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Analysis of fishery and some aspects of the biology of six species of deep-sea sharks *(Centrophorus lusitanicus, Centrophorus squamosus, Centrophorus uyato, Centrophorus molluccensis, Dalatias licha and Daenia quadrispinasum)* captured in the Mozambique channel, in 2016

Abstract

This work was carried out between April and December 2016 on board of the commercial vessels of the Pescamar Company, in order to evaluate the level of exploitation of the target species in the deep shark fishery. The gear used was the bottom gillnet with mesh size of 180 mm. The sampling consisted in addition to the collection of information of the resource, information of the fishing gear used and the fishing effort. The target resource consisted of the species *Centrophorus lusitânicus*, *Centrophorus squamosus*, *Centrophorus moluccensis*, *Centrophorus uyato*, *Dalatias licha* and *Daenia quadrispinosum*. The estimated maximum age (longevity) recorded a minimum value of 34 years and a maximum of 121 years, on the other hand, the analysis of the length frequencies illustrates that all species were caught already adult or in the advanced phase of the life cycle, being considered that the fishery is sustainable. With the results and conclusions obtained, it is recommended to regularly monitor of the specific composition and extent the samples approached in ways to determine the seasonality of the resource.

Keyswords: Deep water sharks, *Centrophorus squamosus, Dalatias licha, Centrophorus lusitanicus, Centrophorus uyato, Centrophorus moluccensis*, Mozambique channel.

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Abbreviations: InOM, Oceanografic Institute of Mozambique; IIP, Institute of Fisheries Resources;

TL, Total length; TW, Total weigth; Lmat, Length of maturity; Linf, Assintoptical length; Lopt, Optimal length; Lmax, Maximal length; to, Theoretical age; K, Growth rate; Tmax, Maximal age; Z, Total mortality; M, Natural mortality; F, Fish mortality; N, Number of individuals

Introduction

Squalidae family is the most representative family of Deep-sea sharks with 13 genera and 27 species. The squaliformes adults can reach sizes over 6.4 meters in total length.[1] Deep-sea sharks can occur both in coastal regions and in the great depths of all oceans, more frequently in the three largest, Indian, Atlantic and Pacific including in the Mozambique Channel, they have been observed from the surface to more than 3000 meters depths from cold to tropical temperate zones.[2-6] Many species of sharks are known to undertake extensive migrations,[7] some of which even cross the oceans. However, information on the movement and migration of elasmobranchs in the southwest Indian Ocean region (SWIO) is very limited because most of the information available on the movement of sharks has been collected from fisheries as bycatch or from studies of charismatic species. Their diet ranges from plantivores to large predators and can feed on fish including other sharks, as well as crabs, octopuses and squid. They are known to be highly vulnerable to fishing, mainly due to their very specific life strategies, many of the elasmobranchs (sharks and rays) and chimeras are characterized by low fertility and productivity, slow growth, late age of maturity, larger size at birth, high natural survival and long life.[3,5,8]

They exhibit all known of reproduction of vertebrates, from oviparous to placentalia viviparity.[1,2,4] These characteristics of life history make them a fragile resource and more susceptible to overfishing than most teleost fish.[5,8] Such characteristics have serious implications for the sustainability of sharks and rays fishing.[2] Until the 1980´s, deep-sea species had little commercial interest, driven either by the difficulty of accessing traditional fishing equipment to areas of great depth, or by the difficulty of introducing these species to the market.[9] However, sharks are becoming increasingly important and their commercial value has increased, leading to a considerable decrease in populations.[8] Deep-sea shark fishing is mainly driven by the liver oil markets for lubricants, medicines and leather tanning products,[4,8] although this resource is sometimes used for human consumption. The main species caught belong to the genus Centroscymnus, Centrophorus and Deania.[4,8]

In order to manage this resource, licenses for shark fisheries are issued in some countries, such as the shark fishery (*Galeorhinus galeus*) in South Africa, the demersal gill fishery for deep sea sharks by Mozambique and Madagascar and the artisanal shark fishing legally authorized in Seychelles.[10] In Mozambique, the fishing sector contributes significantly, direct and indirectly to the reduction of poverty and socio-economic development of the coastal community (www.fao.org). At 2%, the sector's contribution to GDP,[11] contributes to food security and especially as a source of income, employment, as well as the supply of animal protein to communities.

Deep sea shark fishing in Mozambique began in February 2008 with two vessels that operated on an experimental basis until June 2011, during which the Oceanografic Institute of Mozambique (InOM) (extinct National Fisheries Research Institute (IIP)) issued some recommendations according to which fishing should stop to be experimental, as it had already been around for three years and that only two vessels should be licensed maintaining the same effort as that of 2010.[12] The fishery is licensed to operate in the area between 10º 30´S to 26º 30´S, at depths between 400 to 800 meters and is carried out with the help of the bottom gill net. To date, there are no specific analyzes related to this fishery and it was therefore necessary to carry out studies on the biology aspects of the main deep-sea shark species that occur in Mozambique.

The low knowledge of resource dynamics is a problem for the management and conservation of these resources, mainly due to their life characteristics that make them more fragile and more susceptible to overfishing than most teleost fish, a fact that in recent years has shown a great concern both nationally, regionally and internationally.

In this sense and in order to guarantee a sustainable exploitation of the resource, it is necessary to know the species of deep-sea sharks that occur in Mozambique Channel, the aspects of biology and the respective state of exploitation.

