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Trophic level of the *Octopus vulgaris* in the continental shelf of the area Cape Blanc - Cape Juby

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Abstract— Studies on biological interactions of marine species are a fundamental mean to settle on their importance in the trophic network and then ellucidate more the marine ecosystem process. This study focuses on functional relationships of a key species of the Moroccan Atlantic ecosystem, *Octopus vulgaris* (Cuvier, 1795), which is also the main targeted species by many demersal fisheries in the region. Based on diet studies and statistical analysis on Stomach samples collected during the period 2001 to 2003, feeding strategies are defined of *O.vulgaris* in two zones localized north and south Cap Boujador (26°00N). These zones are indeed considered to be areas of presence of two different stocks that are harvested differently. We estimated trophic indices of the species for each stock, in this case the relative importance index of preys (IRI), the trophic level (TL) and the omnivory index (IO) are calculated. The trophic strategies of the two populations are then compared using statistical tests according to different biological parameters.

Index Terms— Cephalopods, *Octopus vulgaris*, diet analysis, Trophic index, Ecosystem dynamics, Moroccan Atlantic.

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1 Introduction

THE marine Atlantic ecosystem of Moroccan coast is subject of different particular factors that characterize the hydrology of the Canary current system and which are particularly unstable over time and space. This ecosystem constitute an area of high biological productivity and intensive fisheries activity. *Octopus vulagris* is a key species of great importance in the cephalopod group of this region either for its biomass or for economical considerations. It is the subject of a multi fishing fleets consisting in industrial, coastal and small-scale fleets, and whose production is fluctuating in both seasonal and annual scales [1, 2, 3]. Analyzing the mechanisms, from ecological perspectives, that drive this high variability is therefore necessary for present and future sustainability of this fishery.

O. vulgaris is a merobenthic incirrate octopod, common in temperate shallow habitats from the coastline untel the 200 m depths [4, 5]. Its life span was estimated in different regions, from one year in Morroco to two years in Galician waters, it reaches relatively large sizes, to 25 cm mantle length [6, 7, 2]. and up to 6000 g in weight. The common Octopus is the most important cephalopod species playing a significant role in the ecosystem by its tropic activities [2]. The feeding activity of this species was investigated in the natural environment [2, 8, 9, 10, 11, 12].

The importance of feeding ethology in the life cycle of this key species in the Moroccan Atlantic ecosystem motivated us to deepen our knowledge on its feeding strategies and its biological interactions in a changing ecosystem.

2 MATERIEL AND METHODS

2.1 Study site, fishery samples

A total of 1034 *O. vulgaris* was collected from the fishing ports of Laayoune and Agadir. These individuals was captured by the local coastal trawling fleet during 2001 and 2002 in the area located between the latitudes (26°N) and (28°N).

On the other hand, 215 *O. vulgaris* stomachs are extracted by the biological sampling onboard the research vessel Charif Idrissi, during surveys conducted in March- April and September – October 2001 and 2002 (Fig 1). For each specimen, dorsal mantle length (DML), weight, sex and maturity stage were cllected. The digestive tract was then removed and stomach contents were weighed and stored in 70 % ethanol before analysis. Preys were identified to the lowest possible level. Fish sagittal otoliths were identified by consulting the work of [13]. Cephalopod beaks were identified following [14, 15]. Crustaceans were identified by their exoskeleton depicted by [16, 17].

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2.2 Index trophic

Occurrence frequency, numeric and gravimetric methods are used to quantify the diet composition. Occurrence frequency (%FO) is calculated as the percentage of Octopus that fed on some preys, number (%N) is the individuals number of some preys relative to the total number of individual preys, and weight (%W) is defined as the weight of a some preys relative to the total weight of all preys[18]. The explecite expression of IRI index is given as follows ,

$$IRI = (\%\ N + \%\ W) \times (\%\ FO) \quad \mathbf{(1)}$$

Graphs of indices of relative importance (IRI), were plotted to illustrate the diet by Octopus species.

The octopus stomachs sis was used to estimate the tribution of different prey types in its food bowls in both areas north and south Cape Boujador.

