = 0.1(1+lnQ_h) + exp\left[-5\frac{A-A_{min}}{A_{max}-A_{min}}\right] - 0.1(1+lnQ_h)exp\left[-5\frac{A-A_{min}}{A_{max}-A_{min}}\right] \quad (4)$$

$Q_h$ is the total catch in tons per tow in one hour duration, $A_{min}$ and $A_{max}$ are the mesh sizes corresponding to the minimum and maximum fish length in the size composition of the targeted shoals.

A min and A max can be define as:

$$A_{min} = 0.9\frac{K_m l_{min}}{2} \quad (5)$$

$$A_{max} = 0.9\frac{K_m l_{max}}{2} \quad (6)$$

The determination of the codend mesh size was based on the condition that the quantity of juveniles $n_j$ does not exceed the allowable $[n_j]$. Thereby, it is also important to know the relative quantity $n_t$ of mature fish that escape through the mesh codend. These characteristics of the selective action of codend were determined using the following basic selectivity models:

$$n_j - \frac{y_j}{y_0} = \frac{\int_{l_{min}}^{l_j} g(l)S(l)dl}{\int_{l_{min}}^{l_{max}} g(l)S(l)dl} \quad (7)$$

$$n_t - 1 - \frac{y_T}{N_T} = 1 - \frac{\int_{l_j}^{l_{max}} g(l)S(l)dl}{\int_{l_j}^{l_{max}} g(l)S(l)dl} \quad (9)$$

$$n_j - \alpha_p\left(1 - \frac{\int_{l_{min}}^{l_{max}} g(l)S(l)dl}{\int_{l_{min}}^{l_{max}} g(l)dl}\right) \quad (10)$$

where $y_j$ is the relative juveniles catch, $y_T$ is the relative catch of mature fish size, $y_0$ is the relative total catch ($y_0$ = $y_T$ +$y_j$), $y_{em}$ is the relative quantity of entangled fishes, $n_t$ is the fraction of mature fish in the targeted shoals, $n_{em}$ is the fraction of fishes entangled, $g(l)$ is the function of the distribution density of the size composition of the targeted shoals, S(*l*) is the function of the selectivity curve of the codends, P(*l*) represents the function of the codend entanglement capacity (function of the selectivity curve of gillnets), $l_j$ is the mature fish length, and $\alpha_p$ expresses the post-selection mortality rate.

The input data for determining the parameters and the function of the selectivity curve as well as the mesh size or dimension taking into consideration the allowable catch of juveniles are:

1. Coefficient of fullness of fish's body $K_m$;
2. Compression coefficient $K_{com}$ of fish's body as it goes out via the mesh;
3. Coefficient of correspondence $K_{cor}$ between the working shape of the mesh and the maximum cross-sectional area of the fish's body;
4. Relative working lengthening of the mesh $\varepsilon_m$ ;
5. Catch per hour of trawling $Q_h$;
6. Minimum fish length size in the targeted fish shoal $l_{min}$;
7. Maximum fish length size in the targeted fish shoal $l_{max}$;
8. Mature fish size $l_j$;
9. Allowable catch of juveniles $[n_j]$;
10. Allowable escape of mature fish through mesh of the trawl codend $[n_t]$;
11. Twenty four internal mesh sizes whose selectivity curves cover the range of the size composition of fish in the targeted shoal;
12. Variation series characterizing the size composition of the targeted shoal;
13. The value of the mature fish size $l_j$ and the allowable catch of juveniles $[n_j]$ are contained in the laws regulating maritime fishing in Cameroon [33].

**2.3 Data analysis and parameter estimation**

The predicted model was implemented in Matlab and during this simulation, the input data obtained experimentally to determine the mesh size of the codend were:

Material for the trawl codend: Polyamide, 3,0 mm double twine;

1. Trawling speed: $u_{tr}$ = 2 m/s.
2. Tow duration: 2hours.
3. Average catch per one tow: $Q_h$ = 1.5 tons
4. Allowable mature fish size by the legislation: $l_j$ = 200 mm.
5. Allowable catch of juveniles $[n_j]$ = 0.1.
6. Allowable quantity of fish of mature size, that escape via the mesh $[n_t]$ = 0.25.

The initial data for the calculated size composition was given in the form of a variation series and inserted in Table 1. Taking into consideration the input data, the calculated parameters were determined and inserted in Table 2.

