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Feeding habits of *Pagellus acarne* (Sparidae) in the Gulf of Tunis, central Mediterranean

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SUMMARY: The feeding habits of the axillary seabream, *Pagellus acarne* (Risso, 1810), from the Gulf of Tunis were investigated in relation to season, sex and fish size (juveniles TL<14.5 cm and adults TL≥14.5 cm). A total of 536 specimens (males, females, unsexed and hermaphroditic), ranging between 11.0 and 25.2 cm TL, were collected with trammel nets from June 2005 to July 2006. Their stomach contents were analysed. Of the total number of examined stomachs, 279 stomachs were empty (Vacuity index, *VI* = 52%). The *VI* did not reveal significant seasonal differences when all of the specimens were analysed together; however, significant seasonal variations were observed for females. The diet of the axillary seabream was composed of 36 different prey species. The most important prey were Arthropoda, Mollusca and Echinodermata. Both the dietary indices and the Spearman's coefficient of correlation indicated seasonal variations in the diet. The diet was more diversified in adults than in juveniles. The axillary seabream fed on a wide range of prey items, endofauna and nekton, and can be considered a carnivorous and euryphagous predator.

Keywords: *Pagellus acarne*, diet, dietary indices, Gulf of Tunis, central Mediterranean.

RESUMEN: La dieta de *Pagellus acarne* (Sparidae) en el golfo de Túnez, Mediterráneo central. – Se estudió la dieta del aligote, *Pagellus acarne* (Risso, 1810), del golfo de Túnez en función de las estación del año, del sexo y de dos grupos de talla: juveniles (LT <14.5 cm) y adultos (LT ≥14.5 cm). Entre junio 2005 y julio 2006 se recolectaron con trasmallos, un total de 536 ejemplares (machos, hembras, sexos no determinados) cuya longitud total oscilaba entre 11 y 25.5 cm. Se analizó el contenido estomacal; 279 estaban vacíos (índice de vacuidad, VI = 52.0%). Este índice no reveló diferencias significativas en relación a la estación del año. Sin embargo, se observaron importantes variaciones estacionales para las hembras. Se identificaron un total de 36 especies de presas en la dieta. Las más frecuentes eran artrópodos, moluscos y equinodermos. Los índices de alimentación calculados, así como la aplicación del coeficiente de correlación de Spearman, mostraron variaciones estacionales. El análisis específico de las presas evidenció que la dieta de los machos era diferente a la de las hembras y era más variada en los adultos que en los juveniles. *P. acarne* se alimenta de un amplio espectro de presas, endofauna y necton, y podría considerarse como depredador carnívoro y eurífago.

Palabras clave: *Pagellus acarne*, dieta, índices de alimentación, golfo de Túnez, Mediterráneo central.

INTRODUCTION

In the Mediterranean there are 23 Sparidae species, 4 of which belong to the *Pagellus* genus: the common pandora, *Pagellus erythrinus*, (Linnaeus, 1758), the axillary seabream, *P. acarne* (Risso, 1810), the red pandora, *P. bellottii* (Steindachner, 1882) and the blackspot seabream *P. bogaraveo* (Brünnich, 1756). The last species is more common on the continental slope, while the other species prefer to inhabit the continental shelf (Bonnet, 1969; Spedicato *et al.,* 2002). Andaloro and Rinaldi (1998) suggested that the presence of *P. acarne* in the Mediterranean is the result of the "tropicalisation" of this sea. The *Pagellus* species are generally known as hermaphroditic, *P. acarne* and *P. bogaraveo* as proterandric and *P. erythrinus* and *P. bellottii* as protogynous (D'Ancona, 1949; Larrañeta, 1964;

Lissia and Frau, 1968; Fischer *et al.*, 1987).

P. bellottii has never been recorded in Tunisia; *P. bogaraveo* is confined to the northern coasts of Tunisia whereas *P. erythrinus* and *P. acarne* are found everywhere (Bradaï, 2000). The main target of local fisheries is the common pandora (2441 tons/year, from coastal and trawl fleets). Conversely, landings of the axillary seabream are rather low along the northern coasts and only mentioned occasionally (Lubet and Azouz, 1969; Bouhlel, 1978; Bradaï, 2000). Only one study is available on the reproduction of this species in the Gulf of Tunis (Mokrani *et al.*, 2007). However, the economic interest of the axillary seabream has stimulated some biological studies in other Mediterranean regions, such as in the Ionian Sea (Andaloro, 1983a), Greek waters (Mytilineou, 2000), the Algerian sea (Zerouali-Khodja and Amalou, 2005), around Canary isles (Pajuelo and Lorenzo, 2000) and south Portugal (Coelho *et al.*, 2005). Since 1990, following the adoption of the strategic necessity to diversify the artificial production of finfish species in the Mediterranean (Abellán and Basurco, 1999), the culture of *P. acarne* started in Italy (Greco *et al.*, 1995; Arculeo *et al.*, 2000) and in Spain (Dominguez, 2000). The Feeding habits of *P. acarne* have been studied in Atlantic (Domanevskaya and Patokina, 1984; Morato *et al.*, 2001) and Mediterranean waters (Andaloro, 1983b; Rizkalla *et al.*, 1999).

To improve the stock management of the axillary seabream and to ensure its sustainability, the key parameters relating to its dynamics and exploitation have been defined. Natural and fishing mortalities have been estimated in Atlantic waters (Pajuelo and Lorenzo, 2000). Selectivity of the fishing gears has been studied for this species in Greek (Petrakis and Stergiou, 1996; Tokaç *et al.*, 1998) and Portuguese waters (Santos *et al.* 1995; Campos and Fonseca, 2003).

The purpose of this work was to study the feeding habits of the axillary seabream in the Gulf of Tunis through stomach content analysis.

MATERIAL AND METHODS

Fish sampling

Samples of axillary seabream were collected twice per month from the artisanal fleet operating in the Gulf of Tunis (Fig. 1) with trammel nets of 48 mm mesh size (stretched). The nets were set at night and hauled in the morning.

