Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 25(6): 313 – 326 (2021)
www.ejabf.journals.ekb.eg

Temporal abundance and distribution of *Octopus vulgaris* (Cuvier, 1797) in the southern Atlantic waters of Morocco.

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ARTICLE INFO

Article History:
Received: Oct. 10, 2021
Accepted: Nov. 17, 2021
Online: Dec. 27, 2021

Keywords:
Abundance,
CPUE,
Distribution,
Octopus vulgaris,
Recruitment,
Trawler

ABSTRACT

A study on the presence of *Octopus vulgaris* (Cuvier, 1797) in the southern Atlantic coastal waters of Morocco was carried out using data collected by boarding a cephalopod offshore trawler operating in this area by calculating the catch per unit effort (CPUE). The study showed a remarkable abundance of young *Octopus* individuals in terms of catches compared to large individuals over the entire study period, whether day or night, with lower yields during the nights. Winter trips produced the highest yields. The first days of resumption of fishing, (after a closed season) relating to each trip, showed very large quantities of catch except for the 2016 summer trips. Yields between the 2016 and 2017 summer trip remain relatively constant, while those of the winter trip of 2017/2018 experienced a very significant fall, with a quota achievement rate not reaching 49% compared to 81% achieved during the 2016/2017 winter trip. The results obtained by this study concluded that, such management of *Octopus vulgaris* requires first and foremost good control of its temporal distribution based on the knowledge of the biological and physical phenomena, which interact and govern the abundance and the fluctuations of the stocks of this species.

INTRODUCTION

Octopus vulgaris is a species characterized by a short life cycle (**Katsanevakis & Verriopoulos, 2006; Perales-Raya *et al.*, 2010**), a rapid growth (**Alford & Jackson, 1993**) and a high fertility **(Mangold-Wirz, 1963; Silva *et al.*, 2002**; **Otero *et al.*, 2007)**.The abundance of *O. vulgaris* in the southern Atlantic waters of Morocco as well as its commercial value offer this species great socio-economic importance. It is considered one of the most targeted species by all three fishing sectors (artisanal, coastal and offshore). Despite its abundance and its short life cycle, fishing for this species in the southern zone of Morocco is governed according to specific management measures in order to avoid the collapse of this stock. Those measures include: the authorized market size (more than 0.3 kilogram fresh eviscerated weight or 0.4 kilogram net fresh weight), the prohibition of trawl fishing over a

distance of 10 miles from the coastline for the water column (territorial sea baseline) during the authorized fishing period , quotas per vessel, closed season, well-defined characteristics of fishing gear and prohibition polygons (spawning area or rocky areas that likely afford shelter). Offshore trawlers were granted for 63% of the global *Octopus* quota dedicated to the southern Atlantic waters of Morocco, This percentage is divided among 237 active cephalopod offshore trawlers during the study period **(DPM, 2018)**, large ships according to their horsepower to get more of the percentage (> = 1400 Horse Power ; 750 hp > = MP > 1400 hp; MP < 750 hp). While, 26% is granted to small-scale fishing boats falling within the maritime district of Dakhla, and the remaining 11% of the quota is granted to coastal trawlers coming from the port of Tantan and Laayoune by a rotation system of 150 ships. Small-scale fishing boats, belonging to the maritime district of Boujdour and operating in the southern zone, benefit from an additional quota distributed between them, outside the aforementioned quota.

O. vulgaris has been the subject of several studies, mainly related to its biology, diet and growth, but few authors have described catches of this species in terms of its demography or temporal abundance and distribution. Prior to the present study, there has been no data published on the temporal distribution of this species in Morocco, especially in its southern Atlantic waters. To fill this gap of knowledge, this study has been undertaken. As a result, we set out to provide the first such study using data collected by boarding a cephalopod offshore trawler to the management of this fishery.

The present work was submitted to deepen the study of the temporal abundance and distribution in this area in the objective of providing the temporal analysis of the yields of the poultry fishery. The results drawn from this analysis could indeed help to specify the appropriate periods for the good resumption of fishing for *Octopus vulgaris* in the southern Atlantic waters of Morocco to assert a better management of the *Octopus* fishery. Hence, data obtained would allow us to understand certain aspects related to the ethology of this species.