**Table 2:** Calculated parameters

| $K_m$ | $K_{com}$ | $K_{cor}$ | $\varepsilon_m$ | $Q_h$ | $l_j$ | $l_{min}$ | $l_{max}$ | $[n_j]$ | $[n_t]$ | $A_{min}$ | $A_{max}$ | ΔA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 0.93 | 0.74 | 0.2 | 1.4 | 200 | 140 | 310 | 0.08 | 0.25 | 40 | 86 | 2 |

Note that $K_m$ is the Coefficient of fullness of fish's body, $K_{com}$ is the Compression coefficient of fish's body as it goes out via the mesh, $K_{cor}$ is the Coefficient of correspondence between the working shape of the mesh and the maximum cross-sectional area of the fish's body, $\varepsilon_m$ is the Relative working lengthening of the mesh, $Q_h$ is the Catch in tons per hour of trawling, $l_j$ is the Mature fish size, $l_{min}$ is the minimum fish size in the targeted fish shoal, $l_{max}$ is the Maximum fish size in the targeted fish shoal, [$n_j$] is the Allowable catch of juveniles, [$n_t$] is the Allowable escape of mature fish through mesh of the trawl codend, $A_{\text{ùin}}$ is the Minimum mesh size, $A_{\text{ùax}}$ is the Maximum mesh size, and ΔA= step size.

## 3. Results

### 3.1 Length frequency distribution of the samples used

As shown in Fig.2, the fish length of the silver-rag driftfish ranged from 140 mm to 310 mm. Only the three large fish was recorded with a fish length varied from 300 to 310 mm. The average fish length was estimated to be 225 mm. the retention length (L50) was determined from the cumulated frequency percentage and found to be belonging to be the length group 225 mm. This data was recorded in the Matlab software for the numerical simulation in this study in order to confirm the value of L50 obtain experimentally and the appropriate mesh size.

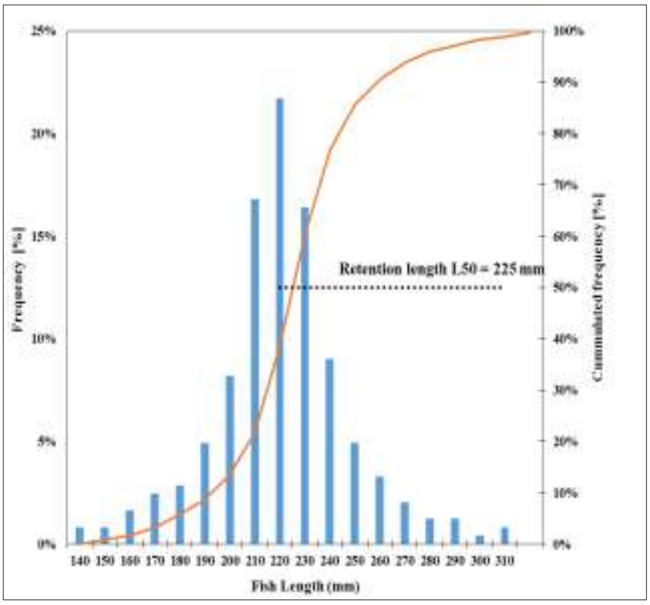


**Fig 2:** Length frequency distribution (bar) and accumulated frequency %( curve) of the silver-rag driftfish in the Cameroonian waters.

### 3.2. Establishment of the predictive models and selective curve parameters

The predictive model for the silver-rag driftfish was obtained using 24 different meshes size, for which it was possible to obtain a size selection curve. Overall, the quantity α which is the proportion of fish not affected by the selective effect of the mesh and the selectivity coefficient $K_s$ increased as the mesh size increases while, the selectivity range $D_s$ decreased as the mesh size increase (Table 3). Fig.3 shows the selectivity curves for all the 24 mesh sizes. When the escarpment probability resource was greater than 0.5, the retention length (L50) for the selectivity varies between 220 mm to 250 mm and the selective mesh size appropriate for these retention lengths was up to 58 mm (A10) which was better according to selectivity parameter results of table 3 up to 58 mm (A10) (Fig.3). Results of the catch parameters $y_0$, $y_j$, $y_t$, $y_{em}$, are given in Table 4 and that of the catch indicators $n_j$, $n_t$, $n_{em}$ and $n_p$, in Table 5. Table 4 shows that the more the mesh size increases, the more the parameter related to the total catch($y_0$) decreases, due to the fact that the increase in the mesh size reduces the number of juvenile captures ($y_j$ relative to the juveniles catch) hence the decrease of the parameter $y_j$ (Table 4 ). Note that the parameter relative to the catch of mature fish size decreased as the mesh size increased while, $y_{em}$ decreased as the mesh size increase and reached the value of 0 when the mesh size was at 58 mm which shown that this mesh size is the predictive mesh size for a good selectivity of the codend for the capture of Arioma bondi, the silver-rag driftfish (Table 4). The results of the Catch indicators showed that the fraction of juvenile fish ($n_j$) in the targeted shoal and the fraction of fishes entangled decreased as the mesh size increased but the parameter $n_{em}$ was 0 from mesh size equal to 58 mm, thus confirming this predictive size. Unlike, the fraction of mature fish in the targeted shoals and the Post selection mortality rate increased as the mesh size increases (Table 5).