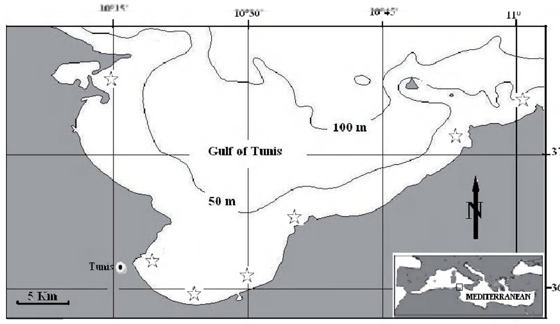

FIG. 1. – Map of the Gulf of Tunis showing the study area of *P. acarne*. (☆): Sampling localities.

From June 2005 to July 2006, all the axillary seabream specimens caught were collected and considered for this study. Each specimen was measured to the nearest mm (TL, total length), dissected and sexed. The individuals were classified into two size groups, juveniles (TL<14.5 cm) and adults (TL≥14.5 cm), on the basis of the smallest size at maturity (Mokrani *et al.*, 2007). The stomach was removed from each specimen and preserved in a 70° alcohol solution.

Stomach content analysis

The stomach contents were washed in a Petri dish and examined under a microscope. The food items were sorted into large taxonomic groups and, when possible, identified to the species level according to Riedel (1983) and Fischer *et al.* (1987). When the state of digestion was not advanced, the number of prey was counted. Otherwise, the number of prey was determined from the hard structures. The vacuity index (*VI*, %), the frequency of occurrence (*FO*, %) and the numerical percentage of a prey item i (*N*, %) were calculated according to Hureau (1970) and Berg (1979) as follows:

$$VI = \frac{Nv}{Ne} \times 100 \qquad FO = \frac{Ndi}{Nnv} \times 100 \qquad N = \frac{Nti}{Ni} \times 100$$

where Nv = number of empty stomachs, Ne = total number of examined stomachs, Ndi = number of stomachs containing the prey i, Nnv = total number of stomachs containing some food, Nti = total number of prey i, Ni = total number of ingested prey.

The point method proposed by Hynes (1950), Berg (1979), Pasquaud *et al.* (2004), and Bouchereau *et al.* (2006) was used to estimate the ingested biomass of each item. Each prey is assigned a number of points (*P*, %) proportional to its estimated contribution to the whole stomach volume (Table1), as

TABLE 1. – Points given to food items of the diet of *P. acarne* in relation to their digestibility and size according to Pasquaud *et al.* (2004) and Bouchereau *et al.* (2006).

Taxa	Points	Taxa	Points
Teleostei	100	Decapoda (crabs)	10
Annelida	40	Mollusca	1
Echinodermata	25	Bacillariophyta	1
Decapoda (shrimps)	25	Phytophyta	1
Amphipoda	10	Bryozoa	1
Isopoda	10	Nemathelminths	1
Cumacea	10	Foraminifera	0.5
Mysidacea	5	Ostracoda	0.5

follows:

$$P = \frac{Npi}{Ntp} \times 100$$

where Npi = total number of points of a prey item, Ntp = total number of points.

The food preference of axillary seabream was determined by applying the Main Food Index (*MFI*) (Zander, 1982):

$$MFIi = \frac{\sqrt{Pi(Ni + Fi)/2}}{\sum_i MFIi} \times 100$$

Prey were classified based on *MFI* values as follows:

MFI > 75 = preferential prey, 50 <*MFI*< 75 = main prey, 25 <*MFI*< 50 = secondary prey and *MFI* < 25 = accessory prey.

Statistical differences of the different indices (*VI*; *FO*; *N*) in relation to season or sex were assessed by the chi-square goodness of fit test (χ^2) at p = 0.05.

Variations in the diet of the axillary seabream were estimated using the Spearman coefficient of correlation (ρ) (Falissard, 2005):

$$\rho = 1 - \frac{6\sum d^2}{n^3 - n}$$

where n = rank number and d = difference between ranks.

The items were classified according to a decreasing order of the coefficient value. For the same sample, the rank attributed to the equally placed items corresponds to the mean ranks that the items would have had if they had not been identical values of the dietary index. Statistical significance of ρ was tested using the t-Student test at p = 0.01:

$$t = \frac{\rho}{(1-\rho^2)^{1/2}} \times (n-2)^{1/2}$$

RESULTS

A total of 536 specimens of *P. acarne* ranging from 11 cm to 25.2 cm were collected over the entire year (Table 2).

Feeding intensity

Out of 536 stomachs examined, 273 were empty (vacuity index, *VI* = 52 %). The vacuity index did not reveal any significant differences over the year (χ^2 = 3.09; p>0.05), and accounted for 58 % in summer, 48 % in autumn, 49 % in winter and 53 % in spring. However, the vacuity index computed by sex showed significant seasonal variations for females (*VI* = 51%; χ^2 = 10.4, p<0.05), but did not present significant seasonal variations for males (*VI* = 52 %; χ^2 = 1.10, p>0.05). *VI* values only differed significantly between sexes in autumn (Table 3). The mean annual *VI* recorded in juveniles (Lt<14.5 cm) was 87.8% with a maximum in autumn and spring (100%) and was higher than that of the adults (Lt≥14.5cm)

TABLE 2. – *P. acarne* specimens collected in the Gulf of Tunis from June 2005 to July 2006.

Seasons	Females	Males	Unsexed	Hermaphroditics	Total
Summer	54	57	9	1	121
Autumn	34	90	0	0	124
Winter	57	103	16	4	180
Spring	42	55	11	3	111
Total	187	305	36	8	536

TABLE 3. – Seasonal variations of the vacuity index (*VI*) of *P. acarne* and statistical comparison between males and females. SD: Standard deviation.

Seasons	*VI* (%) Males	Females	SD	Significance (p=0.01)
Summer	53.1	65.6	0.08	-
Autumn	59.4	32.2	0.10	+
Winter	48.6	53.1	0.07	-
Spring	47.4	53.3	0.09	-
Annual *VI* (%)	52.1	51	0.04	-

TABLE 4. – Seasonal variations of the vacuity index (*VI*, %) of *P. acarne* in juveniles and adults.

Seasons	Juveniles (TL<14.5cm)	Adults (TL≥14.5cm)
Summer	64.3	55.5
Autumn	100	46.6
Winter	86.9	43.6
Spring	100	52.3
Annual *VI* (%)	87.8	49.5

TABLE 5. – Prey identified in the stomach contents of *P. acarne* in relation to season. *FO*, frequency of occurrence; *N*, numerical percentage; *P*, point percentage; *MFI*, main food index; R, classification of prey.

