EGYPTIAN JOURNAL OF AQUATIC RESEARCH ISSN: 1687-4285
VOL. 33 NO. 2, 2007: 202-221

FOOD AND FEEDING HABITS OF ROUND SARDINELLA (*SARDINELLA AURITA*) IN EL MEX BAY, ALEXANDRIA, EGYPT

NAGWA E. ABDEL AZIZ AND SAMIHA M. GHARIB

National Institute of Oceanography and Fisheries, Alexandria, Egypt.

Keywords: Sardinella aurita, feeding habits, diet, El Mex Bay, Alexandria.

ABSTRACT

Stomach content of round *Sardinella*, *Sardinella aurita* Valenciennes, 1847, from El Mex Bay, was analyzed monthly from August 2005 to July 2006 to assess feeding habits. The diet consists of 85 phytoplankton and 57 zooplankton items. The amount of food items and the diversity index varied from one season to another indicating the adaptability of *Sardinella aurita* to change its diet according to the food types available in the environment. During the different seasons (autumn, winter, spring, and summer), the average count/stomach of phytoplankton species was 23040, 504640, 23335, and 9113 organisms/stomach respectively, while for zooplankton items the average count/stomach was 138, 15, 1170, and 50 organisms/ stomach respectively. As indicated from numerical abundance, the preferable food items were the diatoms *Asterionella japonica* (88%), *Cyclotella meneghiniana* (4%), and *Skeletonema costatum* (1%). Zooplankton items appeared to be less important in the diet quantitatively. *Cyclotella meneghiniana* dominated food items consumed by *Sardinella aurita* during autumn, whereas *Asterionella japonica* was the most important food during winter, due to their abundance in El Mex Bay during these seasons. On the other hand a variety of diatoms shared the dominance in the diet during spring and summer. As the fish grew to a certain size (till 12 cm.), the number of prey species increased, reflecting greater prey diversity. Also at the size from 10-11 cm. the consumption of food increased to reach its maximum (376780 organisms/stomach). *Asterionella japonica* was essential food item for all size classes, representing on the average more than 84% of the food composition. *Sardinella aurita* is considered as an omnivorous, filter feeder species belonging to the herbivorous trophic category (%N = > 95% phytoplankton), where the diets among the different seasons were different in species composition and amount of food, but between the different sizes the variations were mainly between the amount of food, little variations were noticed between the types of food items.

1. INTRODUCTION

The study of the feeding preferences of fish species are important in classic ecological theory, mainly in identifying feeding composition (Bacheler *et al.*, 2004), structure and stability of food webs (Post *et al.,* 2000) and assessing predator- prey functional responses (Dorner and Wagner, 2003).

Round *Sardinella, Sardinella aurita* Valenciennes, 1847, is a middle-sized pelagic fish, global landings, accounting for more than 0.5% of the total marine landed catch, largely fluctuate from year to year (FAO, 2000). It is considered an important commercial fishery resource in the Egyptian Mediterranean coast off Alexandria. The earlier works of Rifaat (1960), El- Maghraby (1960), Hashem & Faltas (1979) and Faltas (1983) studied the food items of sardine to the level of groups only.

The aims of the present work are: (a) to study the feeding habits of round *Sardinella* monthly in El Mex Bay, Alexandria, relative to body size class (b) to identify the nature of its feeding ecology (i.e., specialist or generalist) and (c) to compare its diet in El Mex Bay with other populations throughout its distribution and with other *Sardinella* species.

2. MATERIAL AND METHODS

2.1. Study area

El Mex Bay is an embayment on the Mediterranean Coast west of Alexandria, extending parallel to the coast line for about 7 km, between El Agamy head land and the Western Harbor approximately at longitude 29° 50` E and latitude 31° 5` N (Fig.1). It has an average width of 3 km and total area of about 20 km². The depth of water in the bay fluctuates between 1.5 and 15 meters, being more shallow near the shore and increases gradually seawards. The bay receives a heavy load of wastewater from industrial outfalls, besides a huge amount of agricultural drainage water from El Umum Drain partly mixed with polluted Lake Mariut water reaching 6 -11.8 x10^6 m^3 / day (Said *et al*., 1991).