- Only the most important preys were considered. To estimate the Trophic Level Index (TL). (TL_J), were j is designing an *O. vulgaris* predator is estimated for each stomach using the formula adopted by [19, 20, 21]:

$$TL_j = 1 + \sum_{i=1}^{n} DC_{ij} \times TL_i \quad \mathbf{(2)}$$

TL_j : Trophic level of the predator j.
DC_{ij} : Proportion of preys in the stomach of predator j (by weight); the weight percentage of the prey i in the stomach contents of each individuals examined.

In this analysis, the relative weight of each item present in the stomachs is used to estimate (TL) of Octopus as predator, assuming that weight quantifies the importance of the way that energy is the prey [19].

To do this, the values of (TL) of prey are obtained from Fish Base program information. For this reason, the vast majority of available values through literature and the program come from analysis FISHBASE stomach [21, 22, 23, 24, 25, 26, 27, 28, 29] to calculate these two indices (TLJ) and (IOJ).

For purposes of comparison, (TL) and (IO) to the North and South of Boujador are estimated on the basis of data collected during the same periods in 2001 and 2002 in both areas.

- Omnivory Index (IOJ) is proposed to express the variability of the diet of each individual and then the the range of the trophic levels of the ingested preys [20]. This indice is calculated as follows,

$$IO_j = \sum_{i=1}^{n} \left(TL_i - \left(TL_J - 1\right)\right)^2 \times DC_{ij} \quad \mathbf{(3)}$$

IO_j : Index of omnivory of the Octopus , predator j.
TL_i: Trophic level of the Octopus prey i.

Finally, considering the ecosystemic and fishing differences between the areas north and South Cape Boujador, we conducted an ANOVA analysis, which is a nonparametric test, in order to compare the trophic spectrum of Octopus in the two areas.

3 RESULTS

The *O. vulgaris* weights occuring in the samples are ranging from 90 to 6000 g, while sizes are distributed between 90 and 300 mm MDL. Among the 1034 stomachs examined, 301 were without food. In south Boujador sub-area, the sampled sizes are distributed between 50 and 280 mm MDL. Among the analyzed stomachs, 170 were containing food with a list of ingested faunal preys listed in (Fig 2).

3.1 Trophic spectrum of *O. vulgaris* in the area North Cape boujador (26°N - 28°N)

The most abundant taxa of identified preys in the stomachs casually were crustaceans, molluscs, fishes, cnidarians, annelids, and Nemathelminths, rotifers and algae. The taxonomic resolution level in the discernment of preys is important with 63 different species belonging to 50 families. Molluscs show a high taxonomic diversity with 14 families and 18 species, whish are mainly bivalves and gastropods, followed by five families and eight species representing the class of cephalopods. At the same level, 18 families and 20 species represent the class of crustaceans.
Quantitatively, the preys's preferences consist essentially of crustaceans (60.76%), then the molluscs (23.07%) and fish (11.12%), while cnidarians (3.07%) and annelids (1.21%) are the additional items. Rotifers, algae and Nemathelminthes have an IRI index less than 1%, stating that all these groups are among the accessories peys that are casually complementing the diet of common octopus. In terms of ingested species families, the main crustaceans that constitute the preys's preferences, according to their IRI, are Brachyura, Portunidae and then Penaeidae.

Molluscs, that have a secondary importance in the food bowl of *O. vulgaris*, are composed mainly by, Ommastrephidae, Octopodidae and Sepiidae. Identifying the species of the Fish group, which is less abundant in the preys depend on the fish digestion and usualy its organs are deterioed under the action of digestive juices. Among the identified fish we can list the following species: *E. encrasicolus*, *G.auratus*; *L. caudatus*, *P. erythrinus*, *S. pilchardus*, *S. scombus; Solea. spp* and *T.trachurus* (Fig 3).

To quantify the seasonal and interannual variability of different taxa discerned in the diet of *O.vulgaris* in this area, we performed a Variance Analysis test (ANOVA1) at the probabilities P≥ 0.05 and P≥ 0.01. The ANOVA test showed that their is no significant monthly differences in the occurrence of all taxa in the stomach of *O.vulgaris* (Table 1), attesting that the trophic composition is not affected by seasonality. While at the annualy level, the occurrence of crustaceans and molluscs in the food bowl is highly variating (Table 1).