Taxa	Summer *FO* (%)	*N* (%)	*P* (%)	*MFI*	R	Autumn *FO* (%)	*N* (%)	*P* (%)	*MFI*	R
ARTHROPODA										
CRUSTACEA DECAPODA										
Crangon crangon	1.8	1.4	1.2	1.18		7.8	3.9	13.5	8.9	
Ebalia sp.	1.8	1.2	1.3	1.4		11	4.6	5.9	6.7	
Liocarcinus arcuatus	1.8	0.4	0.7	0.8		-	-	-	-	
Pagurus sp.	3.7	2.6	2.1	2.3		1.6	0.3	0.4	0.6	
Unidentified Decapoda	-	-	-	-	-	-	-	-	-	
Total Decapoda	**9.2**	**3.5**	**5.3**	**5.7**		**20.3**	**8.8**	**19.8**	**16.2**	
MYSIDA										
Mysis sp.	14.8	10.1	6.9	9.2		26.6	9.7	6.3	10.7	
ISOPODA										
Sphaeroma serratum	9.2	12.1	18.1	13.9		9.4	4.8	6.3	6.7	
CUMACEA	-	-	-	-		1.6	1	1	1.2	
OSTRACODA										
Cypridina mediterranea	3.7	1.2	0.1	0.4		10.9	2.6	0.1	1	
AMPHIPODA										
Gammarus gammarus	13	7.	9.8	9.9		1.6	1	1.2	1.2	
Total Arthropoda	**50.2**	**37.9**	**40.1**	**39.1**	(1)	**70.2**	**27.9**	**35**	**37.1**	(2)
MOLLUSCA										
BIVALVIA										
Flexopecten flexuosus	7.7	0.7	0.4	2.1		-	-	-	-	
Unidentified	41.4	25.9	3.5	10.3		34.6	14.5	1.7	7.3	
GASTEROPODA										
Phyllonotus trunculus	-	-	-	-		-	-	-	-	
Calliostoma granulatum	8.56	5.72	0.31	1.43		4.68	3.92	0.35	1.08	
Calliostoma ziziphinum	-	-	-	-		-	-	-	-	
Cerithium alucastrum	0.14	0.01	0.01	0.02		-	-	-	-	
Lunatia sp.	4.4	0.8	0.1	0.5		6.2	0.3	0.03	0.3	
Turritella communis	7.4	1.6	0.4	1.2		3.1	3.5	0.4	1.	
Caecum trachea	4.4	0.8	0.1	0.5		-	-	-	-	
Philine catena	-	-	-	-		1.6	0.6	0.2	0.4	
Rissoa sp.	2.8	0.4	0.04	0.2		3.1	1.3	0.1	0.4	
Retusa sp.	2.8	0.4	0.04	0.2		9.1	1	0.4	1.2	
SCAPHOPODA										
Antalis dentalis	3.7	1.6	0.2	0.7		4.7	2.6	0.3	1.1	
CEPHALOPODA										
Sepia officinalis	-	-	-	-		1.6	0.3	0.04	0.2	
Total Mollusca	**83.3**	**37.9**	**5**	**17.1**	(3)	**68.7**	**28.1**	**3.5**	**13**	(3)
ECHINODERMATA										
Paracentrotus lividus	-	-	-	-		7.8	2.3	7.5	8.1	
Neolampas rostellata	7.4	3.9	14.1	8.9		21.9	8.4	34.8	22.9	
Amphipholis squamata	11	8.2	25.1	18.4		28.7	7.4	29.6	19.7	
Total Echinodermata	**18.5**	**12.1**	**39.2**	**27.3**	(2)	**48.4**	**18.1**	**71.8**	**50.7**	(1)
ANNELIDA										
Nereis sp	7.4	2.3	10.8	6.6	-	-	-	-		
Sabellidae	1.8	0.8	3.9	3.5	-	-	-	-		
Serpulidae	1.8	0.8	3.9	3.5		4.7	1.3	6.8	4.5	
Total Annelida	**11.1**	**3.9**	**18.7**	**13.6**	(4)		**1.3**	**6.8**	**4.5**	(4)
BACILLARIOPHYTA	**1.8**	**0.8**	**0.1**	**0.3**	(8)	**10.9**	**6.1**	**0.8**	**2.5**	(6)
BRYOZOA	**3.7**	**1.9**	**0.2**	**0.8**	(6)	**4.7**	**1.3**	**0.1**	**0.6**	(8)
FORAMINIFERA	**9.2**	**5.8**	**0.4**	**1.7**	(5)	**25**	**12.6**	**0.78**	**3.8**	(5)
NEMATHELMINTHA	**-**	**-**	**-**	**-**		**1.6**	**0.3**	**0.04**	**0.2**	(9)
TELEOSTEI	**-**	**-**	**-**	**-**		**-**	**-**	**-**	**-**	
PHYTOPHYTA										
Pyrocystis lunula	3.7	1.2	0.1	0.6		11	2.9	0.3	1.5	
Total Phytophyta	**3.7**	**1.2**	**0.1**	**0.6**	(7)	**10.9**	**2.9**	**0.3**	**1.5**	(7)

(Table 4). The *VI* did not show any significant variations with season for either size group ($\chi^2_{Juveniles} = 5.92$, p>0.05; $\chi^2_{Adults} = 4.05$, p>0.05).

Diet composition

The stomach contents of the axillary seabream were composed of 36 different taxa belonging to nine

Table 5 (cont.). – Prey identified in the stomach contents of *P. acarne* in relation to season. *FO*, frequency of occurrence; *N*, numerical percentage; *P*, point percentage; *MFI*, main food index; R, classification of prey.