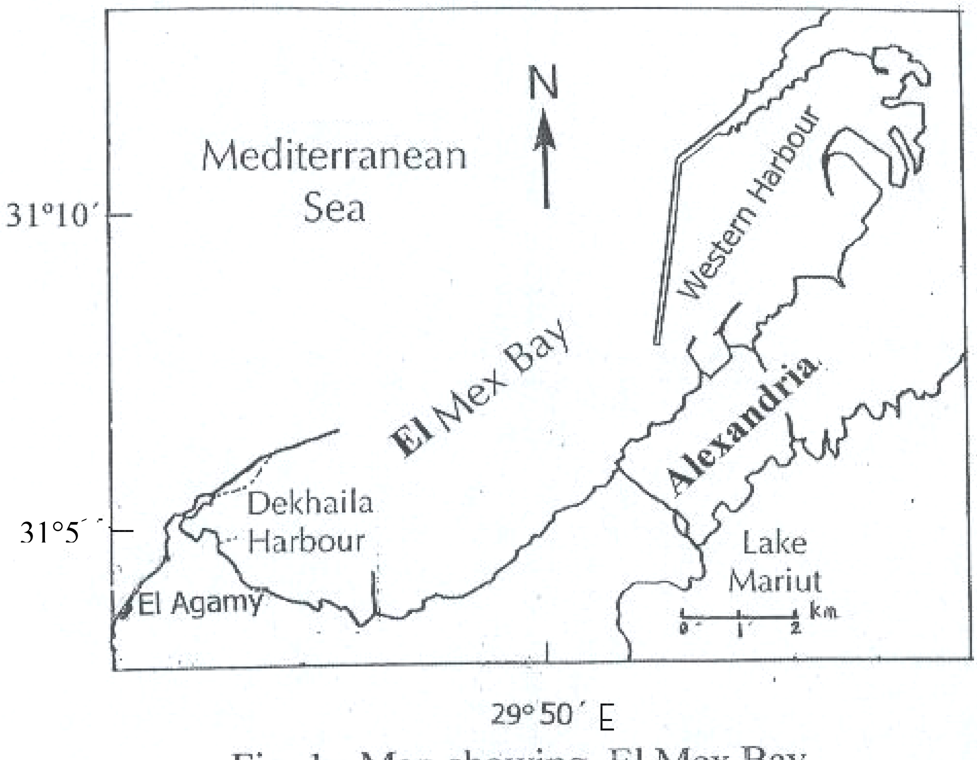

Fig. 1 : Map showing El Mex Bay

2.2. Field and laboratory methods

Stomach content of round *Sardinella* was examined monthly from August 2005 to July 2006. Samples were collected randomly in good condition directly from fishermen at El Mex Bay of Alexandria and kept in ice until arrival at the laboratory for analysis.

A total of 243 specimens were examined. For every specimen, standard length (SL) (tip of the snout to the end of caudal base) was measured to the nearest 0.1 cm. and the total weight (TW) was calculated to the nearest gm. In order to evaluate variations in feeding habits as a function of size, round *Sardinella* specimens were separated into five length classes (<10 cm; 10-10.9 cm;11-11.9 cm;12-13 cm and >13 cm.). The entire gut was removed, and preserved in 5 % formalin solution. Individual guts of specimens of known length class were cut open in a Petri dish with the aid of surgical ocular scissors. Each dietary item was identified to the lowest taxonomic level as possible and counted under a research microscope. The following taxonomic references were consulted for identification of food items: Heurck (1896); Peragallo and Peragallo (1897-1908); Rose (1933); El Nayal (1935 & 1936); Tregouboff and Rose (1957); Edmondson (1959); Hendey (1964); Hutchinson (1967); Khunnah (1967); Dussart (1969); Marshall (1969); Bradford (1972); Park and Dixon (1976); Dodge (1982); Malt (1983) and Sournia (1986). The total count of prey individuals in each stomach was expressed as organisms/ stomach.