3.2 Trophic spectrum of Octopus in the area south Boujador (21°N - 26°N)

Seven classes of preys are discerned in the diet of *O. vulgaris* south Boujdor: crustaceans, fish, molluscs, annelids, cnidarians, echinoderms and algae. The taxonomic level is particularly important with all preys groups (Table 2).
Indeed, 19 families and 23 species of crustaceans have been identi fied, the most abundants are *Carcinus maenas*, *Liocarcinus depurator*, *Squinado Maja*, *Mitella Pollicipes*, *Scyllarus pygmaeus* and Mysidacea. The molluscs are grouped into 21 families and 14 species among them *Illex coindetii*, *Sepia elegans, Sepia orbignyana* and *Circomphalus rosalina*. Ingered fish belong to 11 families and 14 different species, the most common are: *Boops boops*, *Merluccius merluccius*, *Pagellus sp* and *Solea sp*. On the other hand, nematodes, polychaetes, echinoderms and cnidarians have rarely been perceptible at the species level and their identification was usually restricted (Fig 4).

The (ANOVA1) analysis used at the probability P≥ 0.05 to test the varibility of the diet bowl in this area, states that there is no significant difference of the preys compositions at both inter- annual and seasonal scales. The faunistic list of preys discerned is generally stable during a seasonal cycle and the seven main classes are always represented.

3.3 Trophic indices (TL) and (IO) in the sub-areas North and South Boujador

The values assigned to the average TL of *O. vulgaris*, based on its stomachs analysis and preys (TL)i driven from FISHBASE program are estimates to 3.35 in north Cape Boujador and 2.67 in south Cape Boujador. The IO of *Octopus* north of Boujador varies over a wide range between 0.018 and 2.43 with an average estimated to 0.77, while the population in south of Boujador has a higher level of omnivory, which varies between 0.014 and 2.32 with an average of 0.96 (Fig 5).

This difference of the trophic levels in the two areas at seasonnal ans annual scale is tested to elucidate whether it is due to the fortuitous sampling fluctuations. For this aim the nonparametric Wilcoxon-Mann-Whitney, test, known also as U-test is used. After ranking the preys positions in the two groups north and south Boujador, according to their importance in the diet bowl, U-test is testing the simularity of the groups distributions withing their preys importance. The main results are presented in (Table 3).

The observed values of Z ([Zobs]) are greater than the critical value 2.33 at the probability level 1% (respectively 1.64 at the probabulity level 5%). The hypothesis stating that there is a significant difference of the Trophic position of *O. vulgaris* in the two populations is accepted with the lower error risk (1%). At the seasonal scale, the (TL) didn't differ significantly in the two sub-areas during spring season while during autumn, the variation in trophic level is highly significant between the two populations. Probably, this seems to be related to ontogenetic changes in the species (recruitment); Octopus in north Boujador tends to a higher level of the trophic network.

3.4 Variability of *O. vulgaris* trophic indices according to its size

To ellucidate the effect of the *O. vulgaris* size on the two estimated trophic indices, we conducted a Pearson test; based on a student distribution... For this aim, we standardized the (TL) (IO) and the size variations, by transforming the data by a logarithmic function (log (+1)) to approximate the magnitudes of changes in both compared variables. The test results are shown in (Table 4).

For the two populations: the correlation results between size of *O.*

vulgaris and its trophic level (respectively its Omnivory index) did not reveal a significant dependence: the Student test calculated was below the critical value at p = 0.01, for both indices and areas (Table 4).

The hypothesis that the difference of (TL) in the areas north and south Cape Boujador is attributed to the effect of size is not consistant since it did not reveal significant relationships between (TL) and size parameter. So this difference is more likely attributed to the fishing mode wich is more intensive in southern zone, where the large sizes are over fished and access of common octopus to the preferred preys is more restricted.

6 DISCUSION

In both study areas north and south Boujador, the composition of the bowl Food of *O. vulgaris* is relatively close and quite diversified in both zones. The diet strategy is based on mobile benthic invertebrates (crustaceans), which are consumed and digested by a potent enzyme luggage. In northern Boujador besides crustaceans, food consist of shellfish, fish, cnidarians and annelids.