**Table 3:** Selectivity curve parameters α, $K_S$ and $D_S$ by mesh sizes ($A_1$ to $A_{24}$)

| Mesh size | | α | $D_S$ | $K_S$ |
|---|---|---|---|---|
| A1 | 40 | 0.8249 | 162.2551 | 0.1856 |
| A2 | 42 | 0.6870 | 95.5600 | 1.7954 |
| A3 | 44 | 0.5730 | 73.5605 | 2.3410 |
| A4 | 46 | 0.4789 | 63.1387 | 2.6119 |
| A5 | 48 | 0.4011 | 57.4328 | 2.7714 |
| A6 | 50 | 0.3368 | 54.1194 | 2.8750 |
| A7 | 52 | 0.2836 | 52.1926 | 2.9466 |
| A8 | 54 | 0.2397 | 51.1451 | 2.9982 |
| A9 | 56 | 0.2034 | 50.6925 | 3.0366 |
| A10 | 58 | 0.1734 | 50.6627 | 3.0657 |
| A11 | 60 | 0.1486 | 50.9446 | 3.0883 |
| A12 | 62 | 0.1282 | 51.4633 | 3.1059 |
| A13 | 64 | 0.1112 | 52.1661 | 3.1199 |
| A14 | 66 | 0.0973 | 53.0146 | 3.1310 |
| A15 | 68 | 0.0857 | 53.9802 | 3.1400 |
| A16 | 70 | 0.0761 | 55.0410 | 3.1472 |
| A17 | 72 | 0.0683 | 56.1798 | 3.1531 |
| A18 | 74 | 0.0617 | 57.3833 | 3.1579 |
| A19 | 76 | 0.0563 | 58.6404 | 3.1618 |
| A20 | 78 | 0.0519 | 59.9423 | 3.1650 |
| A21 | 80 | 0.0482 | 61.2818 | 3.1676 |
| A22 | 82 | 0.0452 | 62.6529 | 3.1697 |
| A23 | 84 | 0.0427 | 64.0506 | 3.1715 |
| A24 | 86 | 0.0406 | 65.4707 | 3.1729 |