The wet weight of the stomach content of every fish was obtained using a torsion balance. The data were approximated to the nearest 0.01gm. wet weight / stomach. The number of empty stomachs was also recorded.

2.3. Data analysis

Common indices were used to describe the diet of round *Sardinella* as follows:

1. Index of vacuity (IV) defined as the percentage of empty stomachs (Es) in relation to the total number of examined stomachs (N), thus IV= Es /N x 100.
2. Frequency of occurrence (%FO) of food items was calculated by dividing the number of stomachs containing a particular prey item by the total number of stomachs containing prey multiplied by 100. This index reflects the % number of fish predators which utilize that prey, and can be used as a measure of the fish selectivity in feeding habits.
3. Numerical percentage of abundance (%N) was calculated by dividing the number of individuals of each prey item within the category by the total number of individuals of all prey items multiplied by 100; this index is an estimate of relative abundance of that prey item in the diet.
4. An estimate of index of relative importance (IRI) of each food category was obtained by multiplying %FO by %N, from modified equation given by Laroche (1982).

To evaluate seasonal differences in diet, seasons (i.e. three months for each season) considered as: autumn = September to November, winter = December to February, spring = March to May, and summer = June to August.

To examine changes in diet breadth of *Sardinella aurita*, Shannon – Weaver diversity index (Zar, 1984) was used: $H` = -\sum^{r}_{j} P_j \log P_j$

Where P_j = percent that j prey contributes to predator diet, and r = number of prey taxa utilized by predator. The magnitude of this index depends on the number of prey taxa used by the predator. Hence evenness index (relative diversity) is expressed as

$j` = H` / H`_{max}$ , where $H`_{max} = \log r$.

3. RESULTS

3.1. Diet composition

Only one out of 243 stomachs examined was empty, recorded in February. The vacuity index (VI) equal 0.4%. The food contents indicated that *Sardinella aurita* feeds on a wide variety of plankton items (142 items), 85 for phytoplankton (representing 60% of items) belonging mostly to diatoms (53 spp.), Dinophyceae (14 spp.), Chlorophyceae (11 spp.), and 57 species for zooplankton (representing 40% of the food items) belonging mostly to Protozoa (26 spp.), Copepoda (14 spp.) (Table1). Other groups occurred rarely.

Table (1): Annual average values of Frequency of occurrence (FO%), numerical abundance(N%), and index of relative importance(IRI) of food items in gut of *Sardinella aurita* (n=242).