MATERIAL AND METHODS

1-Study zone

Octopus fishing occurs along the entire Moroccan coast within two zones: the first is in the south, with a longitude of 26°24’ N, and the other is situated to its north. The southern Atlantic waters of Morocco are located between Sidi Elghazi L: 26° 24' N and Cap Blanc L: 020° 46' N (the Morocco -Mauritania border) (Fig. 1), and they represent one of the most productive areas on the west coast of Africa **(Minas *et al.*, 1982; Balguerias *et al.*, 2002)** due to the fact that *Octopus* fishing in Morocco by the national Offshore trawlers are limited to this area.

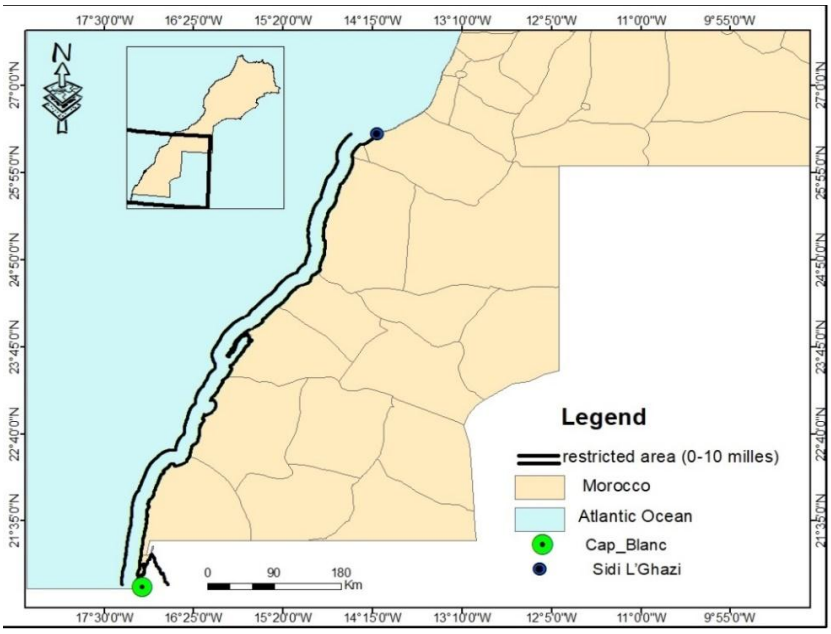

Fig. 1. Delimitation of the study area located between Sidi Elghazi and Cap Blanc

2-Methodology

This study is based on the collection of data from our embarkation on board of the trawler specified for this study (continuous duration of 45 days of embarkation),embedded with a scale to measure the weight and a hand watch. The data were collected by two well-trained observers (fishing lieutenant) that we trained to carry out the rest of this operation related to data collection.

The present work was based on a 3325 series of data, particularly precise date and time of the operation, the duration of the trawling operation and the weight of small individuals (small sizes) associated with those of the large individuals and the total of the catch during the trawling operation.

The data collected on board (3325 trawling operations targeting *Octopus)* formed the inputs of Excel for processing and analysis. Our study extended 423 fishing days (two successive summers and two winter trips) in the national area located south of Sidi Elghazi, which represents a great interest for fishermen. The study period and the number of operations per trip are mentioned in Table (1).

Table 1. Information related to the study period

Trip	Summer trip (1)	Winter trip (1)	Summer trip (2)	Winter trip (2)
Start date	01 -6-2016	01-12-2016	15-6- 2017	05-12-2017
End date	31-08-2016	31-03-2017	15 -09-2017	31-03-2018
Number of trawling operations	723	953	760	889
Number of fishing days	92	121	93	117

After each fising operation, the *Octopus* catches were sorted and placed in boxes based on homogeneous size from T_8 to T_1; while size 1 represented the largest individuals (equal to or greater than 4.5 kilograms eviscerated weight) and size 8 stood for the smallest individuals authorized to be fished, but without exceeding a tolerance threshold set by the competent authority before the resumption of each fishing season (0.3kg < T_8 (eviscerated weight) = < 0.5 Kg. This percentage is generally set at 7% and 15% of the total quota reserved for each vessel respectively during summer trips and winter trips. The other authorized sizes (from T_7 to $T_{1)}$ are not subject to a threshold tolerance. Table (2) shows the different sizes according to the Japanese commercial classification (known as the Mitsubishi classification).