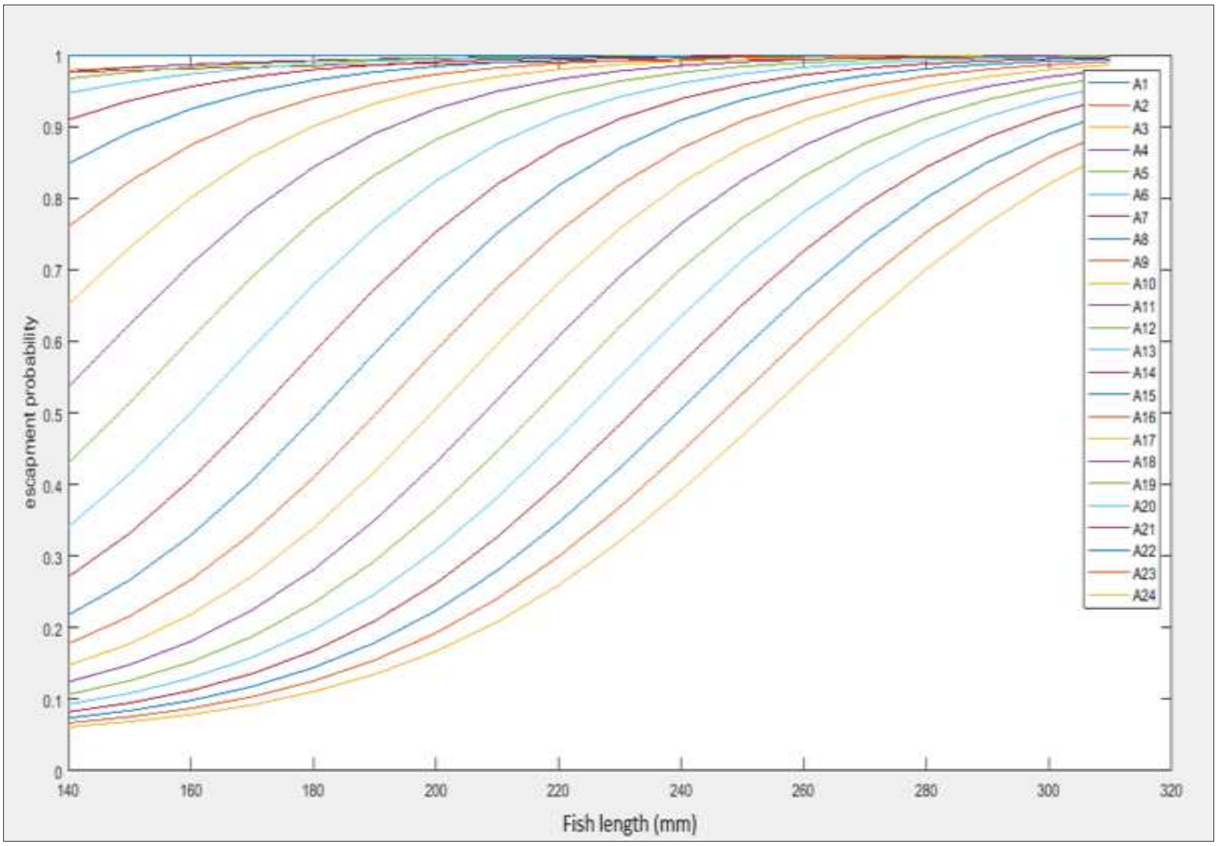


**Fig 3:** Family of selectivity curves for 24 mesh sizes (from $A_1$ =40 mm to $A_{24}$ =88 mm) intended to target Ariomma bondi, the silver-rag driftfish with bottom trawls in Cameroonian fisheries.

**Table 4:** Catch parameters $y_0$, $y_j$, $y_t$, and $y_{em}$ by mesh sizes from A1 to $A_{24}$.

| Mesh size | | Parameter | | | |
|---|---|---|---|---|---|
| | | Y0 | Yj | Yt | Yem |
| A1 | 40 | 0.9896 | 0.1103 | 0.8793 | 0.1832 |
| A2 | 42 | 0.9883 | 0.1096 | 0.8787 | 0.6288 |
| A3 | 44 | 0.9856 | 0.1084 | 0.8772 | 0.7861 |
| A4 | 46 | 0.9811 | 0.1067 | 0.8744 | 0.4942 |
| A5 | 48 | 0.9741 | 0.1041 | 0.8699 | 0.1923 |
| A6 | 50 | 0.9638 | 0.1006 | 0.8632 | 0.0528 |
| A7 | 52 | 0.9493 | 0.0960 | 0.8533 | 0.0111 |
| A8 | 54 | 0.9295 | 0.0901 | 0.8394 | 0.0019 |
| A9 | 56 | 0.9037 | 0.0832 | 0.8205 | 0.0003 |
| A10 | 58 | 0.8712 | 0.0755 | 0.7958 | 0.0000 |
| A11 | 60 | 0.8321 | 0.0673 | 0.7648 | 0.0000 |
| A12 | 62 | 0.7868 | 0.0592 | 0.7276 | 0.0000 |
| A13 | 64 | 0.7362 | 0.0514 | 0.6848 | 0.0000 |
| A14 | 66 | 0.6817 | 0.0442 | 0.6375 | 0.0000 |
| A15 | 68 | 0.6251 | 0.0379 | 0.5872 | 0.0000 |
| A16 | 70 | 0.5679 | 0.0325 | 0.5355 | 0.0000 |
| A17 | 72 | 0.5119 | 0.0278 | 0.4841 | 0.0000 |
| A18 | 74 | 0.4583 | 0.0239 | 0.4344 | 0.0000 |
| A19 | 76 | 0.4082 | 0.0207 | 0.3875 | 0.0000 |
| A20 | 78 | 0.3621 | 0.0180 | 0.3441 | 0.0000 |
| A21 | 80 | 0.3205 | 0.0158 | 0.3047 | 0.0000 |
| A22 | 82 | 0.2835 | 0.0140 | 0.2695 | 0.0000 |
| A23 | 84 | 0.2508 | 0.0125 | 0.2383 | 0.0000 |
| A24 | 86 | 0.2508 | 0.0125 | 0.2383 | 0.0000 |