Food items	FO%	N%	IRI	Food items	FO%	N%	IRI
Phytoplankton [phy.]							
Diatoms				Pleurosigma sp.	8.7	0.014	0.12
Achnanthes brevipes	1.7	0.001	0.002	Podosira sp.	1.7	0.003	0.005
Amphora ovalis	1.7	0.001	0.002	Rhizosolenia alata	2.9	0.008	0.023
Asterionella japonica [As.j.]	20	88.04	1760	R. calcar-avis	5.8	0.025	0.145
Asterolampra sp.	0.4	0.001	0.0004	R. setigera [R.s.]	15.7	0.532	8.35
Aulacodiscus sp.	2.9	0.01	0.029	Skeletonema costatum[Sk.c.]	26.5	1.343	35.59
Bacillaria paradoxa	4.1	0.008	0.0328	Streptotheca themensis	5.4	0.022	0.1188
Bacteriastrum sp.	0.4	0.001	0.0004	Striatella delicatula	0.8	0.001	0.001
Biddulphia alternans	3.3	0.003	0.0099	Surirella sp.	1.7	0.001	0.002
B. laevis	2.5	0.002	0.005	Synedra ulna	15.7	0.021	0.33
B. mobiliensis [B.m.]	13.2	0.126	1.6632	Thalassionema nitzschiodes[Th.nit.]	10.7	0.945	10.112
B. pulchella	7.4	0.013	0.0962	Thalassiothrix sp.[Thx.sp.]	8.7	0.136	1.18
B. rhombus	7.9	0.006	0.0474	Triceratium sp.	2.1	0.003	0.006
B. smithii	2.5	0.001	0.0025	**Dinophyceae**			
B. tuomeyi	5	0.047	0.235	Ceratium furca	5.8	0.034	0.1972
Campylodiscus clypus	2.1	0.001	0.0021	C. tripos	2.5	0.014	0.035
Ceratulina bergonii	9.5	0.043	0.4085	Dinophysis caudata	8.3	0.017	0.14
Chaetoceros sp. [Ch. sp.]	23.6	0.331	7.8116	Exuviella marina[Ex.m.]	5	0.34	1.69
Cocconeis placentula	4.1	0.012	0.0492	Gonyaulax sp.	5	0.008	0.04
Coscinodiscus sp. [Cos. sp.]	34.3	0.071	2.4353	Gymnodinium sp.	8.7	0.009	0.0783
Cyclotella meneghiniana[Cy.m.]	52.1	4.08	212.57	Oxytoxum sceptrum	6.2	0.012	0.0744
Cyclotella sp. [Cy. sp.]	17.4	0.031	0.5394	Prorocentrum micans	16.1	0.028	0.4508
Cymbella sp.	2.1	0.001	0.0021	P. triestinum [Prr.t.]	4.1	1.14	4.674
Gomphonema sp.	0.8	0.001	0.0008	Protoperidinium alexandrinum[Prt.al.]	24.8	0.299	7.4152
Grammatophora angulosa[Gr.n.]	26.5	0.484	12.826	P. cerasus [Prt.cer.]	5.4	0.075	0.405
Licmophora sp.	3.7	0.008	0.0296	P. conicoides [Prt.con.]	11.6	0.211	2.4476
Mastogloia sp.	0.4	0.001	0.0004	P. depressum [Prt.dep.]	36.8	0.174	6.403
Melosira granulata	3.3	0.004	0.0132	P. trochoideum	12.4	0.03	0.372
M. varians	0.4	0.001	0.0004	**Chlorophyceae**			
Navicula glopiceps	1.2	0.001	0.0012	Cosmarium sp.	0.4	0.001	0.0004
N. gracilis	1.2	0.001	0.0012	Curcigenia quadrata	0.8	0.001	0.001
Navicula sp.[Nv.sp.]	24.4	0.048	1.1712	C. rectangularis	3.3	0.008	0.03
Nitzschia apiculata	2.9	0.002	0.0058	Pediastrum clathratum[P.cl.]	2.5	0.031	0.08
N. closterium	0.8	0.001	0.0008	P. duplex[P.dup.]	1.2	0.106	0.13
N. circumastata	2.9	0.012	0.0348	P. simplex	3.7	0.024	0.09
N. longissima	2.1	0.004	0.0084	P. tetras	1.2	0.004	0.005
N. microcephala	0.8	0.001	0.0008	Scenedesmus quadricauda[Sc.q.]	18.2	0.05	0.91
N. obtusa	0.4	0.001	0.0004	Spirogyra sp.	0.4	0.002	0.001
N. palea	6.6	0.014	0.0924	Staurastrum tetracerum	0.8	0.001	0.001
N. sigma[Nit.s.]	21.1	0.278	5.8658	Tetraedron minimum	0.8	0.001	0.0008
N. scalaris	16.9	0.034	0.5746				

Table 1 (Continue)