Taxa	Winter *FO* (%)	*N* (%)	*P* (%)	*MFI*	R	Spring *FO* (%)	*N* (%)	*P* (%)	*MFI*	R
ARTHROPODA										
CRUSTACEA DECAPODA										
Crangon crangon	13.4	8.1	28.7	17.4		13.5	12.1	42.3	19	
Ebalia sp.	10.3	5.3	5.6	5.8		3.8	1.3	2.1	1.9	
Liocarcinus arcuatus	12.3	4	1.6	2.9		1.9	0.7	0.3	0.5	
Pagurus sp.	3.3	1.5	1.6	1.8		5.8	2	2	2.3	
Unidentified Decapoda	-	-	-	-		1.9	0.7	0.3	0.5	
Total Decapoda	**39.1**	**18.8**	**37.5**	**44.3**		**26.9**	**27**	**46.9**	**24.1**	
MYSIDA										
Mysis sp.	5.4	8.1	4.7	5.6		3.8	2	1	2.1	
ISOPODA										
Sphaeroma serratum	6.5	3.3	3.8	4.3		15.4	9.7	9.4	8	
CUMACEA	1.1	0.5	0.8	0.8		-	-	-	-	
OSTRACODA										
Cypridina mediterranea	10.9	8.5	0.4	1.9		1.9	1.3	0.1	0.3	
AMPHIPODA										
Gammarus gammarus	20.1	18.1	13.9	13.3		11.5	9.7	9.4	1	
Total Arthropoda	**83.1**	**57.3**	**57.3**	**70.3**	**(1)**	**59.6**	**49.8**	**66.7**	**42.4**	**(1)**
MOLLUSCA										
BIVALVIA										
Flexopecten flexuosus	0.2	0.8	0.2	0.6		-	-	-	-	
Unidentified	9.6	5.3	0.4	1.6		-	-	-	-	
GASTEROPODA										
Phyllonotus trunculus	-	-	-	-		14.1	7.3	1.4	4.8	
Calliostoma granulatum	2.3	0.5	0.1	2.3		-	-	-	-	
Calliostoma ziziphinum	-	-	-	-		5.7	2	0.2	0.7	
Cerithium alucastrum	-	-	-	-		-	-	-	-	
Lunatia sp.	-	-	-	-		-	-	-	-	
Turritella communis	1.1	0.5	0.06	0.2		7.7	2.7	0.3	0.9	
Caecum trachea	-	-	-	-		3.8	0.2	0.3	0.6	
Philine catena	1.1	0.2	0.02	0.2		-	-	-	-	
Rissoa sp.	1.1	0.2	0.02	0.2		1.8	0.2	0.3	0.6	
Retusa sp	2.2	0.5	0.1	0.2		-	-	-	-	
SCAPHOPODA										
Antalis dentalis	2.2	0.5	0.05	0.2		-	-	-	-	
CEPHALOPODA										
Sepia officinalis	1.1	0.2	0.02	0.1		-	-	-	-	
Total Mollusca	**21**	**8.8**	**0.8**	**3.6**	**(5)**	**33.2**	**13.5**	**2.3**	**7.8**	**(3)**
ECHINODERMATA										
Paracentrotus lividus	2.2	0.5	1.4	1.4		3.8	1.3	3.4	2.4	
Neolampas rostellata	1.1	0.2	0.7	0.7		3.8	1.3	3.4	2.4	
Amphipholis squamata	12	6	14	10.1		28.8	27.8	27	28.9	
Total Echinodermata	**15.2**	**6.78**	**16.1**	**12.9**	**(2)**	**36.5**	**30.4**	**33.8**	**33.7**	**(2)**
ANNELIDA										
Nereis sp	4.3	1.9	15.1	6.3		-	-	-	-	
Sabellidae	4.3	2.1	6.6	5.5		-	-	-	-	
Serpulidae	-	-	-	-		-	-	-	-	
Total Annelida	**8.7**	**4**	**21.7**	**11.8**	**(3)**	**-**	**-**	**-**	**-**	**-**
BACILLARIOPHYTA	**1.1**	**0.2**	**0.02**	**0.1**	**(10)**	**3.8**	**2**	**0.2**	**0.6**	**(6)**
BRYOZOA	**1.1**	**0.5**	**0.05**	**0.2**	**(9)**	**-**	**-**	**-**	**-**	**-**
FORAMINIFERA	**17.4**	**9.8**	**0.5**	**2.7**	**(6)**	**17.3**	**7.4**	**0.4**	**1.7**	**(4)**
NEMATHELMINTHA	**5.4**	**2.3**	**0.2**	**1**	**(8)**	**-**	**-**	**-**	**-**	**-**
TELEOSTEI	**3.3**	**1**	**12.5**	**5.2**	**(4)**	**-**	**-**	**-**	**-**	**-**
PHYTOPHYTA										
Pyrocystis lunula	13.4	4	0.4	1.9		7.7	2.7	0.3	0.9	
Total Phytophyta	**13**	**4**	**0.4**	**1.9**	**(7)**	**7.7**	**2.7**	**0.3**	**0.9**	**(5)**

major taxa (Table 5). The most important prey were Arthropoda (10 taxa), Mollusca (14 taxa) and Echinodermata (3 taxa). Arthropoda were mainly represented by crustaceans such as Decapoda (*Crangon crangon*, *Ebalia* sp., *Liocarcinus arcuatus*, *Pagurus* sp.), Amphipoda (*Gammarus gammarus*), Mysida (*Mysis* sp.), Isopoda (*Sphaeroma serratum*), and one unidentified Cumacea and one Ostracoda (*Cypridina* *mediterranea*). The phylum Mollusca was represented by Gastropoda (*Phyllonotus trunculus*, *Calliostoma granulatum*, *C. ziziphinum*, *Cerithium alucastrum*, *Lunatia* sp., *Turritella communis*, *Caecum trachea*, *Philine catena*, *Rissoa* sp. and *Retusa* sp.), 2 bivalves (*Flexopecten flexuosus* and one unidentified), 1 Scaphopoda (*Antalis dentalis*) and 1 Cephalopoda (*Sepia officinalis*). Echinodermata were represented by 1 Echinoideae (*Pracentrotus lividus*), 1 Neolampapidae (*Neolampas rostellata*) and 1 Amphiuridae (*Amphipholis squamata*). It should be noted that both Gastropoda and bivalve shells were found intact in the alimentary tract of the axillary seabream. Annelida were represented by 3 taxa, namely *Nereis* sp., Serpulidae and Sabellidae. Bacillariophyta, Bryozoa, Foraminifera, Nemathelmintha and Teleostei, were only represented by single taxa. Finally, Phytophyta were exclusively represented by Dinophyceae (*Pyrocystis lunula*).