**Table 5:** Catch indicators $n_j$, $n_t$, $n_{em}$ and $n_p$ by mesh sizes (from $A_1$ to $A_{24}$)

| Mesh size | | Indicator | | | |
|---|---|---|---|---|---|
| | | $n_j$ | $n_t$ | $n_p$ | $n_{em}$ |
| A1 | 40 | 0.1115 | 0.0087 | 0.0004 | 0.1852 |
| A2 | 42 | 0.1109 | 0.0093 | 0.0004 | 0.6362 |
| A3 | 44 | 0.1100 | 0.0110 | 0.0006 | 0.7976 |
| A4 | 46 | 0.1087 | 0.0141 | 0.0007 | 0.5037 |
| A5 | 48 | 0.1069 | 0.0192 | 0.0010 | 0.1974 |
| A6 | 50 | 0.1044 | 0.0268 | 0.0014 | 0.0548 |
| A7 | 52 | 0.1011 | 0.0380 | 0.0020 | 0.0117 |
| A8 | 54 | 0.0970 | 0.0537 | 0.0028 | 0.0021 |
| A9 | 56 | 0.0921 | 0.0750 | 0.0038 | 0.0003 |
| A10 | 58 | 0.0866 | 0.1028 | 0.0051 | 0.0000 |
| A11 | 60 | 0.0809 | 0.1377 | 0.0067 | 0.0000 |
| A12 | 62 | 0.0752 | 0.1797 | 0.0085 | 0.0000 |
| A13 | 64 | 0.0698 | 0.2279 | 0.0105 | 0.0000 |
| A14 | 66 | 0.0649 | 0.2813 | 0.0127 | 0.0000 |
| A15 | 68 | 0.0607 | 0.3380 | 0.0150 | 0.0000 |
| A16 | 70 | 0.0572 | 0.3963 | 0.0173 | 0.0000 |
| A17 | 72 | 0.0544 | 0.4542 | 0.0195 | 0.0000 |
| A18 | 74 | 0.0522 | 0.5103 | 0.0217 | 0.0000 |
| A19 | 76 | 0.0507 | 0.5631 | 0.0237 | 0.0000 |
| A20 | 78 | 0.0498 | 0.6120 | 0.0255 | 0.0000 |
| A21 | 80 | 0.0493 | 0.6564 | 0.0272 | 0.0000 |
| A22 | 82 | 0.0493 | 0.6962 | 0.0287 | 0.0000 |
| A23 | 84 | 0.0497 | 0.7313 | 0.0300 | 0.0000 |
| A24 | 86 | 0.0504 | 0.7621 | 0.0311 | 0.0000 |

### 3.3. Size selectivity

The data thus collected, estimated, and simulated in Matlab software allowed analysing the size selection properties of the bottom trawl codend for this target specie for the Cameroonian fishery. The size selection parameters and fit statistics were calculated using the semi-empirical models developed (Figs.4 to 8). The density curve of length size distribution of arioma bondi, the silver-rag driftfish can be approximated to the normal density curve as shown in Fig.4. Indeed, the number of small size fish (140-160 mm) and large size (280-310mm) is low compared to that of medium size fish (200-220 mm). The Fig. 4 shows that the distribution density function of the size composition of the targeted shoals reaches the peak at 23 when the length fish was at 225 mm representing and confirming the retention length (L50) which represented the selective length size(Fig.4).