In the North area, IRI revealed that shellfish is in second place of preys after crustaceans. While more in the south, the food has a pisivory character, where the fish are mostly in the second position of the preys bowl (IRI=37.35). This can be explainable since the continental shelf is wider south Boujador and exceeds 60 nautical miles in some areas, particularly at the area located between lthe latitudes (24°00N) and (25°00N). This makes the fish more available and therefore more accessible to predators.

The chinoderms, algae, rotifers and Nemathelminthes are rarely observed in the stomach contents. Some octopuses seem completing their ration food by these species. They are also likely to adopt an herbivore behavior depending on the food availability offered by the habitats. The wide variety of prey ingested by *O. vulgaris* is consistent with his benthic behavior. This result is in accordance with those found in other areas of the North West African region [9, 11, 30, 31, 32, 33, 34] and also found in other benthic species of cephalopods [35, 36].

It is interesting to note that the hydrozoa also participate significantly in the octopus diet bowl in Moroccan, south Atlantic. This fact is not reported in other works.

However, according to [31], octopus adopt under some conditions a more scavenger behavior than a predator. 63 designations of species are listed in the digestive tubes of *O. vulgaris* of the Moroccan Atlantic. Compared to other regions, in southern Africa, [9] has identified 14 preys in the digestive tracts, on the Spanish coast in Mallorca, [34] has reported 50 prey species in the *O.vulgaris* diet. The number of preys captured in this work is therefore higher than that observed by many other studies; crustaceans are the preferred preys, with a high abundance rate in the stomachs.

These results are consistent with other similar studies conducted in other regions in the world, such ass [8, 9, 10, 11, 30, 31, 32, 34, 37, 38, 39, 40]. The food composition seems not to be related to the seasonal availability and abundance of preys; the bolus composition is generally stable during a seasonal cycle. With the seven taxa dic

erned, but their proportions are varying during seasons. This result was also found in Mediterranean Sea. By [10, 31] who reported that the nutritional behavior of Octopus remains constant throughout the year. *O.vulgaris* is usually a macrophage species, which prefer eating mobile crustaceans, probably for energy reasons. Indeed, [41] showed that the octopus needs a level of hemocyanim in its metabolism; this macro-element is of capital importance for the species to perform its vital functions (respiration growth and reproduction).

The assigned (TL) values are respectively 3.35 and 2.67 in the areas north and south Boujador. These values remain lower than that of 3.5 assigned to the cephalopods group by [42] in the Moroccan Atlantic coast (20°N - 36°N). Regarding the difference of the (TL) revealed at the spatial scale, it is probably due to a difference in, availability and diversity of preys in the ecosystem that can be strongly influenced by the deployed fishing activities. Indeed, the fishing intensity can be perceived as disturbance of the trophic balance of the species in its ecosystem and may be a factor that regulates even the spatial distribution of the species.

Moreover, studies conducted in modeling the species interactions, which are subject to such disruptions stipulate that predation is a structuring factor of their spatial behavior. Those studies approved in a modelling context that the spatial effect is very important in structuring the populations subject to predation activities, and that some particular disturbances could lead to unstable asymptotic behavior of the whole sys tem, in this case, the predators and preys system.

Numerical Simulations was implemented to illustrate this phenomenon. An example of the prey-predator Segel model Segel et al. (1972) simulated in one dimension by [43] reveals that if the system is initially disrupted under some special circumstances, both preys and predators will drive to a configuration of presence and absence of the species in different areas corresponding to the patchiness structures usually observed in nature (Fig 5), particulary with marine ressources. *O.vulgaris* could nevertheless be subject to a dynamic resulting from this context of spatiotemporal instability induced by the predation effects.

7 CONCLUSION

Knowledge of feeding behavior of a species in its natural environment is an essential step to understand its trophic position and its predation strategies. The study consists of analyzing the gastric contents of *Octopus vulgaris* as key species in the North West African ecosystem. The study focused on the Moroccan Atlantic region located between (28°N) and (21° N) revealed that *O. vulgaris* is considered a carnivorous predator of mobile invertebrates and conchyliens molluscs. This attitude is gained through his intelligence and high degree of development at the the digestive tract and its performance camouflage and mimicry.

