CIÊNCIAS DO MAR:

Estudos Sobre o Ambiente Marinho e Costeiro

Paulo Alexandre de Sousa Falé
(organizador)

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INTRODUÇÃO

As ciências do mar desempenham um papel crucial na compreensão dos ecossistemas marinhos e costeiros, que são essenciais para a biodiversidade e a saúde do planeta.

Neste contexto, o presente livro, "Ciências do Mar: Estudos Sobre o Ambiente Marinho e Costeiro", reúne uma série de pesquisas que exploram aspectos fundamentais desses ambientes, desde a ecologia de assembleias de peixes até os impactos ambientais causados por atividades industriais.

Os estudos apresentados aqui abordam questões relevantes, como a dinâmica das comunidades de peixes em manguezais e a avaliação dos efeitos de poluentes em solos portuários. Além disso, são discutidos aspectos da biologia marinha, como os hábitos alimentares de espécies de cefalópodes, contribuindo para uma melhor compreensão da dinâmica das cadeias alimentares marinhas.

A governança e a sustentabilidade são temas centrais nas investigações, destacando a importância de uma gestão adequada dos recursos marinhos e costeiros para a resiliência desses ecossistemas. A reflexão sobre práticas de governança portuária e suas implicações para o meio ambiente é fundamental para promover um futuro mais sustentável.

Este livro visa não apenas compartilhar conhecimentos científicos, mas também inspirar novas discussões e ações voltadas para a conservação e o uso sustentável dos ambientes marinhos. Ao explorar as interconexões entre a biologia, a ecologia e as práticas de gestão, esperamos contribuir para um entendimento mais amplo sobre a importância de proteger nossos oceanos e costas.

Convidamos o leitor a embarcar nesta jornada de descoberta e reflexão, explorando as contribuições que moldam o nosso entendimento sobre os oceanos e seus ecossistemas.

Paulo Alexandre de Sousa Falé

SUMÁRIO

CAPÍTULO 4

ANNUAL STOMACH CONTENTS OF THE CUTTLEFISH *SEPIA OFFICINALIS*, L., 1758 FROM THE CENTRAL ALGERIAN COAST

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ABSTRACT: The gastric contents of 284 common cuttlefish Sepia officinalis, Linnaeus 1758 (145 females and 139 males) were studied on the basis of sampling carried out at commercial trawl fishing landings in the central region of the Algerian coast during 2011. Based on qualitative and quantitative analysis, this first study carried out in Algeria revealed a list of prey ingested in the natural environment, as well as prey frequency indices and seasonal replenishment indices. The calculation of prey frequencies was used to study variations in diet between the sexes, its seasonal evolution and its variation according to size. Crustaceans and fish were the preferred prey, with a slight predominance of fish for females. Molluscs and worms are secondary prey throughout the year. Females have a higher replenishment index than males. The results of this study are correlated with the cuttlefish's life cycle and sexual maturity.
KEYWORDS: Cuttlefish. Diet. Prey frequency. Diet indices. Seasons.

1 INTRODUCTION

Cephalopod molluscs can be found in all the world's oceans and seas, from the surface to depths of over 7,000 meters, from the neritic coastal province to the pelagic offshore domain (Mangold and Boletzky, 1988). Today, the Cephalopods class includes over 700 species that have colonized most marine biotopes. This testifies to the evolutionary success of this group. Cephalopod resources have long been a secondary concern. Yet it is undeniable that the squid, octopus and cuttlefish resources accessible to artisanal and trawler fisheries play an important economic role.

The interest shown in this resource by fisheries led to the creation of the Study

Group on Squid Biology, which later gave rise to the ICES Working Group on Cephalopod Fisheries and life History (WGCEPH). This interest in Cephalopods also contributed to the creation of the Cephalopods International Advisory Concil (CIAC) in 1983. According to FAO statistics (2002), 5959 thousand tonnes of molluscs were caught in 2018, including 348 thousand tonnes of cuttlefish and sepiola, representing 6% of this group. Since the beginning of the 20th century, the Mediterranean has been the site of numerous research projects on cephalopods carried out by the Naples zoological station in Italy, the Arago laboratory in Banyuls-sur-mer, France, and the University of Athens, among others.