Material and methods

Study area

The Mozambique Channel is located between the Mozambican coast and the west coast of the island of Madagascar with a width in its most extreme part of about 400 km.[13] The waters are of the tropical type, varying the surface temperature between 23º to 30º C with a salinity of about 35 ‰ in areas outside the influence of rivers where the salinity is lower. The main rivers, the Rovuma and Lúrio in the north, the Zambezi, Púngue, Buzi and Save in the center and Limpopo, Incomáti and Maputo in the south, transport large volumes of sediment, a factor of great importance for the living organisms of the continental shelf.[13] The Mozambican coast is characterized by a great diversity of habitats including sandy beaches, dunes, coral reefs, estuarine systems, bays, mangroves and seagrass.[14] The distribution of fishing resources is dependent on different conditions: in the estuaries and bays small pelagic fish, soft bottom demersal fish, abundant crustaceans, bottom demersal species and some large pelagic fish near the islands.[11]

Sampling

The present work was carried out on board the commercial vessels Chomapi Maru and Vega 12 belonging to the company Pescamar, from April to December 2016. The fishing gear was bottom gillnet with mesh sizes of 180 mm. The sampling plan consisted in addition to information on the captured resources; Information of the gear used: Total number of the net, height and length (m) as well as the respective mesh size (mm); From the samples collected, the specific composition was determined to the species level using a species identification manual prepared for the purpose,[15] identification guide to the deep–sea cartilaginous fishes of the indian ocean[16] and field guide for commercial marine species in Mozambique[13] which was taken on board. For the target species of deep-sea shark, sex was identified based on the presence or absence of a sexual structure easily visible to the naked eye called "Clasper". Each individual was measured the total length (TL) in cm, using a straight-line tape measure from the tip of the snout to the tip of the upper lobe of the tail fin,[17] and the total weight (TW) in grams was recorded.

Data analysis

The fisheries was analysed based on Catch, effort and abundance (Catch Per Unity Effort) data by month, this results was compared with results obtained in the last year, in this case whith the 2015. To verify what was the bahaviour of the resource on each year.

The size of the first maturity was estimated from Linf using the empirical equation according Mateus and Penha,[18] citing Froese and Binohlan, where:

$$\log_{10} Lmat = 0.898x \log_{10} Linf - 0.0781$$

The obtained value was then compared with the available literature.

The optimal size of the catch was estimated according to Froese and Binohlan cited by Mateus and Penha,[18] by the equation:

$$\log_{10} Lopt = 1.0003x \log_{10} Linf - 0.2161$$

The total weight and total length relationship between the sexes for each target species was also established according to the formula by Kotas:[19]

$$TW = aTL^b$$

Where:

TW is the total weight in grains;

TL is the total length in cm; a is the intercept and b is the slope[20]

The population structure in length, was determined for separate sexes through the distribution of total length frequencies classes.

Growth and mortality parameters

Growth and mortality parameters were calculated in the excell statistical package.

The growth rate (K) calculated was corresponding to the slope (a) of the exponential equation of the weight-length relationship, that is, it is the unknown coefficient x. Linf (asymptotic length) was calculated based on the formula:

$$Linf = \frac{Lmax}{0.95}$$

Where: Lmax corresponds to the maximum length recorded.

The theoretical age estimate (to) was obtained according to Pauly's impirical equation:

$$\log_{10} to = -0.392 - 0.275x \log_{10} Linf - 1.038x \log_{10} k$$

The species longevity (tmax) was calculated using the formula below:

$$tmax = 3/k$$

Where k corresponds to the growth rate.

Total Z mortality was obtained in two ways, namely from the linearized catch curve and according to Beverton and Holt because the catch curve presented inconsistent results for the species *C.uyato*. However, for females of the *C.uyato* species the total mortality Z, was estimated according to the formula of Beverton and Holt below, since based on the linearized catch curve the result was shown to be incoherent.

$$Z = \frac{\mathrm{K} \times (\mathrm{Linf} - \mathrm{Lmed})}{\mathrm{Lmed} - \mathrm{Lc}}$$

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Where: K is the growth rate corresponding to the slope of the exponential equation of the weight-length relationship.

Linf is the asymptotic length

Lmed is the average length

Lc is the average size of the first catch, which corresponds to the size from which the species is likely to be captured (in this case, the minimum size recorded).

Of the Six species of deep-sea shark recorded, the mortality parameters, namely fishing mortality (F) and exploitation rate (E), were considered only for the species *Centrophorus lusitanicus, C. squamosus* and *C.uyato* due to the fact that the species *C. moluccensis, Daenia quadrispinosa and Dalatias licha* the results of the calculated parameters do not present consistency and viability.

Natural mortality (M) was obtained using Pauly's empirical formula, between Linf, K and the average ambient temperature (ºC)[21] in this case considered 25ºC, as described below:

$\ln (M) = -0.0152 - 0.279 * \ln (Linf) + 0.654 * \ln (K) + 0.463 * \ln (T)$ Pauly (1980)

Fishing mortality F was calculated based on the difference between total mortality Z and natural mortality (M), that is F = Z-M.

To obtain the exploitation rate, the quotient between fishing mortality and total mortality was used (E = F / Z)

Results

Fisheries indicators

Figure 1 illustrate the fishery indicators (Catch, Fishing effort, and yield or catch per Unity Effort, CPUE) in the study period and a comparison of these with the 2015. The results show that, in 2016, were captured 28 tons of deep-sea sharks, compared to 219.33 tons recorded in 2015, indicating a decrease of 191.33 tons. The fishing effort also decreased from 209 to 59 fishing days in 2016. Similar to the catch and fishing effort, 2015 was the year with the highest average yield per fishing day, 1050 kg against 480 kgs observed in 2016. Observing the variation in catches over the years it can be seen that in 2016 the largest catches and the highest yields were observed in September and December, the results also shows that both in 2015 and 2016 the lowest yields were recorded in May.