Table 2. Weight limits (in kgs of eviscerated fresh weight) defining the Mitsubishi classification by size

Size	Limit of Sizes (in kgs, eviscerated fresh weight)
T1	➢ 4.5
T2	3 < W ≤ 4.5
T3	2 < W ≤ 3
T4	1.5 < W ≤ 2
T5	1.2 < W ≤ 1.5
T6	0.8 < W ≤ 1.2
T7	0.5 < W ≤ 0.8
T8	3 < W ≤ 0.5

The catches from each fishing operation were placed in boxes containing homogeneous sizes and then grouped according to two major categories (C1: boxes representing the large individuals caught; C2: boxes representing the young *Octopus* caught) (Table 3).

The total weight of C_1, C_2 and the total weight of catch by operation were calculated. The landing and marketing of eviscerated *Octopus* not weighing more than 0.3 kg (Juveniles) are strictly prohibited by regulations.

Table 3. Information related to the categories studied

Category	Sizes	Weight of the cases (Kg)
Large individuals caught Category 1 (C_1)	T_1	14.2
	T_2	14,685
	T_3	15.24
	T_4	15,295
	T_5	15.86
Young O*ctopus* caught Category 2 (C_2)	T_6	16,925
	T_7	17.2
	T_8	18,354

The catch per unit effort (CPUE = Weight of octopus caught per hour of trawling) was then calculated as an index of abundance for small sizes, large sizes and total of the catch.

$$\textbf{CPUE (Kg/h)} = \frac{\textbf{Weight of octopus caught per fishing operation} * \textbf{60}}{\textbf{trawling time of each operation (in minutes)}}$$

3-Statistical analysis tools

The data processing is based on the temporal analysis of the CPUE to support the differences between day and night on the one hand and between the fishing seasons on the other, relying on statistical analysis.

The data collected was studied as statistical variables, and the mean values per sample type were compared using the least significant difference (LSD) test at $P < 0.05$ that was considered to be statistically significant. Analyses of variance (ANOVA) were computed using General Linear Model.

Statistical analysis is performed using STATGRAPHICS software (version XVII, Statpoint Technologies, Inc., Virginia, USA). The means are considered significantly different at $P < 0.05$ and highly significant at $P < 0.01$.

RESULTS

1-Data analysis

1-1-Daily analysis of catches

Analysis of the catches from bottom trawling during this study period shows that the day's catches are higher than those made during the night in all four trips (Fig. 2).

The analysis of the quantities fished between day and night by referring to the catch per unit effort (CPUE) shows that, the small sizes are more dominant in terms of weight than the large sizes of day and night. This, in turn, reflects the dominance in weight and number of the young individuals newly recruited compared to large individuals (Fig. 2).