Sepia officinalis is the cephalopod whose biology is best known (Boletzky, 1983). Mangold-Wirz (1963 and 1966) particularly studied this species in the western Mediterranean and Richard (1971) in the eastern Channel. It has also been the subject of several physiological and ethological studies, thanks to its relatively easy rearing in the laboratory (Wilson, 1946; Denton and Gilpin-Brown 1961; Richard, 1967 and 1971, Lemaire 1970; Boletzky 1971; Pascual, 1978). More recently, *S. officinalis* has been studied for growth (Agus et al., 2024; Al-BeaK, 2024), biology (Martinez-solar et al. 2007; Souquet et al., 2023), ecology (Guerra, 2006; Safi, 2013,) and exploitation (Royer et al. 2006; Gras 2013). In Algeria, few studies have been carried out on this species, apart from the work of Oumouna (1991), Yanat (1994) and Seddikioui et al. (2017). For the first time in Algeria, this work provides data on the composition of the food bolus of cuttlefish *S. officinalis* in the central Algerian region, as well as its variations over time and between the sexes.

2 MATERIALS AND METHODS

This study is based on 284 stomachs from individuals harvested from the trawl fishery in the Algerian region from January 2011 to January 2012. All cuttlefish sampled were weighed, measured and sexed. The measurement taken corresponds to the dorsal length of the mantle (expressed in cm). The stomach contents are preserved in 10% formalin before examination, where they are observed under a binocular magnifying glass (magnification from 10 to 40). Prey are determined by the highest possible taxonomic rank and, for fish, by comparison with a collection of otoliths. Two types of analysis are used. The first, qualitative, consists in drawing up a faunal list of identified prey. The second, quantitative, is based on the calculation and monitoring of the replenishment index (RI). This index indicates the ratio of stomach weight to the total weight of the individual as a percentage (Bliss, 1967). In addition, Hureau's (1970) frequency f, which corresponds to the percentage of stomachs containing a prey category in relation to the number of full stomachs examined, was used to establish Sorbe's (1972) prey classification. When the frequency is less than 10%, they are accidental prey of no particular significance in the species' diet. When the frequency is between 10 and 50%, they are secondary prey, representing accessory or replacement food for the species. A prey frequency value of over 50%, on the other hand, reflects preferential prey, constituting the main diet and characterizing the type of diet of the species. This study is based on the sex, season and size of the individuals.

3 RESULTS

The gastric contents of 284 individuals were examined, 159 in the cold season (autumn and winter) and 125 in the warm season (spring and summer). Table 1 shows the number of S. officinalis individuals collected by season and sex.

Table 1. Number of individuals sampled per season.

Season	Number of females	Number of males	Total number of stomachs per season
Winter	41	34	75
Spring	39	28	67
Summer	26	32	58
Fall	39	45	84

Specific prey analysis enables us to determine the composition of cuttlefish diets in the wild. The diet consists mainly of fish, crustaceans, worms and molluscs (Table 2). Fish are all benthic or bottom-dwelling teleosts, identified by their otoliths. Crustaceans are mainly represented by shrimps and crabs. Only one cephalopod genus is present, sepia sp, where there were no bones or jaws, but only pieces of flesh or tentacles.

3.1 PREY FREQUENCY INDEX

The different prey groups of *S. officinalis*, expressed in frequency (f), the number of stomachs containing a given prey (N) and the number of stomachs examined (284) for all sexes combined are shown in Table 3.

Table 2. Inventory of prey ingested by *S. officinalis.*

Branch	Family/Class/Order
Fiches	Soleidae Gobiidae Apogonidae

Crustaceans	Isopoda (sphaeromatidae) Amphipodae Ostracodae Crabs *Gonoplax romboides* Copepodae Shrimps Cladocerae
Echinoderms	Holothuria
Worms	Polychaete Nematodae
Molluscs	Thecosomes Bivalves Gasteropodae Cephalopods (*Sepia*)
foraminiferal protists	Nonion Elphidium

Table 3. Number of stomachs (N) containing prey and their frequency (f). The number of stomachs examined was 284, with 160 full stomachs and 124 empty stomachs.

prey groups	f	N
Crustaceans	59.17	171
Fishes	58.13	168
Worms	21.8	63
Crabs	19.03	55
Molluscs	15.92	46
Thecosomes	8.65	25
Shrimps	8.30	24
Cephalopods (*Sepia*)	4.49	13
Holothurias	0.69	2

Based on Sorbe's (1972) classification of prey frequency, *S. officinalis* prefers crustaceans and fish. Secondary prey are worms, crabs and molluscs. Cephalopods and Holothurians are accidental prey. Cuttlefish tentacles were ingested by some individuals weighing over 200g (or 11.4cm MDL): in January (3 individuals), March (3 individuals), November (2 individuals) and a single individual in April and July

3.1.1 Comparison of diets between the sexes

When comparing the two sexes, there were no notable differences in the quality of their diets. Nevertheless, it is possible to observe a very slight dominance of fish in the diet of females (39% vs. 35% in males) and a slight dominance of crustaceans in males (39% vs. 37% in females).