Indeed, the octopus stock in the southern Moroccan Atlantic was subjected to a wide range of disturbances (increased fishing, hydrological conditions, climatic changes ...). In addition, the spatial distribution of Octopus in its ecosystem seems to be conditioned, firstly, by a soft substrate and a habitat that give it a refuge to protect and reproduce, and secondly, by abundance of preferred prey including benthic invertebrates.

Acknowledgment

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8 Figures and Tables

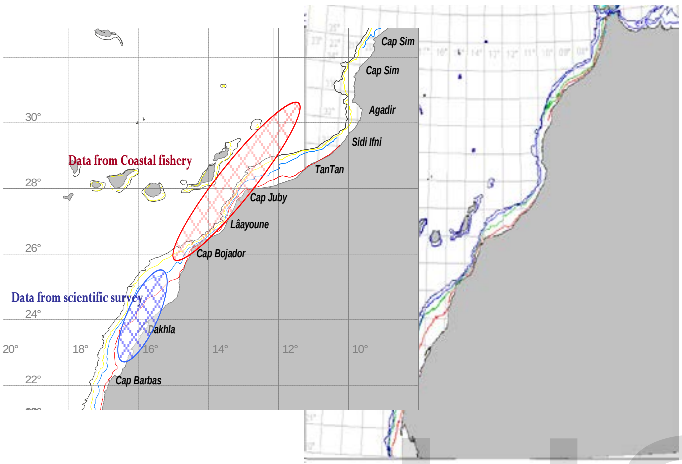
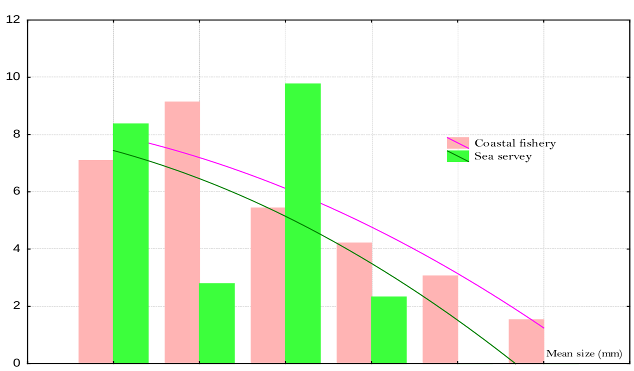


Fig.1. Locations where samples of *O. vulgaris* were obtained along the south coast of Morroco from coastal fishery and scientific survey between (26°N 21°N)



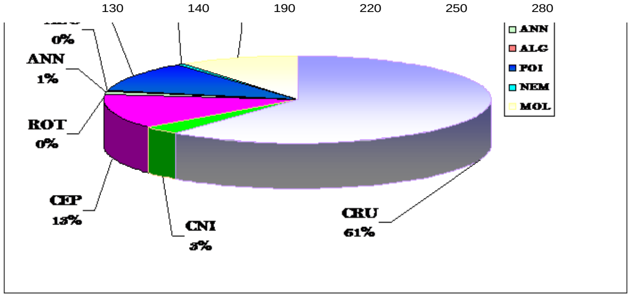


Fig. 2. Percent of mean size of sampled *O. vulgaris* in coastal fishery and sea surveys

Fig. 3. IRI Percentage of prey discerned in the digestive tracts of Octopus in northe Boujador

TABLE 1

ANOVA I taxa identified by year and month. (F) Statistical test , (P) N.S PROBABILITY VALUES (P≥0,005); * (P<0,005); ** (P<0.01); *** (P<0.001)

Taxa	Year		Month	
Parameters	F	P	F	P
Algae	0.56	n.s	0.84	n.s
Annelids	0.48	n.s	0.64	n.s
Cnidarians	1.36	n.s	0.95	n.s
Crustaceans	16.17	***	0.49	n.s
Mollusks	8.47	***	0.36	n.s
Nemathelminthes	0.22	n.s	1.92	n.s
Fishes	2.70	n.s	0.44	n.s
Rotifers	0.56	n.s	0.67	n.s