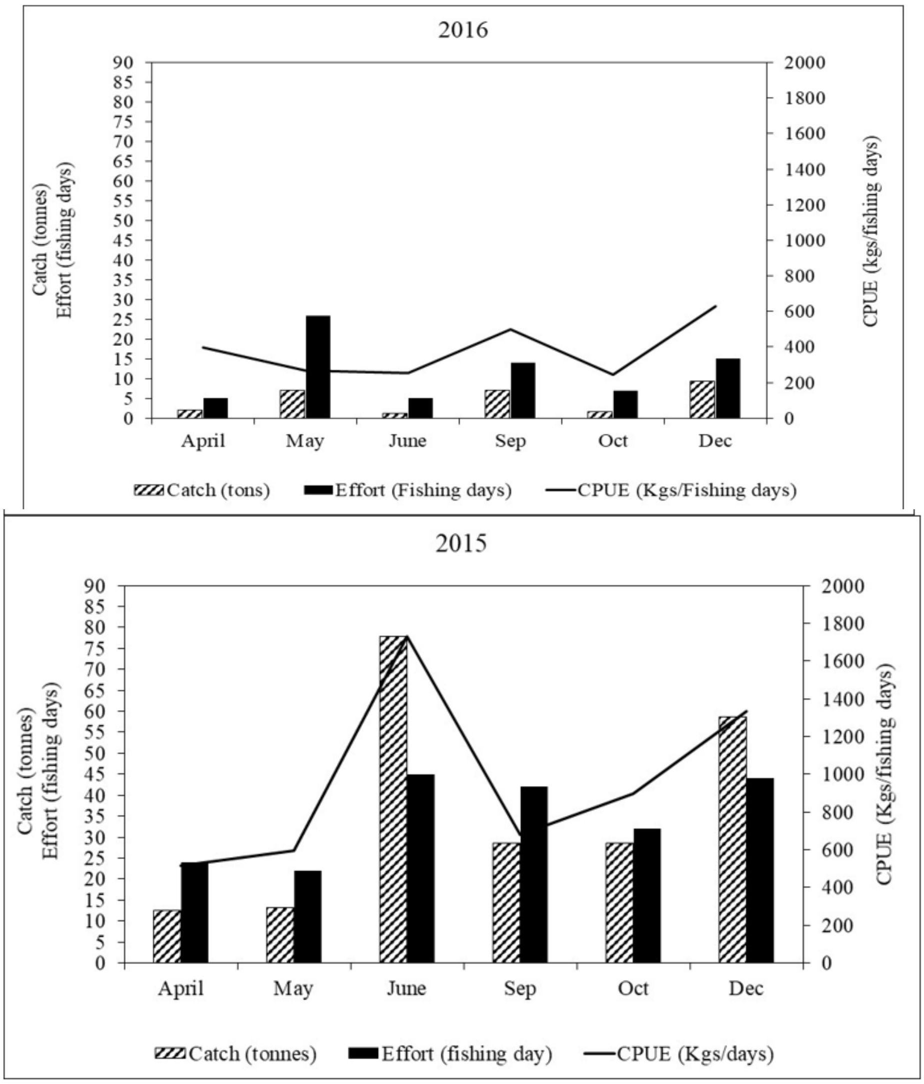

Figure 1 Catch, effort and CPUE registered in 2015 and in 2016.

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Species composition

During the study period, a total of 2374 specimens belonging to 41 species were captured, among sharks, rays, fish, crabs, lobsters and squid. Of these, 6 species belong to the target species of deep-sea sharks' fisheries. Three species of the target species of deep-sea sharks namely *Centrophorus lusitanicus*, *Centrophorus squamosus*, *Centrophorus uyato* were the most representative, in terms of number of individuals, with 325, 625 and 402 respectively. On the other hand, the species *Centrophorus moluccensis* and *Daenia quadrispinasum* were the ones with the lowest number of individuals registered with 40 and 29 individuals, Table 1. Regarding the of deep-sea sharks, the results show that for all target species, females dominated the catches when compared to males, the results also shows that females have a higher average weight compared to males. However, this trend is not seen in the average values of the total lengths, Table 2.

Table 1 Specie composition of the Deep Sea Shark fisheries in the study period, from April to December of 2016

Group	Species	N	Weigth (grs)			Length (cm)		
			Min	Max	Average	Min	Max	Average
Lobster	Acanthacaris tenuimana	3	40	1000	396,7	14	40	26
	Unidentified species	2	60	1800	930,0	40	40	40
	Palinurus sp	1	400	400	400,0	35	35	35
Fishes	Argyroso mus ho lo lepido tus	4	300	1100	675	28	47	39
	Atrobuca morleyi	1	650	650	650,0	39	39	39
	Beryx decadactylus	25	100	3500	1326,0	18	60	38
	Cheilopogon cyanopterum	1	50	50	50,0	18	18	18
	Cynoglossus sp	1	250	250	250,0	27	27	27
	Etelis carbunculos	19	2000	16500	7989,5	49	103	82
	Hop lostethus mediterraneum	42	150	3000	956,0	14	52	33
	Lo phiodes insidiator	3	800	2000	1533,3	20	45	36
	Peixe (sp não identificada)	1	430	430	430,0	27	27	27
	Saurida undosquasmis	1	300	300	300,0	38	38	38
	Scyllarides elisabethae	1	300	300	300,0	28	28	28
	Unidentified species	4	685	11700	3508,8	31	112	52
	Ventrifossa divergens	48	130	3000	780,2	16	74	48
	Dactyloptena peterseni	1	110	110	110,0	21	21	21
	Merluccius capenzis	1	1480	1480	1480,0	58	58	58
Sharks	Carcharinus sp	1	1800	1800	1800,0	73	73	73
	Cephaloscylium sufflans	20	500	12000	3060,0	29	93	71
	Etmopterus pusillus	1	1200	1200	1200,0	71	71	71
	Hexanchus vitulus	3	900	2800	1666,7	61	93	74
	Sphyrna lewini	3	12000	25000	16500,0	135	150	143
	Squalus megalops	16	500	6000	2686,0	45	102	79
Target Deep sea Sharks	Centrophorus lusitanicus	325	450	125000	10778,8	45	160	116
	Centrophorus moluccensis	40	1200	9000	3544,6	61	113	85
	Centrophorus squamosus	625	300	14335	6551,9	13	149	109
	Centrophorus uyato	402	500	12140	3955,4	45	127	89
	Dalatias licha	65	500	28000	14142,5	48	166	130
	Daenia quadrispinasum	29	1200	8000	3441,3	60	113	93
Crabs	chaceon macphersoni	513	80	2956	1133,9	7	23	14
	Lithodes sp	33	345	9025	1260,9	12	40	17
	Paralithodes camtschaticus	101	200	1435	712.6	11	165	16
Rays	Himantura gerard	2	500	3500	2000,0	24	60	42
	Raja stenorhynchus	33	350	12000	2749,8	20	107	63
Squids	Loligo sp	1	2200	2200	2200,0	46	46	46
Prawns	Unidentified species	2	20	25	22,5	20	25	
	Grand Total	2374						

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Table 2 Number (N), Weigth (gr) and Total Length (cm) of the target deep-sea sharks registered in the study period, April to December 2016