3.1.2 Seasonal changes in diet

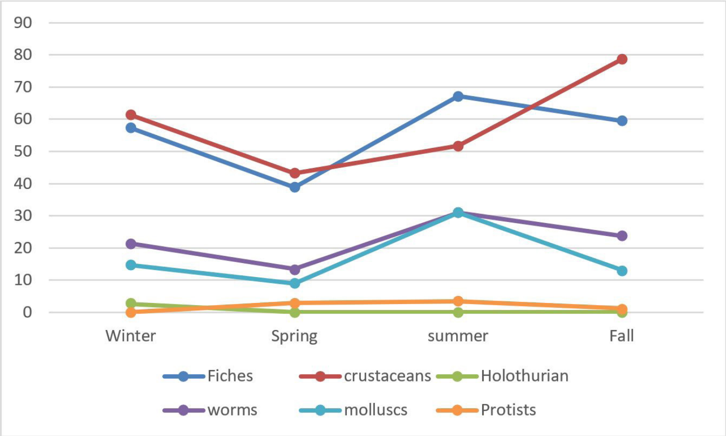
Seasonal monitoring of stomach contents is intended to detect any variations in diet as a function of cuttlefish sexual maturity. This monitoring is based on 145 females and 139 males. Figure 1 shows the variations in the frequency index.

Fish and crustaceans are preferred prey in all seasons, except spring, when all frequencies decrease. This is probably due to the breeding season. It can be noted that fish are dominated by crustaceans throughout the year, except in summer. Molluscs and worms, with a similar pattern, are secondary prey in all seasons, while sea cucumbers and protists remain accidental prey.

3.1.3 Seasonal variations by gender

For males, fish remain the preferred prey, except in spring, when the frequency drops considerably. Worms are secondary prey for males in all seasons. Crustaceans are preferred prey in spring and autumn. They become secondary in winter and summer. Molluscs are preferred prey in two seasons: winter and spring, and secondary in summer and autumn.

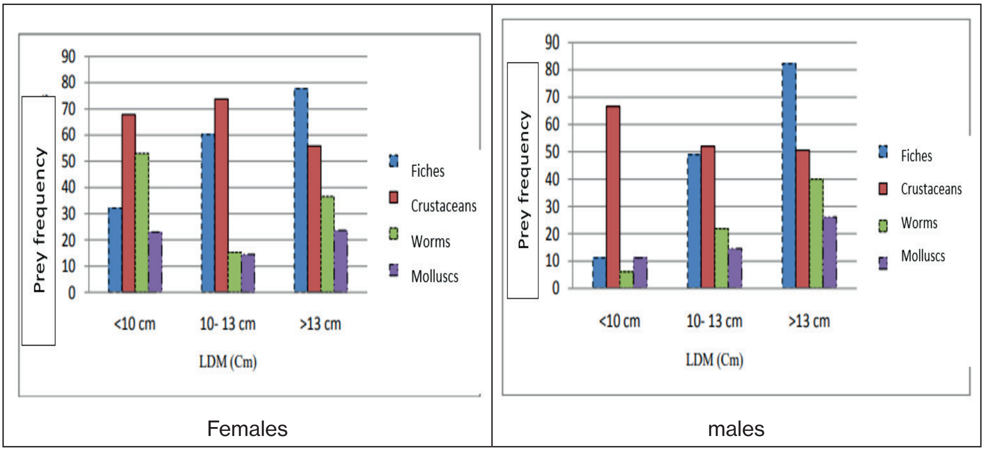
Figure 1. Seasonal variations in the diet of *S. officinalis*, sexes combined.



3.1.4 Diet variations according to size and sex

A distinction is made according to the size of the individuals: less than 10cm, between 10 and 13cm and greater than 13cm (Figure 2 and 3), taking into account that above 13cm, all individuals are mature.