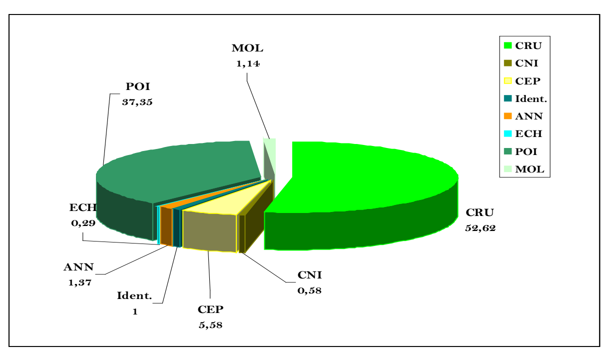


Fig 4. IRI Percentage of prey discerned in the digestive tracts Octopus south Boujador

TABLE 2
PREY IDENTIFIED IN THE FOOD BOWL OF COMMON OCTOPUS IN SOUTHERN PART OF THE MOROCCAN ATLANTIC COAST

Prey	Cap Juby- Cap Boujdor	Cap Blanc- Cap Boujdor
	IRI%	IRI%
CRUSTACEANS		
Alphius glaber	-	0.02
Amphipoda	0.63	2.12
Anomura	-	0.04
Brachyura unidentified	42.03	28.68
Carcinus maenas	2.60	0.21
Copepoda	0.29	0.37
Shrimps	0.40	6.13
Crustacea unidentified	0.01	10.09
Euphosiidae	0.44	0.97
Homarus gammarus	0.10	-
Hoplocaridea unidentified	0.01	0.03
Isopoda	1.93	0.62
Lepas anatifera	0.10	-
Liocarcinus depurator	0.12	0.06
Maja squinado	0.37	0.12
Menippe nodiforme	0.41	-
Mitella pollicipes	0.44	0.14
Mysidacea	1.34	1.42
Natantia unidentified	2.82	0.62
Nephros norvegicus	0.13	0.01
Ostracoda	0.07	0.06
Parapenaeus longistris	4.16	0.11
Parapenaeus serrata	-	0.19
Philocheras echinulatus	0.08	-
Processa canaliculata	0.53	0.08
Scyllarus arctus	0.31	0.04
Scyllarus pygmaeus	1.07	0.25
Squilla mantis	0.39	0.12
TOTAL	60,76	52.62
SHELLFISH		
Allothetus subulata	1.72	-
Benthonella tenella	0.06	0.01
Bivalvia	1.39	-
Cephalopoda unidentified	0,12	2.32
Chalmys spp	0.06	0.07
Charonia rubicunda	0.01	0.09
Circomphalus rosalina	0.40	0.32
Conus spp	0.21	0.03
Donax trunculus	0.46	0.02
Eledone cirrosha	0.07	-
Glycymeris scripta	0.10	-
Haliotis tuberculata	0.65	0.02
Illex coindetii	6.05	2.05
Modiolus rhomboideus	0.14	0.01
Shellfish unidentified	5.01	0.01
Murex trunculus	0.66	0.2
Natica adansoni	0.10	-
Natica spp	0.01	0.02
Octopus vulgaris	2.64	0.33
Patella nigra	0.17	0.11
Pecten spp	0.02	0.02
Rossia macrosoma	0,47	0.29
Sepia elegans	1.46	0.16
Sepia officinalis	0.03	-
Sepia orbingyana	0.08	0.3
Sepia spp	0.32	0.11
Strombus latus	0.09	0.01
Thais haemastoma	0.37	0.01
Turritella spp	0.01	0.09
Venus spp	0.18	0.12
TOTAL	23.06	6.70
FISHES		
Aspitrigla obscura	-	0.01
Boops boops	-	0.25
Engraulis encrasicolus	0.10	-
Gobius auratus	0,06	0.01
Lepidopus caudatus	0.01	0.02
Merluccidae	0.50	-
Merluccius merluccius	-	0.07
Pagellus erythrinus	0.06	0.01
Pagellus spp	0.15	0.23
Fishes unidentified	8.85	36.51
Sardina pilchardus	0.14	-
Scomber scombus	0.03	-
Solea spp	0.50	-
Trachurus trachurus	0.29	0.04
Trichiuridae spp	-	0.02
TOTAL	11.12	37.35
ALGAE		
Algae	0.09	0.07
TOTAL	0.09	0.07
Annelid		
Polychaete	1.21	1.31
TOTAL	1.21	1.31
Cnidarians		
Coelenterea	0.07	-
Hydrozoa	3.00	0.58
TOTAL	3.07	0.58
Rotifers		
Rotifers unidentified	0.14	-
Nemathelminthes		
Nematodea	0.55	0.03