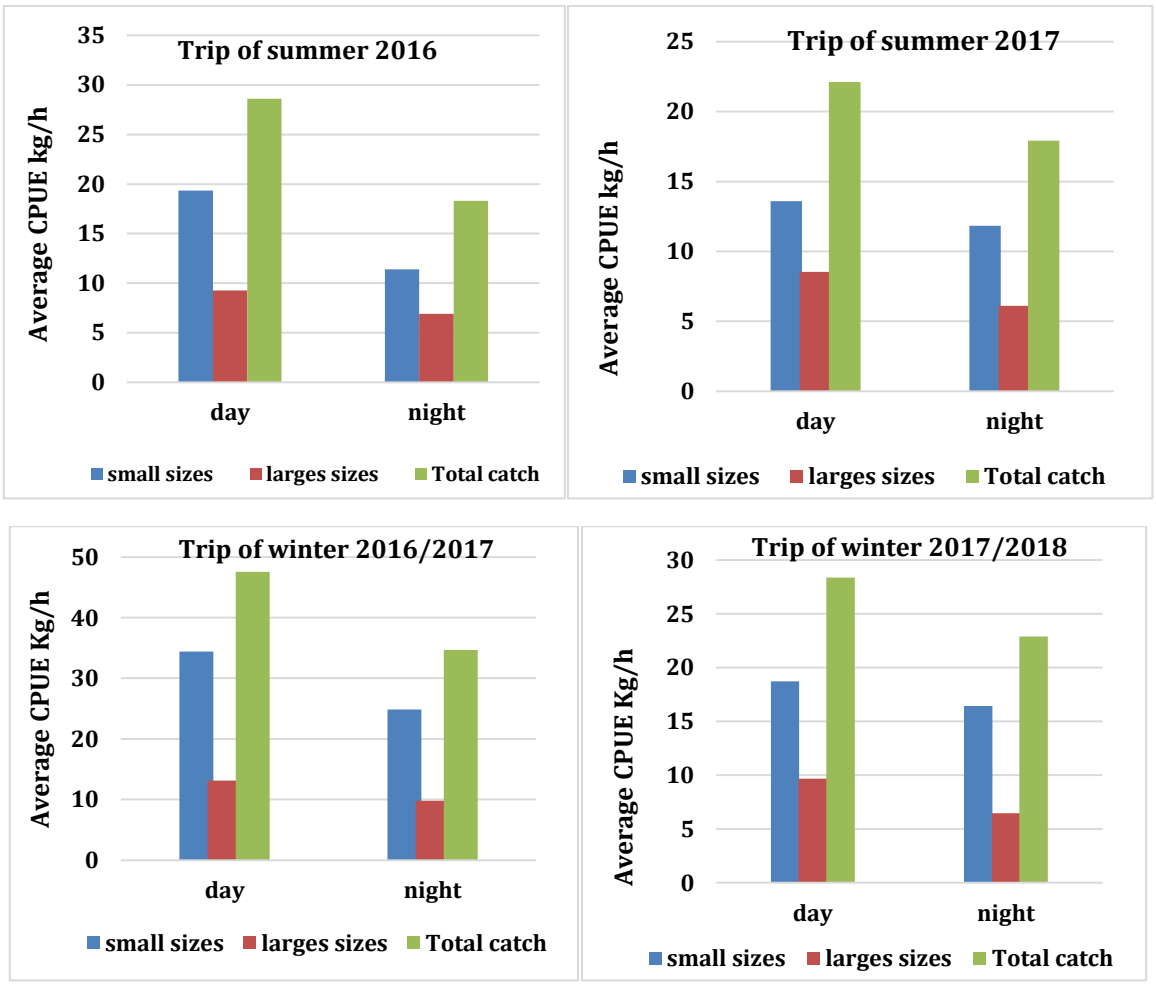

Fig. 2. The demographic composition of *Octopus* in day and night catches during four trips

1-2-Monthly analysis of catches

Monthly *Octopus* catch during the four trips represents very apparent oscillations between these trips which are part of the study period (Fig. 3).

For the summer trip 2016, a maximum CPUE was recorded during the month of August; composed mainly of young individuals (small sizes), with a peak between the 1st and the 5th of the same month, and a minimum value between July 21st and 25th which was corresponded to the entry of the offshore trawler (the object of the mentioned study) in the port of Dakhla for unloading its catch and refueling which caused a halt in fishing operations (Fig. 3).

The oscillations in production during the 2017 summer trip were less significant than those of the 2016 summer trip, with a maximum during the start of the trip (June) dominated by small sizes. A noteworthy fact is the sharp decrease in the level of abundance at the beginning of August when the ship returned to the port of Dakhla for refueling and unloading the catch.

For the two winter trips, a high mass production composed mainly of young *Octopus* was observed at the start of the two trips (December); this period corresponded to the end of the autumn season. Almost the entire study period (four trips) showed a dominance in catch weight of young individuals (small sizes).