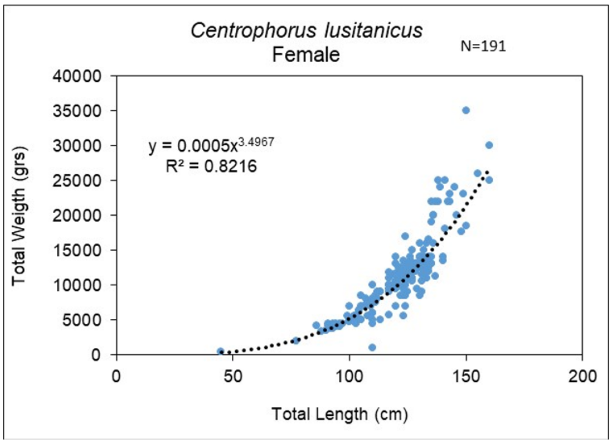
Species	N	Weigth (gr)			Total length (cm)		
		Min	Max	Average	Min	Max	Average
Centrophorus Lusitanicus							
F	191	450	35000	11464	45	160	122
m	133	900	14000	6917	65	134	107
n	1	9480	9480	9480	116	116	116
Centrophorus moluccensis							
F	24	1200	7000	3631	61	112	87
m	16	1800	9000	3414	67	113	83
Centrophorus squamosus							
F	348	300	14335	7240	13	149	112
m	268	2125	11030	5653	83	122	105
n		3155	13520	6711	82	135	106
Centrophorus uyato							
F	301	500	12140	4319	45	127	92
m	101	1165	11900	2873	58	121	80
Daenia quadrispinasum							
F	17	1500	8000	4199	60	113	99
m	12	1200	5185	2369	72	102	84
Dalatias licha							
F	47	2300	28000	17014	94	166	138
m	18	500	9500	6644	48	125	108
Total	1486						

Length and weigth relationship

The weight-length relationship is widely used in fisheries science, beyond to allowing weight estimation from length data, it is applied for example to compare growth in size between sexes and stocks and to estimate the total number of individuals caught from length composition samples and landing data. It is also applied to the study of the reproductive cycle since the coefficient is related to the average health condition of the sample population.[19] In this report, only the weight-length relationship of the target species will be made

Centrophorus lusitanicus

The weigth-Length relationship equation for females was $Wt=0.0005TL^{3.4967}$, with R=0.8216 and for males was $Wt=0.0005TL^{3.4962}$ with R=0.7669. This equation shows that both males and females in this species have positive allometric growth (b>3) indicating that the species has greater growth in weight than in length (Figure 2).



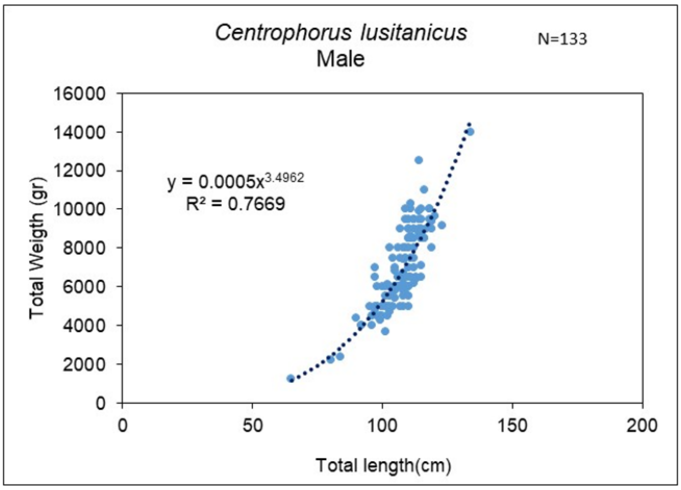


Figure 2 Total weigth-Total length relationship for female and male of the *Centrophorus lusitanicus* specie.

Centrophorus uyato

The total weight-total length relationship of the species *C.uyato* was represented by the equation $Wt = 0.0091TL^{2.8808}$ and $R^2 = 0.7648$ in females and, $Wt = 0.0079TL^{2.9082}$ and $R^2 = 0.8219$ in males. The b values for both males and females suggest negative allometric growth (b<3) in both sexes, indicating that this species has less growth in weight than in length (Figure 3).

Centrophorus moluccensis

The total weight-total length relationship of the *C. moluccensis* species was represented by the equation $Wt = 0.0377TL^{2.5591}$ and $R^2 = 0.7753$ in females and, $Wt = 0.0008TL^{3.4287}$, $R^2 = 0.931$ in males.

The b values suggest that there are differences in growth between the two sexes, with the females having greater growth in length (negative allometric growth, b<3) when compared to the males (Figure 4).

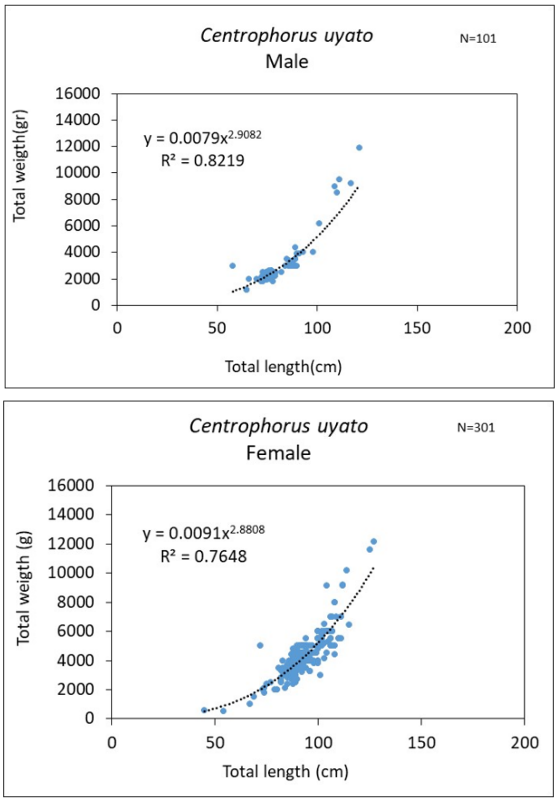


Figure 3 Total weigth-Total length relationship for female and male of the *Centrophorus uyato* specie.