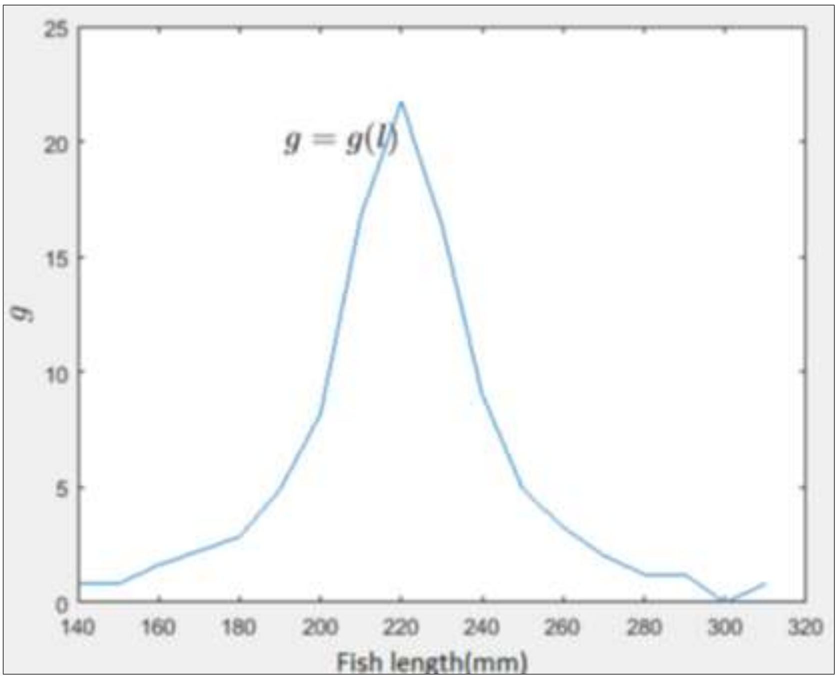


**Fig 4:** Density of size distribution of targeted shoals curve (*g (l)*).

Evenly, the mesh-size also influences the selective parameters $K_S$, $D_S$, and $\alpha$. The relationship between the mesh size A and the parameter $\alpha$ is complex and tends to take an exponential shape (Fig. 5). As the mesh decreases, the value of $\alpha$ increases and vice versa. For a mesh-size of 40 mm, α approaches 1 (0.82) and all fish caught is retained at the codend. For a mesh-size of 88 mm, α approaches 0 (0.006), and all the catch might escape from the codend. It depends more on the concrete values of $\alpha$. The increase in catch will result into the decrease of α and vice-versa. Generally, the larger the fish in the shoal, the more *g(l)* influences the shape and the lay-out of the curve *S(l).*

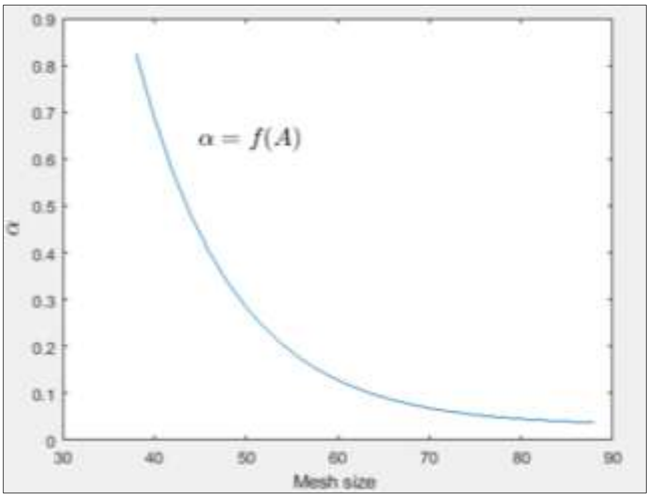


**Fig 5:** Relationship between the mesh size A and the parameter $\alpha$.

The relationship between the mesh sizes A and the selectivity coefficient $K_s$ is shown in Fig. 6. The selectivity coefficient $K_s$ rapidly increases as the mesh-size A increases until it attains a critical value (around K=3.2), then it becomes practically constant. This mode of variation depends on the character of the influence of α on $K_s$. When the quantity of the capture inside the codend is low, the selectivity coefficient $K_s$ does not depend upon the mesh size.

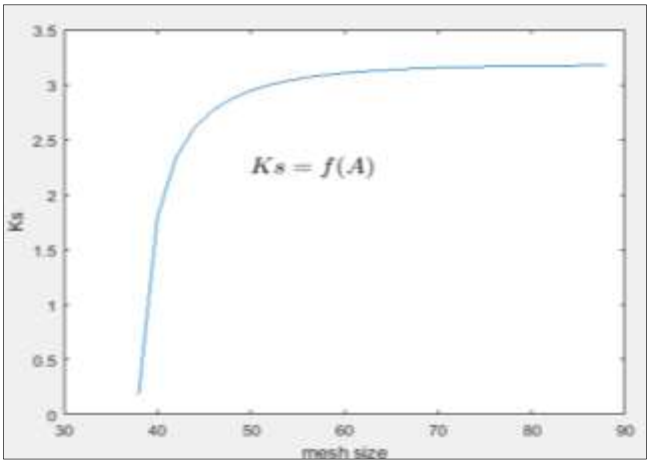


**Fig 6:** Relationship between the mesh size A and the selectivity coefficient $K_S$

The relationship between the mesh size A and the selectivity coefficient $D_s$ is shown in Fig.7. The selectivity range $D_s$ tends toward infinity for a mesh-size that tends to retain or allow all the fish to escape (A=88mm), while the values of $D_s$ corresponding to intermediary mesh-sizes are minimal.