Food items	FO%	N%	IRI	**Food items**	FO%	N%	IRI
Euglenophyceae				**Rotifera**			
Euglena acus	2.1	0.011	0.02	Brachionus calyciflorus	0.8	0.001	0.001
Cyanophyceae				Br. plicatilis	0.4	0.001	0.0004
Lymbya sp.	0.4	0.001	0.0004	Trichocerca marina	0.4	0.001	0.0004
Merismopedia sp.	2.5	0.001	0.0025	**Nematodes**			
Oscillatoria brevis	2.1	0.03	0.06	Achromadora sp.	1.2	0.001	0.001
O. irrigua[Os.irr.]	6.2	0.262	1.62	Aphelenchoids sp.	0.8	0.001	0.001
Spirulina platensis [Sp.pl.]	9.1	0.025	0.23	**Polychaetes**			
Silicoflagellata				Spionid larvae	2.9	0.001	0.003
Dictyocha fibula	2.5	0.018	0.04	**Copepoda**			
				Acartia clausi	2.9	0.001	0.003
Zooplankton [Zoo.]				A. grani	1.7	0.001	0.002
Protozoa				Centropages kroyeri	0.8	0.001	0.001
Amphorellopsis tetragona	1.2	0.001	0.001	Corycaeus clausi	2.1	0.001	0.002
Codonellopsis morchella	2.1	0.001	0.002	Ergasilus sieboldi	0.4	0.001	0.0004
Eutintinnus losus undae	1.2	0.001	0.001	Eucalanus crassus	0.4	0.001	0.0004
Favella adriatica	0.8	0.001	0.001	Euterpina acutifrons[Eut.a.]	32.7	0.034	1.11
F. azorica	1.7	0.001	0.002	Oithona nana [O.n.]	23.6	0.033	0.78
F. composita	0.8	0.001	0.001	O. plumifera	2.9	0.001	0.003
F. ehrenbergii	2.9	0.001	0.003	Oncaea venusta	0.4	0.001	0.0004
F. markusoveski	0.4	0.001	0.001	Onychocamptus mohammed	1.7	0.001	0.002
F. serrata	0.8	0.001	0.001	Paracalanus parvus[P.p.]	14.1	0.006	0.08
Helicostomella subulata[Hel.s.]	18.2	0.004	0.07	Temora stylifera	0.8	0.001	0.001
Metacylis mediterranean	9.1	0.001	0.009	Copepodite stages[C.s.]	19.4	0.006	0.12
Proplectella pentagona	0.4	0.001	0.0004	Nauplius larvae[N.l.]	69	0.062	4.28
Protorhabdonella simplex	2.1	0.001	0.002	**Cladocera**			
Rhabdonella elegans	0.4	0.001	0.0004	Moina micrura	0.4	0.001	0.0004
Tintinnopsis beroidea	1.2	0.001	0.001	Podon polyphymoides	0.8	0.001	0.001
T. cylinderica	4.1	0.001	0.004	**Decapodes**			
T. nana	3.7	0.001	0.004	Mysis relicta[M.r.]	8.3	0.002	0.02
T. vosmarie	0.4	0.001	0.0004	Porcellana longicornis	0.4	0.001	0.0004
Adelosina elegans	0.4	0.001	0.0004	Mysis stages of Decapoda	1.2	0.001	0.001
Ammonia beccarii	4.6	0.001	0.005	**Cirripedes**			
Cycloforina contorta	6.2	0.001	0.006	Cirriped larvae [C.l.]	27.3	0.011	0.3
Loxostomum plaitum	0.8	0.001	0.001	**Mollusca**			
Nonion sp.	0.4	0.001	0.0004	Lamillibranch veliger [L.v.]	21.5	0.077	1.6555
Quinqloculina seminulum	1.2	0.001	0.001	**Fish eggs**	8.3	0.001	0.01
Spirillina vivipara	1.7	0.001	0.002	**Fish larvae**	0.4	0.001	0.0004
Textularia sp.	1.2	0.001	0.001				
Coelentrates							
Obelia sp.	0.4	0.001	0.0004				

Note: Abbreviations represented in this table between [ ], used in all figures.