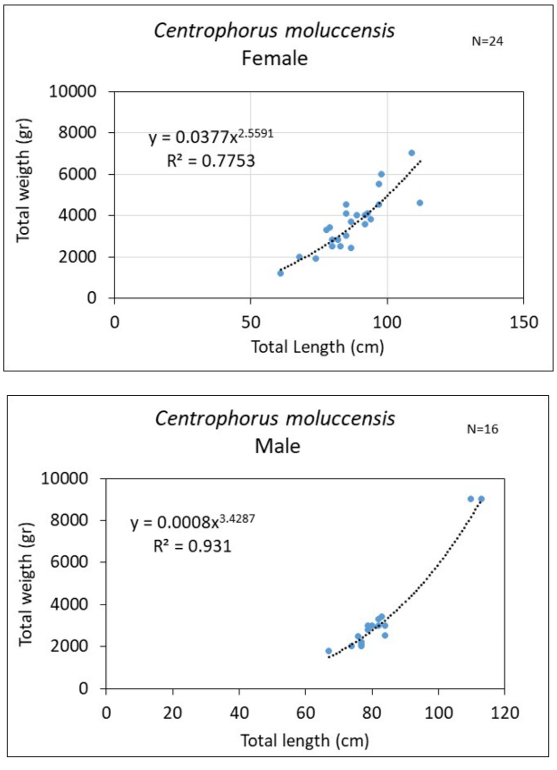


Figura 4 Total weigth-Total length relationship for female and male of the *Centrophorus moluccensis* specie.

Centrophorus squamosus

The total length-total weigth relationship for the *C.squamosus* specie is presented by the equation $Wt = 0{,}0013TL^{3{,}2673}$ and $R^2 = 0{,}5994$ for females, and $Wt = 0{,}0119TL^{2{,}8048}$ with $R^2 = 0{,}5293$ on males. The b values, similar to the species *C.moluccensis* showed differences in the growth pattern between males and females. Females have positive allometric growth (b>3) while males have negative allometric growth (b<3) indicating that females have greater growth in weight than males (Figure 5).

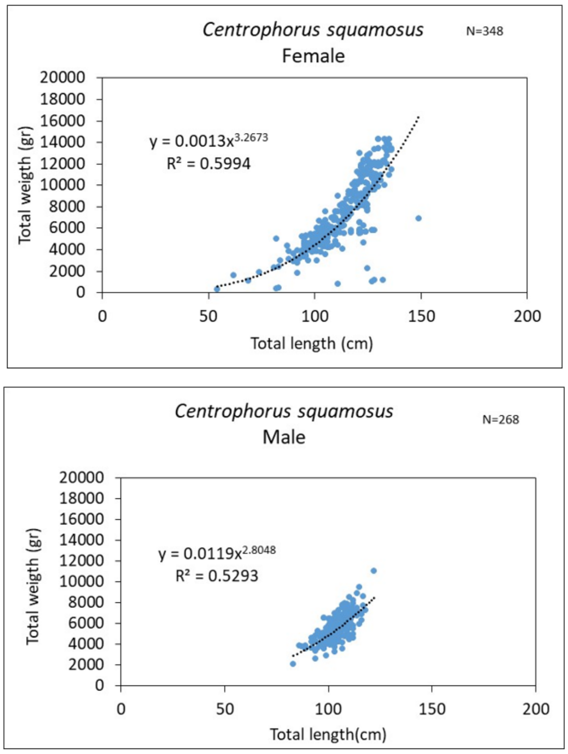


Figura 5 Total weigth-Total length relationship for female and male of the *Centrophorus squamosus* specie.

Growth and mortality parameters

he growth and mortality parameters of the target deep sea shark's fisheries species are shown in Tables 3&4. The results obtained shows that mortality parameters differ between species and between sexes of the same species. The maximum age, tmax, for each species also presents differences at an interspecific and intraspecific level, this fact may be associated with the level of tolerance of each individual to the environment.

Due to the inconsistency of the results obtained, that think to be motivated by the low number of individuals registered as mentioned in the methodology, the fishing mortality parameters and the exploitation rate for the species *C. moluccensis*, *Dalatias licha* and *Daenia quadrispinosus* where not considered (Table 4).

Population structure

Lowfin gulper shark (Centrophorus lusitanicus, Bocage and Capello)

Of a total of 325 individuals of the species **Lowfin gulper shark** (*C. Lusitanicus*) registered, the total length ranged from 45-160 cm. Females were dominated by individuals with total lengths ranging from 125 to 135 cm while males the highest lengths frequency classes was recorded in the 105 to 115 cm, showing that the largest recorded sizes were seen in females, although there was a low frequency class of occurrence of females in the 50 cm, Figure 6.

Table 3 Growth and mortality parameters of the main species of catfish caught. N, number of individuals; Lmax, maximum size registered; Lmed, average size; Lopt, optimal size to be captured; Lc, minimum size recorded; Lmat, size of first maturity; Linf, asymptotic length (infinite); K, growth rate; to, theoretical age (initial); tmax, maximum size (longevity); Z, total mortality rate; M, natural mortality rate; F, fishing mortality; E, exploitation rate

Parameters	*C. lusitanicus*		*C. squamosus*		*C. uyato*	
	Female	Male	Female	Male	Female	Male
N	191	133	348	268	301	101
Lmax (cm)	160	134	149	122	127	121
Lmed (cm)	129	107	112.8	104.7	92.4	79.5
Lopt (cm)	102	85.9	95.5	78.1	81.4	77.6
Lc (cm)	92	65	54	83	45	58
Lmat (cm)	82.4	71.1	78.2	65.3	67.8	64.9
Linf (cm)	168,4	141.05	156.84	128.42	133.68	127.37
K ($year^{-1}$)	0.032	0.03	0.03	0.027	0.032	0.034
To (year)	-3.5	-3.39	-0.97	-1.44	-1.37	-0.94
Tmax (year)	93	86	98.6	109.8	93.5	88.2
Z	0.178	0.65	0.565	0.202	0.69	0.075
M	0.11	0.12	0.11	0.11	0.12	0.051
F	0.067	0.53	0.46	0.09	0.57	0.024
E	0.81	0.38	0.80	0.47	0.83	0.322

Table 4 Growth and mortality parameters of the main species of Deep-sea sharks caught. N, number of individuals; Lmax, maximum size registered; Lmed, average size; Lopt, optimal size to be captured; Lc, minimum size recorded; Lmat, size of first maturity; Linf, asymptotic length (infinite); K, growth rate; to, theoretical age (initial); tmax, maximum size (longevity); Z, total mortality rate; M, natural mortality rate; F, fishing mortality; E, exploitation rate