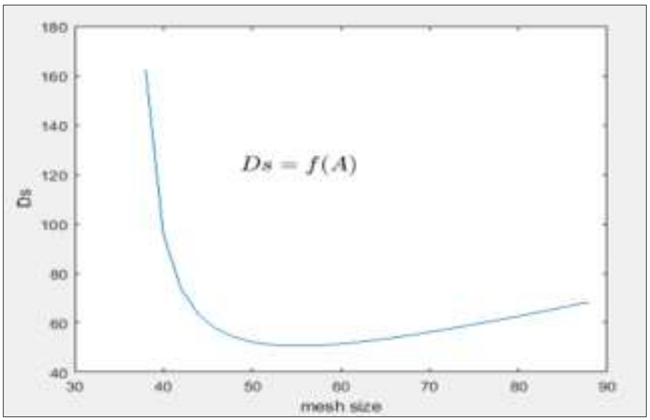


**Fig 7:** Relationship between the mesh size A and the selectivity coefficient $D_S$.

The selectivity curve corresponding to the optimal mesh size A = 58 mm, is shown in Fig. 8. In this case, the selectivity coefficient K = 3.08; $D_S$ =50.94 and the average inclination angle of the curve φ = 0.005. The probability for retention length (L50) determined on the cumulative frequency curve (Fig.2) to escape the mesh size of 58 mm is greater than 0.7. However, Fig.8 shows that the retention length (L50) for the mesh size of 58 mm is 170 mm.

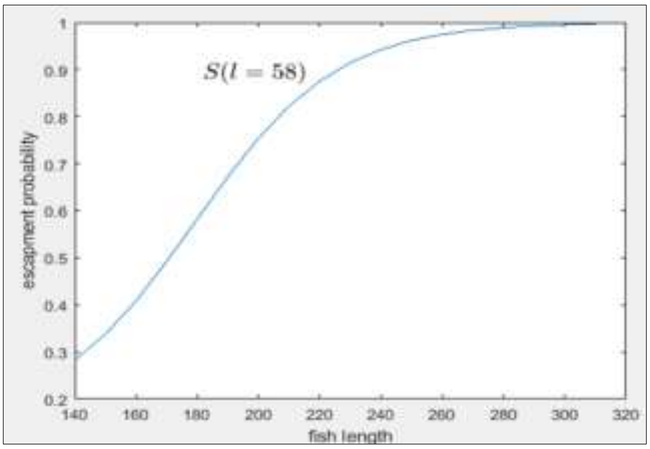


**Fig 8:** Selectivity curve corresponding of the optimal mesh size A=58m.

## 4. Discussion

In this study we established a better understanding of size selectivity of arioma bondi, the silver-rag drift fish based on the resolution of empirical models in Matlab software, investigate, and predicted the influence of mesh size on the size selection of silver-rag drift fish in diamond mesh codends for bottom trawls. Indeed, the reduction of the catch of juvenile fish or unwanted species is the main reason of the size selectivity study in trawls. Therefore, this problem has been devoted much attention in recent decades[16]. However, arioma bondi, the silver-rag driftfish fishery has relatively interesting economic terms because they are almost unexploited species in Cameroonian waters, which has led to a delicate situation for other species which are overexploited thus highlighting the need to study it in the research work[2,19]. This analysis makes it possible to understand and characterize the selective length distribution, the necessary selective mesh size and the selectivity parameters curve allowing the catches of these species by bottom trawls in Cameroonian waters and their distribution, in order to lay the foundations for the development of appropriate management strategies to minimize bycatch and juveniles catch, maintain catch volumes and economic performance. According to this study and the previous studies done by Hillisand Earley [34] and Petetta *et al*.[35], the factors that influenced the selective properties of the codend were biological, physic-technical, and exploitation parameters. In the present study, the effect of the mesh size which is an easily modifiable technical factor on the selective properties of the codends. According to some research such as Krakstad *et al*.[36] and sala *et al*.[37], the mesh size has the most significant influence on the selective properties of the trawl codend. This was justified in this study which demonstrated that the increasing in mesh size cause a displacement of the selectivity curve toward the right (Fig. 3). This is the first study on the selectivity of bottom trawls for catching arioma bondi, the silver-rag drift fish in order to encourage fishermen and Cameroonian government to orient themselves towards this fishery in Cameroon while ensuring sustainable fishing.