1-3-Analysis of catches between trips

The ratio of the total quantity caught in *Octopus* per number of fishing days shows a large and remarkable difference between the winter trips and those in summer. In the summer of 2016 and 2017, this ratio is noted to be much lower compared to the winter trips of 2016/2017 and 2017/2018 (Fig. 4).

The catch of this species shows a big difference between the winter and summer seasons in terms of *Octopus* production; the yields achieved by trawl sets in winter are greater in terms of weight compared to trawl hauls carried out in summer (Fig. 4).

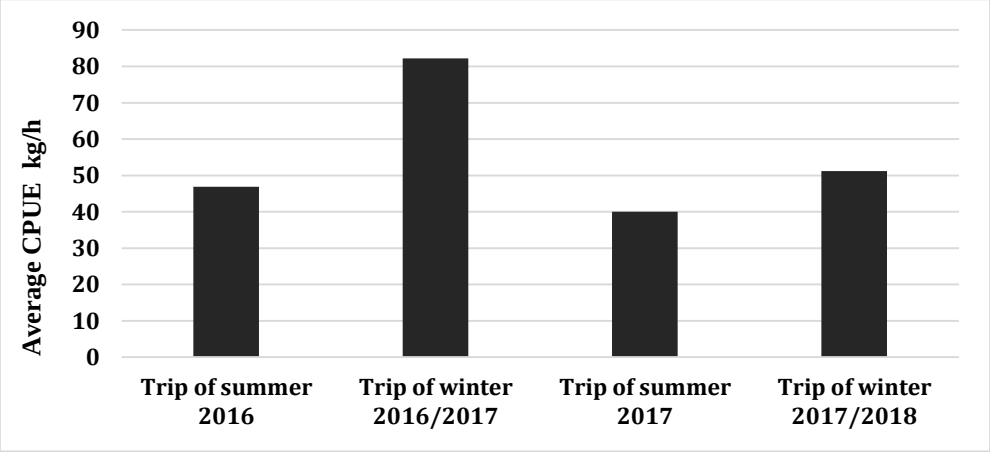

Fig. 4. Catch per unit effort per trip

The *Octopus* production during the winter trip of 2017/2018 showed a significant and exceptional drop of around 38% compared to the previous winter trip. This was also observed in other offshore trawlers, with an overall quota achievement rate of around 48% during the 2017/2018 winter trip compared to 81% achieved in the 2016/2017 winter by all offshore trawlers.