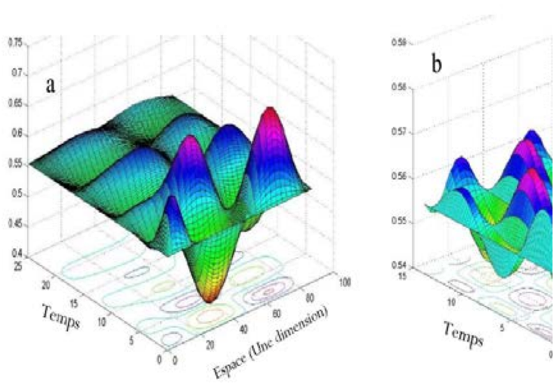


TABLE 3
U WILCOXON- MANN- WHITNEY TEST, |ZCRITICAL| TO1.64 AT THE 5% TO 2.33 AT THE 1%, 1, BETWEEN SEASONS, 2 IN THE TWO AREAS OF STUDY

	H0 : P [XiF> XjF] = 0.5 H1 : P [XiM> XjF] > 0.5			
1. *Seasonality*	Scientific servey		Costal fishery	
	|Zobs|	|Zcritical|	|Zobs|	|Zcritical|
Spring (2001- 2002)	1.31	n.s	0.10	n.s
Autum(2001- 2002)	2.68	**	3.27	**
2. Zonning	H0 : P [XiF> XjF] = 0.5 H1 : P [XiM> XjF] > 0.5			
	|Zobs|		|Zcritical|	
Year 2001	4.99		**	
Year 2002	6.31		**	

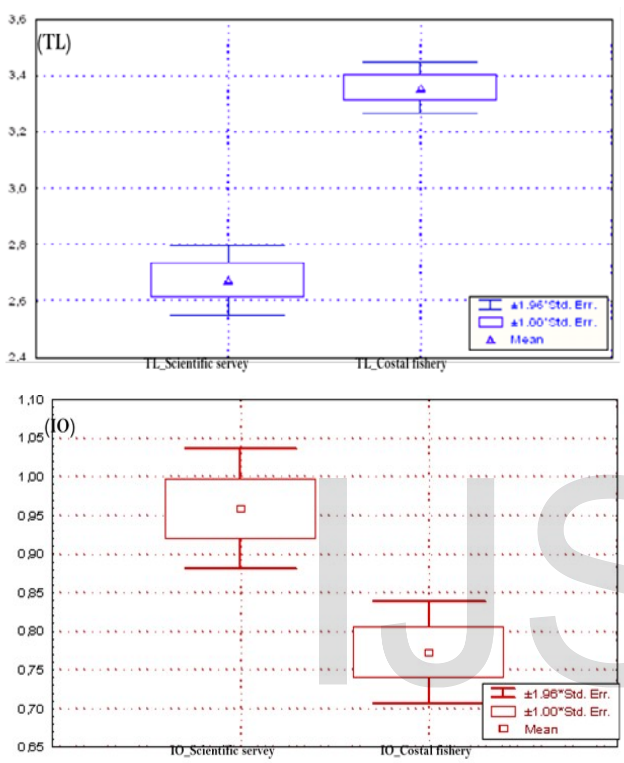


Fig 5 Graphical representation of the trophic level (TL) and Om nivory index (IO) of *Octopus* at both areas and during the same periods

TABLE 4
PEARSON CORRELATION TEST PARAMETERS OF THE TL (RESPECTIVELY IO) AGAINST THE OCTOPUS SIZE ON THE TWO AREAS OF STUDY

Trophics indexs	Data from the Costal fishery			Data from the Scientific survey		
	Coef. Pearson	TStudent 239	TCritical (0.01)	Coef. Pearson	TStudent 174	TCritical (0.01)
TL	0.123	1.919	2.59	0.093	1.234	2.6
IO	0.011	0.178		0.124	1.648	

Fig 5 Spatio-temporal evolution of predators (a) without instability dissipative, (b) with dissipative instability (Chaouki, 2002)

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