Parameters	*C. moluccensis*		*Dalatias licha*		*Daenia quadrispinosa*	
	Female	Male	Female	Male	Female	Male
N	24	16	47	18	17	12
Lmax (cm)	112	113	166	125	113	102
Lmed (cm)	86.9	82.7	138.3	107.8	99.2	84.3
Lopt (cm)	71.8	72.4	106.4	80.1	72.4	65.3
Lc (cm)	61	67	94	48	60	72
Lmat (cm)	60.5	61.03	86.2	66.8	61	55.6
Linf (cm)	117.9	118.9	171.7	131.5	118.9	107.3
K ($year^{-1}$)	0.029	0.037	0.018	0.037	0.024	0.04
To (year)	-1.02	-0.9	-2.9	-3.18	-1.09	-0.89
Tmax (year)	103.4	34.4	79.5	79.5	121	75
Z	0.03	0.087	0.015	0.014	0.01	0.07
M	0.1	0.13	0.076	0.13	0.10	0.14

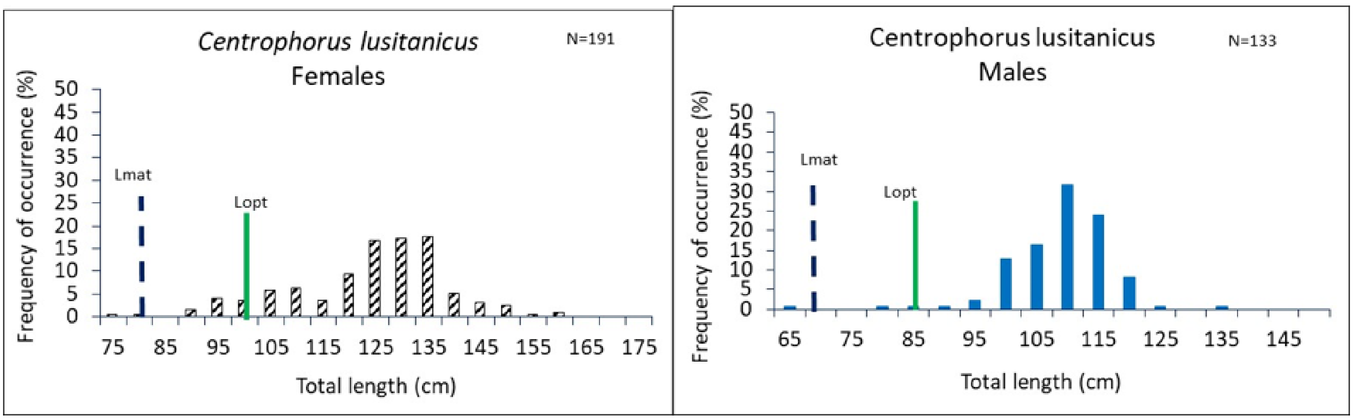


Figure 6 Length Frequencies distribution by sex of the species *Centrophorus lusitanicus* (**Lowfin gulper shark**).

Smallfin gulper shark (*Centrophorus moluccensis*, Bleker)

In the *Centrophorus moluccensis* species, a total of 40 individuals were sampled whose lengths varied between 61 cm and 115 cm, of this number 24 were females and 16 males. The length-frequency analysis showed that the majority of individuals were concentrated in classes between 80 and 95 cm in females and 80 and 85 cm in males (Figure 7).

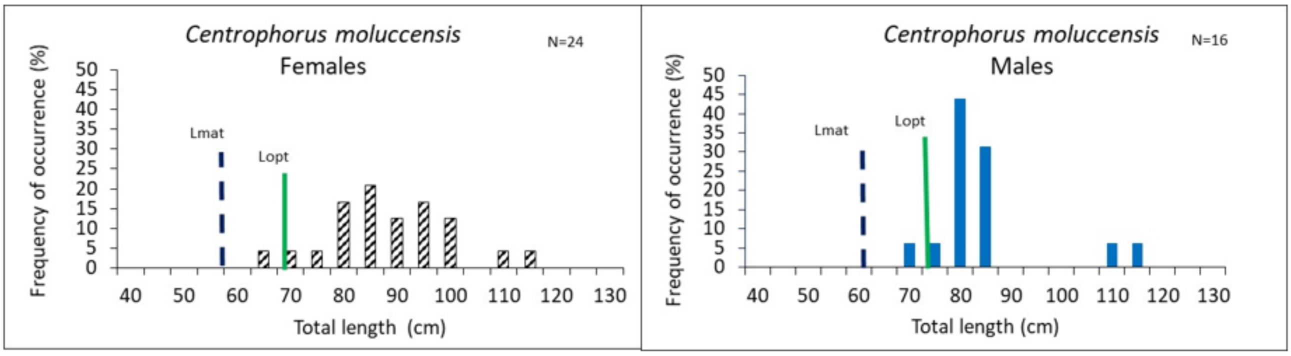


Figure 7 Length Frequencies distribution by sex of length of the species *Centrophorus moluccensis* (**Smallfin gulper shark**).

Little gulper shark (*Centrophorus uyato*, Rafinesque)

The species *Centrophorus uyato*, mostly composed of adult individuals, was the second most captured species in this study with a total of 402 sampled individuals. The highest frequencies classes of individuals were registered between 75 cm to 95 cm, with males having modes in the 75 and 80 cm frequencies classes, In females the mode were registered in the classes 90 and 95 cm (Figure 8).