Seasonal variations in the diet

Dietary indices calculated for each prey indicated that the axillary seabream fed mainly on Arthropoda and Mollusca over the year (Table 5). Arthropoda, more frequent and abundant in winter and autumn, showed significant seasonal variations in frequency of occurrence ($\chi^2 = 8.64$, $p<0.05$) but not in abundance ($\chi^2 = 6.29$, $p>0.05$). The point method showed that Arthropoda were more than 50 % of the ingested biomass in spring (P = 66.7%), while in summer and autumn they represented only 40.1% and 35% respectively, which shows significant seasonal variations ($\chi^2 = 17.21$, $p<0.05$). Mollusca attained the highest frequency of occurrence in summer (FO = 83.3%) and the lowest in winter (FO = 21%), thus revealing significant seasonal variations ($\chi^2 = 46$, $p<0.05$). Arthropoda constituted the main prey of the axillary seabream in winter (MFI = 70) and secondary prey during the rest of the year, while Mollusca were accessory prey all year round (MFI<25). Echinodermata were secondary prey ($13<MFI<51$), and showed seasonal variations in frequency of occurrence ($\chi^2 = 50.77$, $p<0.05$), number ($\chi^2 = 13.19$, $p<0.05$) and biomass ($\chi^2 = 69.58$, $p<0.05$). Annelida were absent in the diet in spring, poorly represented in autumn and increased in winter and summer. The other prey contributed very little to the ingested biomass (Table 5). The ingestion of fish, Bryozoa and Nemathelmintha was seasonal and scarce. The Spearman coefficient of correlation confirmed the changes in the diet of the axillary seabream, which indicates seasonal differences in diet. Homogeneity of diet was noted between spring and summer and between summer and autumn (Table 6).

TABLE 6. – Statistical comparison of the diet of *P. acarne* according to season. ρ, Spearman coefficient of correlation; t_{obs}, Student test values; (+), homogeneous diet; (-), heterogeneous diet.

Seasons	ρ	t_{obs}	Significance (p=0.01)
Summer-Autumn	0.936	7.521	+
Autumn-Winter	0.624	2.258	-
Winter-Spring	0.506	1.659	-
Spring-Summer	0.765	3.359	+

Food in relation to sex

The diet composition of *P. acarne* varied seasonally in relation to sex, attaining 19 to 22 taxa of prey for females and 14 to 22 taxa for males (Tables 7 and 8). Arthropoda showed significant seasonal variations in the ingested biomass in males ($\chi^2 = 91.13$, $p>0.05$) but not in females ($\chi^2 = 4.38$, $p<0.05$). In summer, Mollusca predominated both in number and in frequency of occurrence in both males and females (Tables 7 and 8).

The Mollusca contribution to the ingested biomass, varied between 0.6% and 4.8% for males and between 1.2% and 7.2% for females and did not show any significant seasonal difference for either sex ($\chi^2_{(P♂)} = 6.96$, $p>0.05$; $\chi^2_{(P♀)} = 3.28$, $p>0.05$). According to the Main Food Index value, Arthropoda constituted the main prey for both sexes in winter, but became the secondary prey in spring and summer for males and accessory for females (Tables 7 and 8). However, Mollusca were accessory prey for both sexes all year round. Echinodermata were always present in the diet of the axillary seabream, and showed the highest indices in autumn for both sexes. These indices varied significantly during the year ($\chi^2_{(FO♂)} = 15.21$, $p<0.05$; $\chi^2_{(N♂)} = 9.94$, $p<0.05$; $\chi^2_{(P♂)} = 29.76$, $p<0.05$; $\chi^2_{(FO♀)} = 31.61$, $p<0.05$; $\chi^2_{(N♀)} = 12.59$, $p<0.05$; $\chi^2_{(P♀)} = 41.33$, $p<0.05$). Echinodermata were the main prey in males and secondary prey in females in autumn but accessory prey in winter for both sexes. The seasonal variations of the ingested prey and differences between male and female diet were confirmed by the Spearman test (Table 9). No significant seasonal variations were observed in females ($0.383<\rho<0.754$). However, in males, variations were observed between autumn and winter and between autumn and spring.

Table 7. – Prey identified in the stomach contents of *P. acarne* females according to season. *FO*, frequency of occurrence; *N*, numerical percentage; *P*, point percentage; *MFI*, Main Food Index; R, classification of prey.

Taxa	Summer *FO* (%)	*N* (%)	*P* (%)	*MFI*	R	Autumn *FO* (%)	*N* (%)	*P* (%)	*MFI*	R
Arthropoda	80.9	33.8	51.8	46.4	**1**	69.1	39.6	46.9	42.7	**1**
Mollusca	88	35.6	7.2	21	**2**	61	30	2.9	11.6	**3**
Echinodermata	19	8.3	23.8	15.3	**3**	47.7	17.3	38	38.6	**2**
Annelida	19	3.1	21.8	13.8	**4**	-	-	-	-	-
Bacillariophyta	-	-	-	-	-	4.3	2.2	1	1.1	**6**
Bryozoa	4.8	0.8	0.1	0.5	**6.5**	4.3	1.1	0.7	0.7	**7**
Foraminifera	14.3	4.7	0.4	1.6	**5**	17	13.2	3.2	3.2	**4**
Nemathelmintha	-	-	-	-	-	-	-	-	-	-
Teleostei	-	-	-	-	-	-	-	-	-	-
Phytophyta	4.8	0.8	0.2	0.5	**6.5**	13	3.3	2	2.1	**5**
Taxa	**Winter *FO* (%)**	***N* (%)**	***P* (%)**	***MFI***	***R***	**Spring *FO* (%)**	***N* (%)**	***P* (%)**	***MFI***	***R***
Arthropoda	68.6	58.1	49.9	55.4	**1**	71.3	30.8	45.9	36.9	**1**
Mollusca	20	12.6	1.2	4.7	**6**	50.7	30.5	3.1	9.6	**3**
Echinodermata	16.7	5.3	14.4	14.3	**2**	42.8	14.8	46.5	32.4	**2**
Annelidae	6.7	2.7	11.3	7.7	**3**	-	-	-	-	-
Bacillariophyta	3.3	0.9	0.1	0.5	**9.5**	4.8	4.9	0.6	1.5	**4**
Bryozoa	3.3	0.9	0.1	0.5	**9.5**	-	-	-	-	-
Foraminifera	23.3	20.5	1.1	5.1	**5**	-	-	-	-	-
Nemathelminths	6.7	1.8	0.2	0.9	**8**	-	-	-	-	-
Teleostei	3.3	1.8	18.8	7.4	**4**	-	-	-	-	-
Phytophyta	13.3	3.6	0.4	1.8	**7**	9.5	3.6	0.4	1.4	**5**

Table 8. – Prey identified in the stomach contents of *Pagellus acarne* males in relation to season. *FO*, frequency of occurrence; *N*, numerical percentage; *P*, point percentage; *MFI*, Main Food Index; R, classification of prey.