Figure 2 and 3. Diet variation by size and sex.



Crustaceans are the preferred prey, whatever the size of the female. Worms are the preferred prey for small females (under 10cm), with crustaceans predominating. Fish and molluscs are secondary prey for these small individuals.

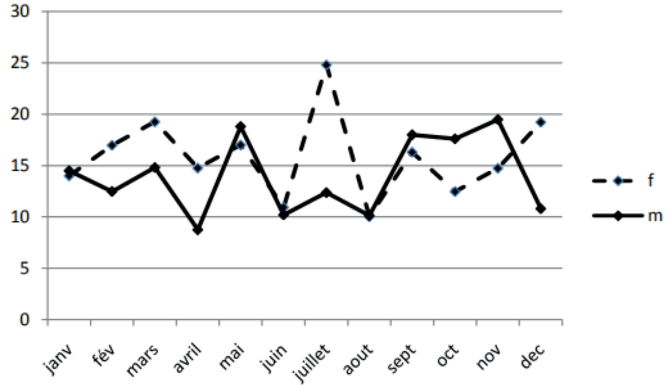
For medium-sized individuals (10 to 13 cm), fish are the preferred prey. Worms and molluscs are secondary prey in almost equal proportions. In the case of large females, over 13cm in size, fish are still the preferred prey, with crustaceans dominating. Worms and molluscs remain secondary prey. Crustaceans are the preferred prey for males. Small individuals feed mainly on crustaceans, while medium-sized individuals (10-13cm) feed on fish and crustaceans. In larger individuals, fish are the preferred prey, followed by crustaceans, while worms and molluscs are secondary prey.

3.2 REPLENISHMENT INDEX

The replenishment index values for females range from 10.03 in August to 24.8 in July. For males, the values ranged from 8.75 in April to 19.48 in November. This observation shows that females have higher replenishment indices.

The curve for this index shows jagged variations depending on the month (Figure 4). The first major peak for females was in July, followed by a second peak in March. For males, on the other hand, the first peak was in May and the second in November. It should be noted that this index is higher in winter for females and in autumn for males, with minimal values in spring for both sexes.

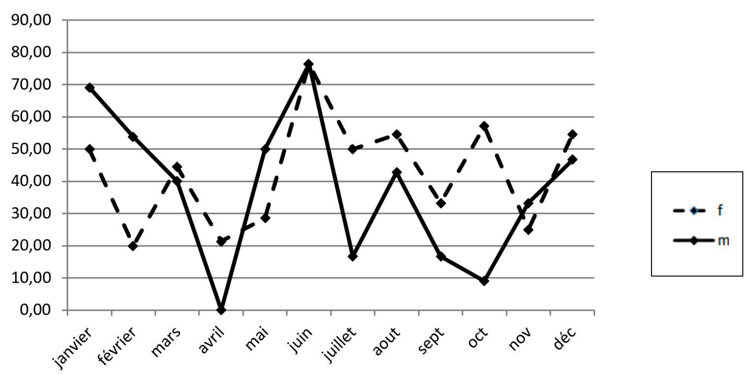
Figure 4. Monthly variation in the replenishment index.



3.3 VACUUM COEFFICIENT

The curve of this coefficient as a function of the month also shows jagged variations (Fig. 5). The values of the vacuity coefficient for females range from 20 in February to 76.47 in June. For males, the values range from 9.09 in October to 76.47 in June. The zero value for males in April means that there was no empty stomach. The first major peak was in June for both sexes, while the second peak was in January for males and October for females. Depending on the season, the emptiness coefficient is higher in spring for both sexes.

Figure 5. Monthly variation in the vacuity coefficient in *S. officinalis.*



4 DISCUSSION

Knowledge of the diet makes it possible to explain the foraging behaviour of the species studied, its migrations, certain aspects of its reproduction, its place in the food chain and its impact on the environment in which it lives. Generally speaking, the diet is based on fish and crustaceans, which is consistent with the results of other authors: Najai and Ktari (1979) in the Gulf of Tunis; Guerra (1985) and Castro and Guerra (1990) in the Ria de Vigo; Le Mao (1985) in the Bay of Rance; Pincson du sel and Daguzen (1992) in the Bay of Biscay, Alves et al. (2006) in northern Portugal and Evans (2012) in the Channel. Qualitative analysis of cuttlefish stomach contents is often made difficult by the advanced stage at which the prey is examined. Generally, the parts that are resistant to the mechanical and chemical action of stomach digestion (mandibles, setae, valves, otolith, claws, appendages, etc.) are the only ones that can be easily identified in the stomach. Consequently, identification was limited to the class of animals ingested. Feeding habits are similar between males and females. This is consistent with the observations of Guerra (2006) and Neves et al (2009), who add that this species is an opportunistic predator.