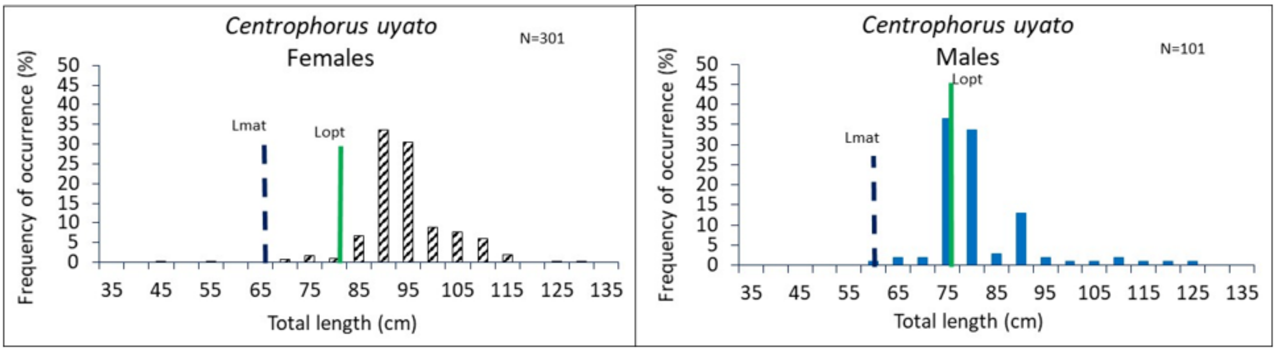


Figure 8 Length Frequencies distribution by sex of the species Centrophorus *uyato* (**Little gulper shark**).

Leafscale gulper shark (*Centrophorus squamosus*, Bonnaterre)

The **Leafscale gulper shark** was the most captured species with a total of 616 individuals sampled. The analysis of length frequencies shows that the mode was located between 100 cm to 110 cm for males. Females registered two modes of length frequencies classes, the first in the 105 cm and the second in the 125 cm of total length class (Figure 9).

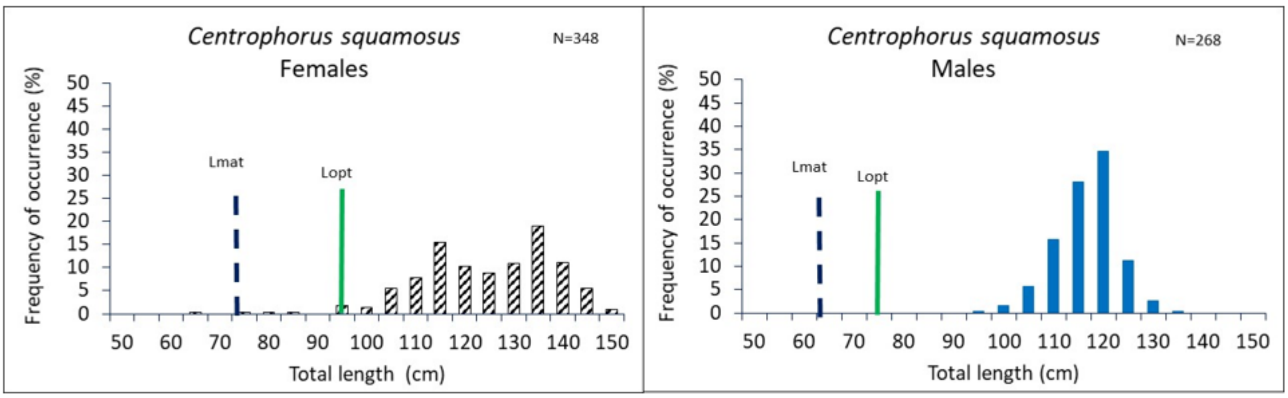


Figure 9 Length Frequencies distribution by sex of the species *C. squamosus* **(Leafscale gulper shark)**.

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Longsnout dogfish (*Deania quadrispinosa*, McCulloch)

This was the least captured species with only 29 individuals, 17 females and 12 males. The highest frequency of females was registered in the length class of 110 cm of total length while the registered males had the highest frequency in the length class of 90 cm, (Figure 10).

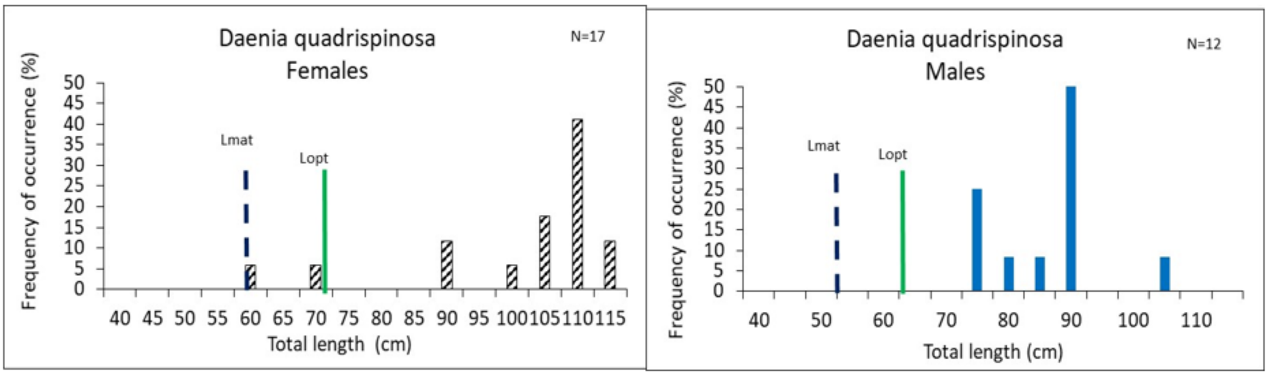

Figure 10 Length Frequencies distribution by sex of the species *Daenia quadrispinosa* (**Longsnout dogfish**).

Kitefin shark (*Dalatias licha*, Bonnaterre)

For this species, was registered 65 individuals with total lengths ranging from 50 to 170 cm. The population structure shows that males was more caught in length classes between 110 and 120 cm, while for females the highest frequency of individuals was seen between 140 to 150 cm in total length (Figure 11).