Taxa	Summer *FO* (%)	*N* (%)	*P* (%)	*MFI*	R	Autumn *FO* (%)	*N* (%)	*P* (%)	*MFI*	R
Arthropoda	53.3	35	33.1	38.6	**1**	48.7	15.9	18.1	18.6	**2**
Mollusca	40	39.3	4.8	16.8	**3**	36.6	16.2	3.1	7	**3**
Echinodermata	33.4	14.5	39.3	31.4	**2**	56.9	36.9	73.3	58.9	**1**
Annelida	6.7	3.4	16.8	9.6	**4**	4.9	0.5	4	2.8	**6**
Bacillariophyta	-	-	-	-	-	14.6	7.5	1.5	3.5	**5**
Bryozoa	-	-	-	-	-	4.5	1	0.2	0.6	**8**
Foraminifera	3.3	0.8	0.05	0.4	**6**	41.5	13.4	1.3	5.2	**4**
Nemathelmintha	-	-	-	-	-	-	-	-	-	-
Teleostei	-	-	-	-	-	-	-	-	-	-
Phytophyta	3.3	0.8	0.1	0.5	**5**	17.1	4	0.8	2.5	**7**
	Winter *FO* (%)	***N* (%)**	***P* (%)**	***MFI***	**R**	**Spring *FO* (%)**	***N* (%)**	***P* (%)**	***MFI***	**R**
Arthropoda	76.8	45.1	49.2	50.4	**1**	70	30.2	50	45.5	**1**
Mollusca	18.6	4.8	0.6	2.4	**5**	70	25.1	2.8	10.8	**3**
Echinodermata	21	7.5	25.1	17	**2**	43.3	16.7	45	35.3	**2**
Annelida	12.5	9.6	23.8	12.7	**3**	-	-	-	-	-
Bacillariophyta	-	-	-	-	-	-	-	-	-	-
Bryozoa	-	-	-	-	-	-	-	-	-	-
Foraminifera	17.5	6.1	0.3	1.8	**7**	26.6	10.4	0.6	3.1	**4**
Nemathelmentha	5.3	2.7	0.3	1	**8**	-	-	-	-	-
Teleostei	3.5	2.8	9.9	4.3	**4**	-	-	-	-	-
Phytophyta	14	4.8	0.5	2	**6**	6.7	2.1	0.2	0.9	**5**

Seasonal variations in relation to fish size

The stomach content analysis of juveniles showed that their diet was poorly diversified in winter, as it consisted of 6 prey taxa, which increased to 10 prey taxa in summer; taxa belonged to Arthropoda, Mollusca and Annelida (Table 10). However, the adult diet was more diversified with 10 prey groups in winter and 8 groups in summer. The most representative prey groups were Arthropoda, Mollusca, Annelida and Echinodermata (Table 11). Ingestion of Arthropoda showed

TABLE 9. – Statistical comparaison of *Pagellus acarne* diet in relation to sex; ρ, Spearman coefficient of correlation; t_{obs}, Student test values; (+), homogeneous diet; (-), heterogeneous diet.

Seasons	ρ	t_{obs}	Signification (p=0.01)
Females			
Summer-Autumn	0.754	3.2466	-
Autumn-Winter	0.418	1.301	-
Winter-Spring	0.383	1.172	-
Spring-Summer	0.617	2.217	-
Males			
Summer-Autumn	0.822	4.082	+
Autumn-Winter	0.634	2.318	-
Winter-Spring	0.447	1.413	-
Spring-Summer	0.847	4.506	+

significant variations between summer and winter in frequency of occurrence and number in juveniles ($\chi^2_{(FO)}$=58.50, p<0.05; $\chi^2_{(N)}$ = 53.80, p<0.05) but not in adults ($\chi^2_{(FO)}$=2.965, p<0.05; $\chi^2_{(N)}$ = 3.78, p<0.05). Their contribution to the ingested biomass, constituted mainly by Amphipoda and Mysida (*Mysis* sp.) in juveniles and Decapoda in adults, increased according to size in winter and decreased in summer (Tables 10 and 11); there were significant variations between these two seasons only for juveniles ($\chi^2_{(P,\ juveniles)}$=23.45, p<0.05; $\chi^2_{(P,\ adults)}$ = 0.165, p>0.05). According to the *MFI*, Arthropoda constituted secondary prey for juveniles both in summer and in winter and main prey for adults in summer and secondary prey in winter. The contribution of Mollusca to the ingested biomass in juveniles varied significantly between summer and winter both in frequency of occurrence and in number ($\chi^2_{(FO)}$=54.65, p<0.05; $\chi^2_{(N)}$ = 90.03, p<0.05). This prey group, including mainly bivalve taxa, constituted a secondary prey in summer and an accessory prey in winter. Its presence in the diet of the axillary seabream decreased according to size and it became the accessory prey in adults, both in summer and winter. In juveniles, the ingested biomass of Annelida showed significant variations between summer and winter ($\chi^2_{(P)}$=27.80, p<0.05). This biomass decreased according to size chiefly in winter and therefore Annelida were secondary prey in juveniles and accessory prey in adults. Echinodermata, absent in the juvenile diet both in winter and summer, seemed to be appreciated indiscriminately by the adults during these two seasons ($\chi^2_{(F)}$=0.619, p>0.05; ($\chi^2_{(N)}$=1.368, p>0.05; $\chi^2_{(P)}$=1.74, p>0.05). They were secondary prey in summer and accessory prey in winter (Table 11), whereas all the other taxa were accessory prey. The Spearman test indicated differences between the summer and winter diets for both juveniles (ρ = 0.945; t_{obs}=8.17 p<0.01) and adults (ρ = 0.9; t_{obs}=5.85 p<0.01).