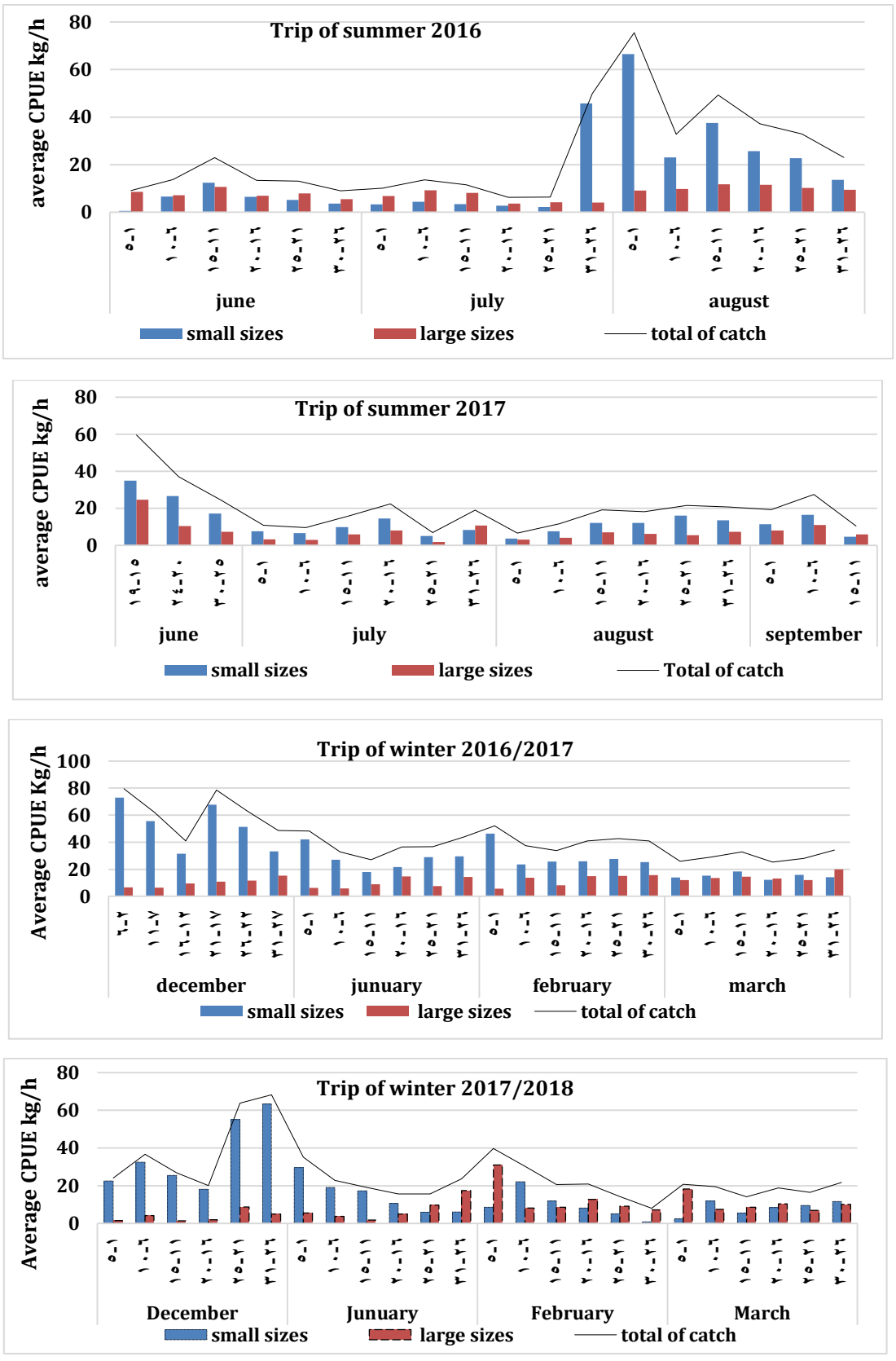

Fig. 3. Monthly evolution of *Octopus* production during four trips

2- Statistical analysis

2-1-Analysis of Variance

The results obtained in Table (4) confirm the existence of a difference in yield with a highly significant difference for three variables (CPUE small size, CPUE large size, and global CPUE) between day and night, seasons and between years. The *P*-value is less than 0,01, and that term is statistically significant at the 95,0% confidence level.

Table 4. Analysis of variance (ANOVA)

Source of variation	degree of freedom	CPUE small sizes	F-Ratio	P-Value	CPUE large sizes	F-Ratio	P-Value	Global CPUE	F-Ratio	P-Value
Year	1	46784,5	72,99	0	3902,81	35,46	0	77597,2	95,98	0
Season	1	38219,8	59,63	0	1291,44	11,74	0,0006	52764,2	65,26	0
Day / Night	3	8251,1	12,87	0	2193,7	19,93	0	18962,3	23,45	0
Residual	3190	640,965			110,049			808,494		
Total (corrected)	3195									

2-2-Multiple Range Tests

The results of the statistical analysis showed that the high yields of *octopus* for the three variables (small sizes, large sizes and total catch) were recorded during the day, while at night they showed low yields (Table 5). On the other hand, the least significant difference (LSD) test showed that, the CPUE quantities recorded in small calibers are much more than in large calibers. The statistical test also shows that winter trips are characterized by high *octopus* yields compared to summer trips. Annual statistical analysis showed that two first trips (summer 2016 and winter 2016/2017) are more productive than the two second trips (summer 2017 and winter 2017/2018). This difference is caused by the drop observed in the 2017/2018 winter trip of around 38% compared to the previous winter trip.