The predictions of size selectivity for the silver-rag drift fish in the current study are in agreement with the experimentally obtained selectivity estimates by Vaz-Dos-Santos *et al*.[38] on the shelf break and the upper slope of the Southeastern Brazilian Bight. By using the basic selectivity equations for the codend, it has been able to provide the mesh-size at the codend likely to arioma bondi with bottom trawls according to the necessary sustainable management requirements in Cameroonian fisheries. Without assumptions, such curves are link the size-composition of the targeted shoal, the selectivity curve of a codend with a determined mesh-size, mature fish size, catch of juveniles and the post selection mortality rate. By using the basic selectivity models, it is possible to determine mesh-size for different limitations in fishing. By solving the equation for different mesh-sizes, it is also possible to draw the graphs $n_j = f_1(A)$, $n_t = f_2(A)$, $n_{em} = f_3(A)$ and $n_p = f_4(A)$. In this work, such a justification is observed when the quantity of juveniles is limited $[n_j=0.08]$ as when as control is carried out for juveniles escaping via the meshes. Using the data from the tables, we plotted graphs of functions $n_j = f_1(A)$ ; $n_t = f_2(A)$ and $n_{em} = f_3(A)$ in one coordinate axes. By the curve $n_j = f_1(A)$ and the given allowable catch of juveniles [nj] =0.08, we determine the needed mesh size A (Fig. 9). For this mesh size A=58 mm, $n_j = [n_j]$=8% and $n_t$ = 28%. The escaping of mature fish at this mesh size was 0.12 and did not exceed the allowable $[n_t]$ = 0.25, while the estimated catch of juveniles [nj] =0.08. The corresponding mesh-size, A=58 mm for a variation in α close to 1 or to 0 also depends on the quality of the catch and on the size-composition of the target shoal *g(l)* as represented in Fig. 4.

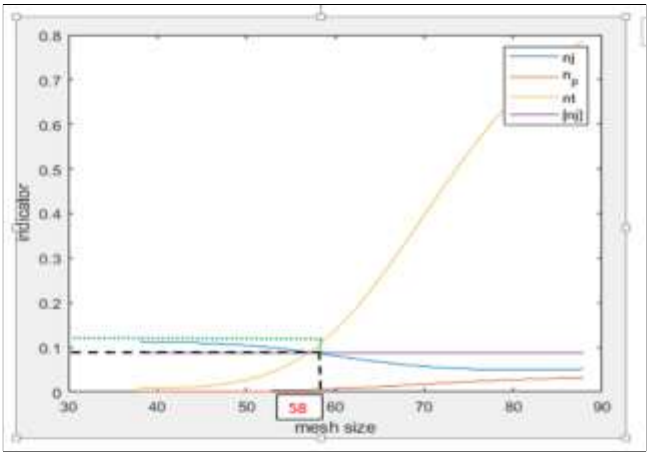


**Fig 9:** Dependence of selectivity indicators for catching Arioma bondi on the mesh size of bottom trawl codend.

The models used above (Eqs.6 to 9) are linked to each other by the regulatory indicators ($l_j$, $n_j$, and $A$), the control indicator ($n_t$) with the composition of the targeted shoal and codend selectivity curve. They do not contain assumptions and their accuracy depends only on the accuracy of the initial data. Thereby, the presented models will provide a better understanding of the selection process, permit a more targeted approach to codends selectivity experiments, and assist fishery managers to assess the impact of proposed technical measures that are introduced to reduce the catch of undersized fish. Currently, there is a lack of precise regulation on the mesh size of fishing gear targeting arioma bondi, or their minimum size and weight of catch authorized, in the texts that regulate fishing activity in Cameroon. The legal framework governing fishing activities is centered on Law No. 94/01 of 20 January 1994 on Forests, Wildlife and Fisheries regime and its application texts. This law and its application texts define the conditions for the practice of industrial fishing and represent, among other things a support framework for stakeholders who wish to invest in it [39].This law sets the minimum codend's mesh size at 70 mm for any type of trawl used. This mesh size will allow an excessive escape of mature fish $n_t$ = 0.40, which exceeds the allowable $[n_t]$ =0.25. There is therefore the need to make amendments in the fishery regulations in Cameroon for more rational exploitation of some demersal fish stocks as arioma bondi.

## 5. Conclusion

The prediction of the size selection for trawl codends with different mesh sizes can be easily done using the empirical models simulation method and therefore can be a useful tool for sustainable fisheries in the Cameroonian bottom trawl fisheries for the arioma bondi, silver-rag drift fish. In this study, the Matlab software was used for the medialization and to analyze the effect of mesh size on the size selection of arioma bondi , silver-rag drift fish in diamond mesh codends made with a double braided PA and a twine diameter of 3 mm. The fish length used was ranged from 140 to 310 mm. This developed model can also be used to easily and quickly predict selectivity for other species relatively at low cost. The results of this study showed that the selected mesh size for the arioma bondi , silver-rag drift fish was 58 mm and that in this mesh size the retention length (L50) was 170 mm. When the mesh size was 40 mm (α equal to 0.82) all the fish caught were retained in the codend, while at a mesh size of 88 mm (α equal to 0.006) all the catches could escape from the codend.

**Acknowledgements**

We are grateful to the fishing Company ‘‘SIPECAM’’ (Société Industrielle de Peche au Cameroun) for permitting us carry out the experimental work onboard the fishing trawler «Yang I».

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