TABLE 10. – Prey identified in the stomach contents of *P. acarne* juveniles in relation to season. *FO*, frequency of occurrence; *N*, numerical percentage; *P*, point percentage; *MFI*, Main Food Index; R, classification of prey.

Taxa	Summer *FO* (%)	*N* (%)	*P* (%)	*MFI*	R	Winter *FO* (%)	*N* (%)	*P* (%)	*MFI*	R
ARTHROPODA										
CRUSTACEA DECAPODA										
Pagurus sp.	7.1	1.4	20	10.5		-	-	-	-	
MYSIDA										
Mysis sp.	14.3	2.8	2.0	4.7		50	40	15.7	26.9	
AMPHIPODA										
Gammarus gammarus	7.2	2.8	40	16		25	6.7	6.3	10.1	
Total Arthropoda	**28.6**	**7**	**62**	**31.2**	**3**	**75**	**46.7**	**24**	**37**	**2**
MOLLUSCA										
BIVALVIA										
Flexopecten flexuosus	50.3	42.4	6.1	18.4		25	6.7	6.3	10.1	
Unidentified Bivalvia	21.1	21.5	3.2	10.1		-	-	-	-	
GASTEROPODA										
Turritella communis	21.4	6.9	1.0	4.3		-	-	-	-	
SCAPHOPODA										
Antalis dentalis	14.3	2.6	0.4	2.1		-	-	-	-	
Total Mollusca	**107.1**	**71.7**	**10.7**	**35.9**	**1**	**25**	**6.7**	**6.3**	**10.1**	**3**
ANNELIDA										
Nereis sp.	18.2	2.5	20.9	14.4		13.8	7.7	23.9	16	
Sabellidae	10.4	1.1	8.2	10		5.5	6.5	29.6	11.6	
Serpulidae	4.7	2.3	11.5	8		5.7	5.8	22	14	
Total Annelida	**33.3**	**5.9**	**40.6**	**32.4**	**2**	**25**	**20**	**75.5**	**41.6**	**1**

TABLE 11. – Prey identified in the stomach contents of *P. acarne* adults in relation to season. *FO*, frequency of occurrence; *N*, numerical percentage; *P*, point percentage; *MFI*, Main Food Index; R, classification of prey.

Taxa	Summer *FO* (%)	*N* (%)	*P* (%)	*MFI*	R	Winter *FO* (%)	*N* (%)	*P* (%)	*MFI*	R
ARTHROPODA										
CRUSTACEA DECAPODA										
Crangon crangon	8.3	2.5	4.9	12.3		7.9	6.5	5.1	13.7	
Ebalia sp.	14.4	6.8	3.7	10.1		16.3	6.8	14.9	12.8	
Liocarcinus arcuatus	10.1	5.5	9	4.4		13.9	3.3	6.6	8.1	
Pagurus sp.	12.5	6.3	2	8.1		11	3.8	2.9	4.6	
MYSIDA										
Mysis sp.	6.6	5.9	7.8	3.2		3.3	5.2	8.3	2.1	
ISOPODA										
Sphaeroma serratum	3.2	0.8	6.3	2		12.1	8.8	1.7	6.2	
CUMACEA	1.2	2.5	2	1		1.8	9.2	1.5	3.4	
OSTRACODA										
Cypridina mediterranea	6.1	2.1	2.5	0.9		4.1	6.1	3.4	0.9	
AMPHIPODA										
Gammarus gammarus	4	2	4.4	0.5		3	0.9	6.1	0.7	
Total Arthropoda	**67.4**	**34.4**	**42.6**	**42.5**	**(1)**	**73.4**	**50.6**	**49.5**	**52.5**	**(1)**
MOLLUSCA										
BIVALVIA										
Flexopecten flexuosus	7.8	4	0.5	2.5		-	-	-	-	
Unidentified	16.2	5.5	0.3	2.5		0.8	0.4	0.05	0.1	
GASTEROPODA										
Phyllonotus trunculus	8.2	3.4	0.1	1.5		-	-	-	-	
Calliostoma granulatum	3.2	4.2	0.7	1.5		3.1	1.2	0.08	0.1	
Cerithium alucastrum	2.1	8	0.6	2.6		-	-	-	-	
Lunatia sp.	2.6	4.1	0.6	1.8		-	-	-	-	
Turritella communis	6.1	3	0.7	1.2		3.5	1.8	0.2	0.5	
Caecum trachea	1.2	0.6	0.3	0.3		-	-	-	-	
Philine catena	-	-	-	-		1.5	0.6	0.1	0.1	
Rissoa sp.	3.7	0.8	0.4	1.2		2.4	0.8	0.2	0.2	
Retusa sp.	5.2	1.6	0.6	1.2		2.4	0.7	0.1	0.2	
SCAPHOPODA										
Antalis dentalis	9.2	2.2	1.2	2		4.5	1.9	0.1	1.4	
CEPHALOPODA										
Sepia officinalis	-	-	-	-		1	0.5	0.06	0.8	
Total Mollusca	**64.5**	**37.4**	**6**	**18.9**	**(3)**	**19.2**	**8**	**0.8**	**3.4**	**(5)**
ECHINODERMATA										
Paracentrotus lividus	6	2	8.9	5.4		2.4	1.8	6.8	4.3	
Neolampas rostellata	12	6.3	12.5	9.2		6.5	1.5	8.2	6.1	
Amphipholis squamata	8	3	10	8.6		10.3	3.3	10.1	5.4	
Total Echinodermata	**26**	**11.3**	**31.4**	**23.2**	**(2)**	**19.2**	**6.58**	**25.1**	**15.8**	**(2)**
ANNELIDA										
Nereis sp.	-	-	-	-		5.7	4.4	11.2	5.9	
Sabellidae	-	-	-	-		4.3	2.3	7.3	4.7	
Serpulidae	13	3.3	19.3	11.7		-	-	-	-	
Total Annelida	**13**	**3.3**	**19.3**	**11.7**	**(4)**	**10**	**6.7**	**18.5**	**10.6**	**(3)**
BACILLARIOPHYTA	-	-	-	-		**1.4**	**0.4**	**0.04**	**0.2**	**(9.5)**
BRYOZOA	-	-	-	-		**1.4**	**0.4**	**0.04**	**0.2**	**(9.5)**
FORAMINIFERA	**10.6**	**3.5**	**0.2**	**1.1**	**(6)**	**20**	**12.1**	**0.6**	**3.23**	**(6)**
NEMATHELMINTHA	**2.7**	**1.4**	**0.1**	**0.5**	**(7)**	**5.8**	**2.3**	**0.2**	**1**	**(8)**
TELEOSTEI	-	-	-	-		**3.4**	**2.3**	**13.6**	**5.6**	**(4)**
PHYTOPHYTA	**8.8**	**2.8**	**0.3**	**1.2**	**(5)**	**13.7**	**4.3**	**0.4**	**1.9**	**(7)**