Table 5. Mean values of CPUE small size, CPUE large size and global CPUE (kg/h) in various times (day/night, seasons and years)

Variable	LS Mean (small)	LS Mean (CPUE large sizes)	LS Mean (Global CPUE)
Night	16,1022 b	7,30564 b	23,411 b
Day	21,5031 a	10,0624 a	31,5781 a
Summer	13,9255 b	7,70797 b	21,6793 b
Winter	22,7934 a	9,33808 a	32,0989 a
2017	13,7408 b	7,18903 b	20,9409 b
2016	22,9781 a	9,85702 a	32,8373 a

Within the same column, for each parameter, values followed by two different letters are significantly different at 0.05.

DISCUSSION

1-Daily analysis of catches

Octopus is more catchable during the day than the night; this is most likely related to the behavior of the *Octopus*; this sedentary species feeds during the day and hides at night, and therefore becomes inactive and less accessible to the trawl even if it does not leave the bottom. Trawling is based on scraping the bottom, and so that the *Octopus* is inaccessible to the trawl during the night despite its sedentary lifestyle. This sets up the hypothesis of developing a strategy of hiding for the *Octopus* during the night so that it is inaccessible to its predators and thus to fishing. It is therefore very likely that, the search for food by this sedentary species occurs more during the day than at night. The same result was obtained during a study of the yields of 2,500 trawl tows in 4 trawlers in the summer of 1986 by **Caverivière (1990)** where he found that, the *Octopus* yields by day are very productive than those at night, which probably indicates the high frequency of being out of the burrows where he hides. Results based on in situ observations of **Caverivière (2002)** have shown that, these burrows where the *Octopus* hide and which have a depth and a diameter in correlation identical with the size of the individual were probably dug by itself. These burrows provide excellent protection for the *Octopus*, which would only leave it for feeding and reproduction reasons.

During our study, it was evident to observe a high frequency of the catchability of the *Octopus* hidden in plastic pots by the trawl by night than by day, this explains why the *Octopus* hides to protect itself during the night.

2-Monthly analysis of catches

The high yields were observed during the start of each trip except for the summer 2016 trip, which showed high yields regarding the last month of the trip (August). The timid yields recorded at the start of the 2016 summer trip compared to other trips put in place the need to cross-check the data collected by boarding the vessel in question with those of other cephalopod offshore trawlers to produce reliable results. For this same trip and around August, the vessel subject to the mentioned study had the right of access to two zones after their opening in August; these areas are known for their productivity. The production achieved during the opening of those two areas is mainly composed of *Octopus* in the recruitment phase (young individuals); this is explained by the non-submission of the area to such a fishing effort. The dominance of young individuals over large individuals during the four trips, forming the subject of this study, may be linked to several conditions, particularly: the accessibility of young individuals in the recruitment phase, and the dispersal of individuals throughout the biological cycle, which makes young individuals more concentrated in an area compared to large individuals. In addition, the escape of large individuals trawling by sinking, following mastery of the art of camouflage, and hiding in rocky areas for reproduction reasons and ultimately the post-reproductive death of parents. This explanation was suggested in the study of **Domain *et al.* (2000)** who limits the lifespan

of the *Octopus* to one year andone and a half year with the absence of overlap between generations.

The start of the winter trips (December 2016 and December 2017) detected very high yields composed mainly of young individuals; this month (December) corresponds to the end of the period of a main recruitment (end of the autumn season). this finding is in agreement with the result of a study carried out by **Idrissi *et al.* (2006)** on the reproduction of *Octopus vulgaris* in southern Morocco.In their study, by monitoring the gonado somatic ratio (GSR)they recorded the presence of two spawning periods: an intense spring laying from March to July, and a less intense fall laying between September and October. Another study showed that the laying during July will give rise to high yields of month of November **(Sánchez & Obarti, 1993)**.