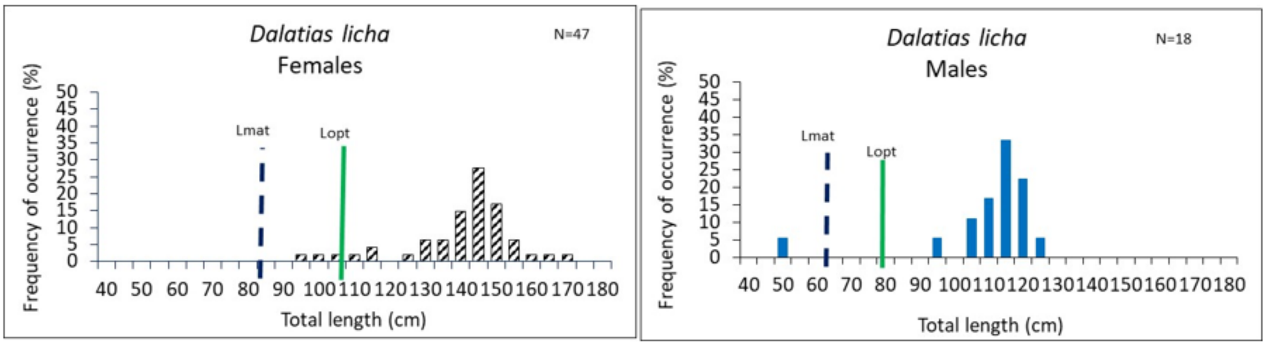

Figure 11 Length Frequencies distribution by sex of the species *Dalatias licha* (Kitefin shark).

Discussion

This is the first study wich analyse the fishery and biological aspects of deep-sea shark species occuring in the Mozambique channel, and therefore has no basis for comparison with similar studies in this area. Of a total of 37 species recorded, the largest number were fish (18 species), 12 species were shark of wich 6 species, *Centrophorus lusitanicus*, *Centrophorus moluccensis*, *Centrophorus squamosus*, *Centrophorus uyato*, *Dalatias licha* and *Daenia quadrispinasum* are deep-sea sharks, and among these, the ones most represented were *C. Lusitanicus* (325 individuals), *C.squamosus* (625 individuals) and *C.uyato* (402 individuals). As mentioned above, this fishery occurs throughout the Mozambique Channel, and the highest number of individuals of this species occur along the entire Mozambique channel suggesting migratory behavior, unlike the species recorded in smaller number (*C. Moluccensis*, *D. Licha* and *D. Quadrispinasum*). According to Machado and Matos,[9] deep-sea shark species exhibit horizontal segregation by latitude and longitude, on the other hand, the horizontal distribution can be explained by migratoy behavior of the species, a fact corroborated by Rodrigues-Cabello and Sanches.[22]

Analyzing the population of *C.lusitanicus,* according to the length at first maturity, (88 cm -144 in females and 72 cm-128 cm in males, Compagno 1984) and (71.1 cm for males and 82.4 in females, in this study) it can be seen that both sexes of this species were captured individuals in the adult age stage. For the *C.moluccensis* specie it appears that all the males were captured after reaching the length at first maturation (L50 between 69-73 cm, Compagno 1984; 60.5 cm, in this study). On the other hand, in females, the largest number of individuals was captured after reaching the length at first maturity (L50 between 89-98 cm, Compagno 1984; L50 = 60-61 cm in this study).

It can be seen that despite larger individuals observed of *C.uyato*, that is, larger than the length at first maturity (81cm-94cm for males and 75-80 cm for females (Compagno 1984) and 67.8 cm for females and 64.9 for males (in this study), the presence of juvenile with sizes below L50, can give an indication of the occurrence of a reproduction of this species throughout the year, however it does not endangering the survival of the species. The presence of two modes on *C. squamosus* specie can be an indication of two cohorts. Studies carried out by Girard *et al*, 2000 cited by Queiroz[23] also refers that the reproduction of this species occurs throughout the year, which may be in accordance with the results obtained in this work. Comparing the sizes captured with the sizes with which this species is considered mature, (L50 = 103 cm for males and, between 137 to 158 cm for females, Compagno 1984), (L50 = 95 cm for males and 110 for females, Ramos *et al*,[15]); (98 cm and 124 cm, Girard and Du Buit, 1999 cited by Ramos et al.,[8]) and 78 cm for females and 65.3 for males, in this study.

This species was captured after reaching maturity, although some small individuals were registered, however in a low percentage. The presence of smaller individuals (sizes less than 90 cm in total length) can probably be an indication of the reproduction in this period, which is supported by Ramos *et al*[15] according to which this species has between 30 to 45 cm at the birth.

Analyzing the registered sizes of the *D.quadrispuinosus* females in relation to the size of the first sexual maturiy, L50=110 cm[4] it can be said that the largest number of individuals was captured in the juvenile phase. Contrary to Compagno,[4] the present study found that both females and males were captured after reaching maturity (55 and 61 cm for males and females respectively).

It should be noted that for *D.licha* specie, studies carried out in other regions indicate that males are considered adults when they reach sizes between 77 cm to 121 cm and females between 117 cm and 159 cm,[4] (Figure 11), however in this study was found that the first sex maturity phase is reached when individuals reach sizes 86 cm in females and 66 cm in males, the sizes obtained revealed a predominance of mature individuals in both sexes.

According to the results, this fishery captures more females than males and most females are mature. A persistent catch of mature female sharks can lead to overfishing in view of the fertility level of these resources. On the other hand, the protection of juvenile sharks (preventing overfishing in growth) will have positive implications for the recovery of adult populations. According to Ramos *et al*.,[8] overfishing growth occurs when recruits are caught before they can grow to a reasonable size.

On the other hand and despite the lower occurrence of juveniles, the male fraction is mainly composed of mature specimens, this fact that must be seen with special care, as part of the stock as it can be reduced to some extent. However, older individuals represent less risk of overexploitation than juvenile specimens. This gives indications that recruitment overfishing is not being carried out on females.

Conclusion

A general analysis of the captured sizes by all species in relation to the size of the first maturity (L50) shows that both males and females were captured in adulthood or in more advanced stages of their life cycle although there is a small percentage of juveniles registered. This fishery captured more females than males and most females are mature. Despite the lower occurence of juveniles, the male fraction is mainly composed of mature specimens. Taking into account the sizes captured and according to the first maturation sizes of the different species of the target resource, the fishery is still considered sustainable.

Biological data indicate that it doesn´t seem to have occurred any major changes in relation to the main species of deep-sea shark captured. Howerver, considering the high vulnerability of these species, regular monitoring of the species is recommended regarding the specific composition of the catches and sizes through regular boarding in this fishery. This report is the result of the just three trips for onboard sampling purposes, wich is not enough to determine the seasonality of the resource. As the longest-lived resource (121 years i n this study), it is recommended to extend the data collection time to one year.

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Conflicts of interest

The authors declare no conflict of interest.

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