TABLE 12. – Statistical variations of the diet of *P. acarne* adults in relation to season. ρ, Spearman coefficient of correlation; t_{obs}, Student test values; (+), homogeneous diet; (-), heterogeneous diet.

Seasons	ρ	t_{obs}	Significance (p=0.01)
Summer-Autumn	0.936	3.246	+
Autumn-Winter	0.6	1.301	-
Winter-Spring	0.463	1.172	-
Spring-Summer	0.765	2.217	+

DISCUSSION

The vacuity index of all the specimens together did not show any significant seasonal variation; however, the *VI* of females was lower than that of males in autumn. This period corresponds to the gonad maturation of the axillary seabream (Mokrani *et al.*, 2007). Females had a higher feeding intensity than males, as they need to consume more energy for the maturation of their gonads. The high vacuity index values revealed low feeding intensity in both sexes during spawning and post-spawning periods (i.e. winter-spring). This may be related to the lower availability of prey mainly in winter, which become less active and are closer to the bottom due to the low water temperature in the Gulf of Tunis (8-13°C) (Daly Yahia, 1998), and are therefore less exposed to predation. In general, the low feeding intensity observed in this study may be due to the fishing gear and/or to the feeding behaviour of fish at the moment of capture, as observed for the Pleuronectiforms caught by static gears (Verheijen and De Groot, 1979). In the Gulf of Tunis, the axillary seabream was captured at night, which is when the fish are most active generally because they are feeding. The individuals caught were hauled onboard the following morning. Hence, some of them may have remained several hours in the net, and their capture may have occurred before the ingestion of prey or after digestion. As a result, many specimens would have had an empty stomach at the moment they were collected.

According to the data obtained, Arthropoda, Mollusca and Echinodermata were the most common prey in the diet of the axillary seabream living in the Gulf of Tunis. Annelida were secondary prey. Other prey, such as, Foraminifera, Bacillariophyta, Bryozoa, Nemathelmintha and Teleostei were of minor importance. This carnivorous type of diet conforms to those of Sparidae species belonging to the *Diplodus* genus reported by several authors (Rosecchi, 1987; Gonçalves and Erzini, 1998; Pallaoro *et al.*, 2006; Derbal *et al.*, 2007) and of other species of the *Pagellus* genus in particular (Larrañeta, 1964; Rijavec and Županović, 1965; Ardizzone and Messina, 1983; Rosecchi, 1983; Ghorbel, 1996).

The axillary seabream, is considered to be an euryphagous species, as it searches for food in the endofauna and crawling fauna (Mollusca, Annelida, Echinodermata). Our results agree with those of Collingnon and Aloncle (1960), who reported the presence of a large number of prey from the endofauna (Bivalvia and Annelida), fish and crustaceans in the stomachs of the axillary seabream from the Atlantic coasts of Morocco. The presence of Echinodermata in the diet of this species was also reported in the eastern Mediterranean along the Egyptian coasts (Rizkalla, 1999) and in the Atlantic, along the northwestern coasts of Africa (Phân and Kompowski, 1972) and around Azores (Morato *et al.*, 2001). The low contribution of fish to the diet of *P. acarne* from the Gulf of Tunis contrasts with the information reported for the same species in the Atlantic, where the frequency of occurrence reached 76.3% in spring (Morato *et al.*, 2001). The scarcity of fish in the diet of *P. acarne* observed in this study may be due to the overexploitation of local fish, which might have led to changes in the existing trophic chain at different levels. The axillary seabream probably uses its thick lips to move the sediment around in order to search for prey moving close to or inside the substratum . Unlike sparids, *P. acarne* does not have sharp anterior teeth. Prey is probably sucked up and then ground with the molars or swallowed whole. Indeed, Linde *et al.* (2000) showed a strong correlation between the diet and the shape of the premaxillary in sparids, but not between the diet and teeth.

The feeding behaviour of *P. acarne* was different between sexes. It showed seasonal variations, mainly in females, which could be related to the reproductive cycle. In fact, prey ingestion is adapted to the energetic needs of the fish throughout the year. In contrast, seasonal variations in males were observed only during maturation of their gonads and the spawning period (autumn-winter). Considering the liver as the storage organ of the energetic reserves, our findings are in agreement with the monthly changes in the hepatosomatic index of *P. acarne*, which are larger in females than in males (Mokrani *et al.*, 2006).

The diet of juveniles was less diversified than that of adults. In summer and in winter, Crustacea and Echinodermata (i.e. prey with hard carapaces and tests) were absent from the diet of juveniles. Their diet is dominated by small organisms, such as Amphipoda (*Gammarus gammarus*), Mysida (*Mysis* sp) and bivalve juveniles, which indicates an increase in prey size in relation to fish size. This difference in feeding behaviour between juveniles and adults is also known in other sparids, such as *Diplodus sargus* (Rosecchi, 1987), *D. vulgaris* (Pallaoro *et al.*, 2006) and *D. annularis* (Derbal *et al.*, 2007). In adults, the larger opening of the mouth and the bony structure of the maxillaries, premaxillaries and mandibles, which makes them stronger, could allow the capture and ingestion of bigger and harder prey.

In conclusion, in the Gulf of Tunis *P. acarne* is a carnivorous and euryphagous predator. This species feeds on benthic organisms such as Arthropoda, Mollusca and Echinodermata. However, sex-related seasonal variations and diet differences between juveniles and adults were observed.

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