The two spawning periods give rise to two recruitment phases, a mass rectification in autumn (Origin of spring spawning) and a less intense recruitment in spring. The same result was reported in the studies of **Dia (1998)** and **Ould Inejih (2000)** in Mauritanian waters. Both authors confirmed the existence of two life cycles, which overlap in time having for origin two types of reproducers. This explains the origin, in our studies, of the remarkable difference between the catchability of *Octopus* in winter andsummer, and therefore two different quotas were set by the Department of Maritime Fisheries.

Another more recent study conducted by **Sobrino *et al.* (2020)** at the golf of Cadix showed fluctuations in the landings of *Octopus* over the seasons, with high landings' rates between the months of November, December and January, which supports the hypothesis of a significant recruitment at the end of autumn and early winter. The dominance of young individuals is a consequence of the ethology of the *Octopus*. When it is juvenile or in period of growth, its main activity is hunting for food, while in period of laying, the females hide in shelters or burrows, which they make for the laying and do not feed more. With respect to the trawl, the vulnerability is therefore much greater in the juvenile phase than in the reproduction phase.

Yields showed high values at the start of each resumption of fishing (except the 2016 summer trip). Similar trends were reported in north-western Africa after closed fishing seasons **(Balguerías *et al.*, 2002)**.

3- Analysis of catches between trips

The production in terms of weight during this period remained relatively constant between the two summer trips, while the 2017/2018 winter trip recorded a sharp decrease compared to that of the previous winter. The physical environment in the upwelling area is particularly unstable over time (on a seasonal and inter-annual scale). There is every reason to believe that this instability could have significant repercussions on the recruitment of *Octopus* and at least partly significant at the origin of their fluctuations. Consequently, to understand this decrease in production during the 2017/2018 winter trip, the results found

must be coupled with the environmental data to estimate the cause of this drop-in production. A close relationship exists between the recruitment rate and the oceanographic parameters, these latter play a very important role in the survival and recruitment success of each generation **(González *et al.*, 2005; Otero *et al.*, 2008**; **Roura *et al.*, 2016).**

Other Studies have shown that fluctuations in biomass of commercial fish from year to year over large spatial and temporal scales are caused by the influence of environmental conditions, especially during the early stages of life, which have a major effect on recruitment **(Agnew *et al.*, 2000)** and, later, on the biomass to be exploited **(Rodhouse, 2001)**.

CONCLUSION

Yields achieved in winter are much higher than those in summer, which means intense recruitment in December resulting from mass spring laying. Another less intense spawning was observed in winter resulting in less intense recruitment. The existence of two types of breeders is the result of the overlap of two life cycles of time. Catches during the first days of the resumption of fishing are very important, reflecting the importance of the biological halt. The dominance of young individuals over large individuals in the catches is due to the vulnerability of young individuals in recruitment phase to the trawl, and the dispersion of individuals over the life cycle as well as the control of big individuals from escaping trawl by sinking and hiding. Catches during the day are greater than those at night, which means that the *Octopus vulgaris* is less active at night (it hides) than during the day (it goes out looking for food). The relative abundance of *Octopus* shows temporal variability at seasonal and interannual scales.

A weekly monitoring of the biological cycle of the *Octopus* coupled with the study of the environmental conditions of the marine environment must be carried out to enable the determination of the true exploitable biomass and ensure better management of the national halieutic potential. This allows to avoid what manifested itself during the 2017/2018 winter trip, which was characterized by a low rate of achievement of the global quota following a false estimate of the biomass exploitable. This could have harmful effects on the variation in *Octopus* abundance and on the renewal capacity of this resource and, of course, on the ecosystem balance of the South Atlantic area. Following all the analyses carried out during this study, it appears that the autumnal biological rest should be extended until the end of December to alleviate the fishing pressure on young individuals during their recruitment.

Acknowledgements

We thank Prof. A.C. Broderick (University of Exeter, UK) for suggestions and editing in earlier versions of the manuscript. We also thank Prof. El Hassan Sakar (Department of Biology Faculty of Sciences-Tetouan Abdelmalek Essaadi University) for his help in the statistical analysis of the data.

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