The presence of cuttlefish arms in the stomachs of some individuals probably reflects struggles and bites in the trawl. This was noted by Pinczon du sel and Daguzen (1992). Another hypothesis explaining the presence of cephalopod arms would be those of Guerra (1985), Castro and Guerra (1990) and Alves et al (2006); this sporadic cannibalism would be a common phenomenon in spawning areas that could be explained by fighting during mating (Pinczon du sel et al., 2000), 2000). There is a seasonal variation in the diet linked to variations in maturity stages, a result already confirmed by Neves et al (2009), who explain these variations by the migrations of cuttlefish (rib-wing). The diet of S. officinalis is based essentially on crustaceans, except in summer, when the diet is reversed, with fish predominating. Pinczon du sel et al (2000) refer to this inversion of the diet between the overwintering area and the spring area as being linked to reproduction. Crustaceans are secondary prey in autumn and summer. These seasons correspond to the breeding season for large individuals. Neves et al (2009) observed Foraminifera exclusively in juveniles, whereas our work revealed these types of prey in females larger than 13 cm and in both sexes between 10 and 13 cm. Foraminifera

The present results show that young cuttlefish feed on small prey. These observations were also reported by Richard (1971) and Duval et al (1984) who demonstrated in the laboratory the existence of an optimal size ratio between cuttlefish and their prey. In fact, we have observed that juveniles feed on amphipods and decapods. In this class (juveniles), prey is varied. This was noted by Castro and Guerra (1990), who found that the number of prey varieties decreased with increasing size. Our study showed that food preferences changed with size. Small individuals under 10 cm in size prefer crustaceans. In medium-sized individuals corresponding to the size of first sexual maturation (10 - 13 cm), fish are added to crustaceans as preferred prey. As they mature, adults feed mainly on fish. The study by Neves et al (2009) highlighted the predominance of crabs and fish in adult cuttlefish, and Le Mao (1985) concluded that the largest individuals sought out large demersal and nectonic fish: Dicentarchus labrax, Belone belone, Gadidae and Labridae. The same author asserted that there was an evolution in the diet according to size, with Mysidacea and Amphipoda being the prey eaten by the smallest specimens, while Dicentarchus labrax, Belone belone, Gadidae and Labridae were the prey eaten by the largest individuals.

The repletion index gives low values. This is demonstrated by Lacoue-Labarthe (2007), who notes that the cuttlefish has a high metabolism and is linked to a carnivorous diet. Najai and Ktari (1979) and Guerra (2006) explain these low values by very rapid digestion. In our study, this index averaged 15.3% in adults in winter. This value falls in spring to 12.8%. This represents a reduction of around 83%. Pinczon du sel and Daguzan (1992) explain this drop by the fact that adults stop feeding because the genital organs compress the digestive system. Interpreting the emptiness coefficient is difficult because it does not accurately reflect the animal's emptiness. In fact, according to Kohler (in Najai, 1983), emptiness may be caused by complete digestion due to the absence of prey within the predator's reach. The values obtained for the coefficient are therefore not very significant; only the shape of the curve gives an idea of the trophic behaviour (Najai, 1983). The vacuity coefficient obtained in this study clearly shows spring reproduction of cuttlefish in the Algerian region. Pinczon du sel et al (2000) show that cuttlefish reduce their trophic activity during spawning. Our results also enabled us to observe a higher vacuity coefficient in males, the same observation made by Quintela and Andrade (2002) who explain that the high values of this coefficient are due to the fact that the males are more active during spawning.

Analysis of the diet of S. officinalis revealed a diet based on fish and crustaceans, with an increase in prey size as cuttlefish size increased. This study compared the feeding habits of this species as a function of sex, size and season, where nutritional activity decreases in spring and summer during gonad maturation, as demonstrated by the increase in the vacuity index.

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