The index of relative importance (Table 1) showed that *Asterionella japonica, Cyclotella meneghiniana,* and *Skeletonema costatum,* constituted the most important food items (IRI= 1760, 213 and 35%), found in 20, 52 and 27% of stomachs examined with numerical abundance of 88; 4 and 1.5% respectively (Table 1). *Grammatophora angulosa, Thalasionema nitzschoides, Rhizosolenia setigera, Chaetoceros* sp. and *Protoperidinium alexandrinum* were second in importance with IRI equal to 13, 10, 8.5, 7.8 and 7.4%, respectively, found in 27, 11, 16, 24 and 25% of the stomachs with low numerical anundance (<1%). Six zooplankters occurred in more than 19% of stomachs examined, represented by the copepods *Euterpina acutifrons* (33%), *Oithona nana* (24%), nauplii larvae (69%), copepodides of copepods (19.4%), cirripedes larvae (27%) and lamellibranch veligers (22%), yet their numerical abundances were small (<0.1%). The other prey items were found with numerical abundances less than 0.01%.

3.2. Seasonal variations of food patterns

In autumn the diet consisted of 77 items, 86% (i.e. 66 species) belonging to phytoplankton and 14% (i.e. 11 species) belonging to zooplankton items with average numerical density of 23040 and 138 organisms /stomach respectively (Fig 2). About 13 items were most frequently occurred with a percentage ranged from 20 - 83% (Fig 3 a). Copepod nauplii and *Euterpina acutifrons* occurred in 83% and 40% of the stomachs examined, but with small numerical abundances. *Cyclotella meneghiniana* was the most important food item (IRI = 4030%) with numerical abundance (% N = 62%), followed by *Rhizosolenia setigera* and *Skeletonema costatum* (%N = 12.8 & 11%), while *Biddulphia mobiliensis, Grammatophora angulosa* and *Nitzschia sigma* were recorded in low abundances (%N = 2.7, 1 & 1%). The other items represented collectively 9.3% of the diet. Diversity and evenness indices were 0.7 and 0.2, respectively (Fig 4).

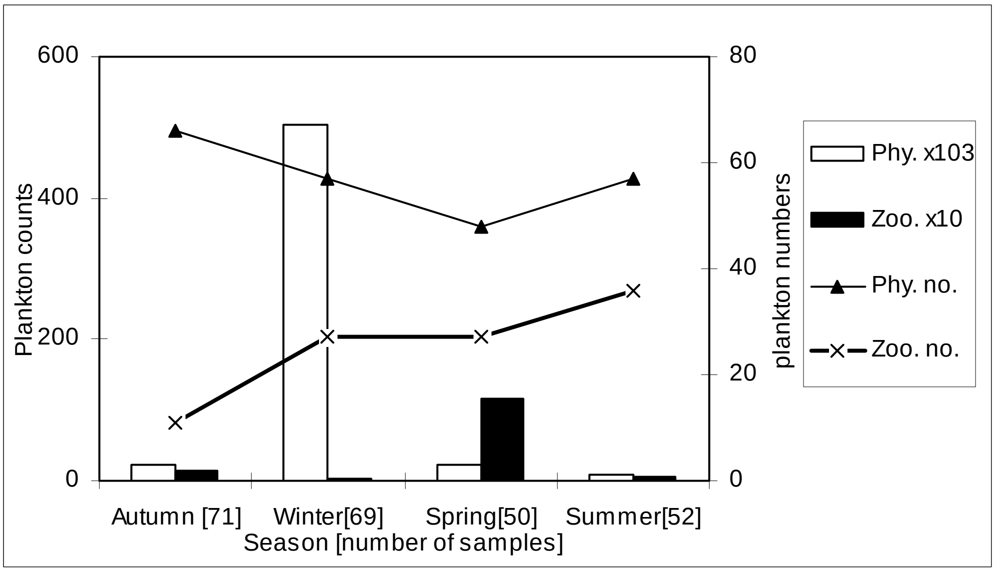

Fig (2): Average plankton counts/stomach and numbers of prey items in the stomach during different seasons.

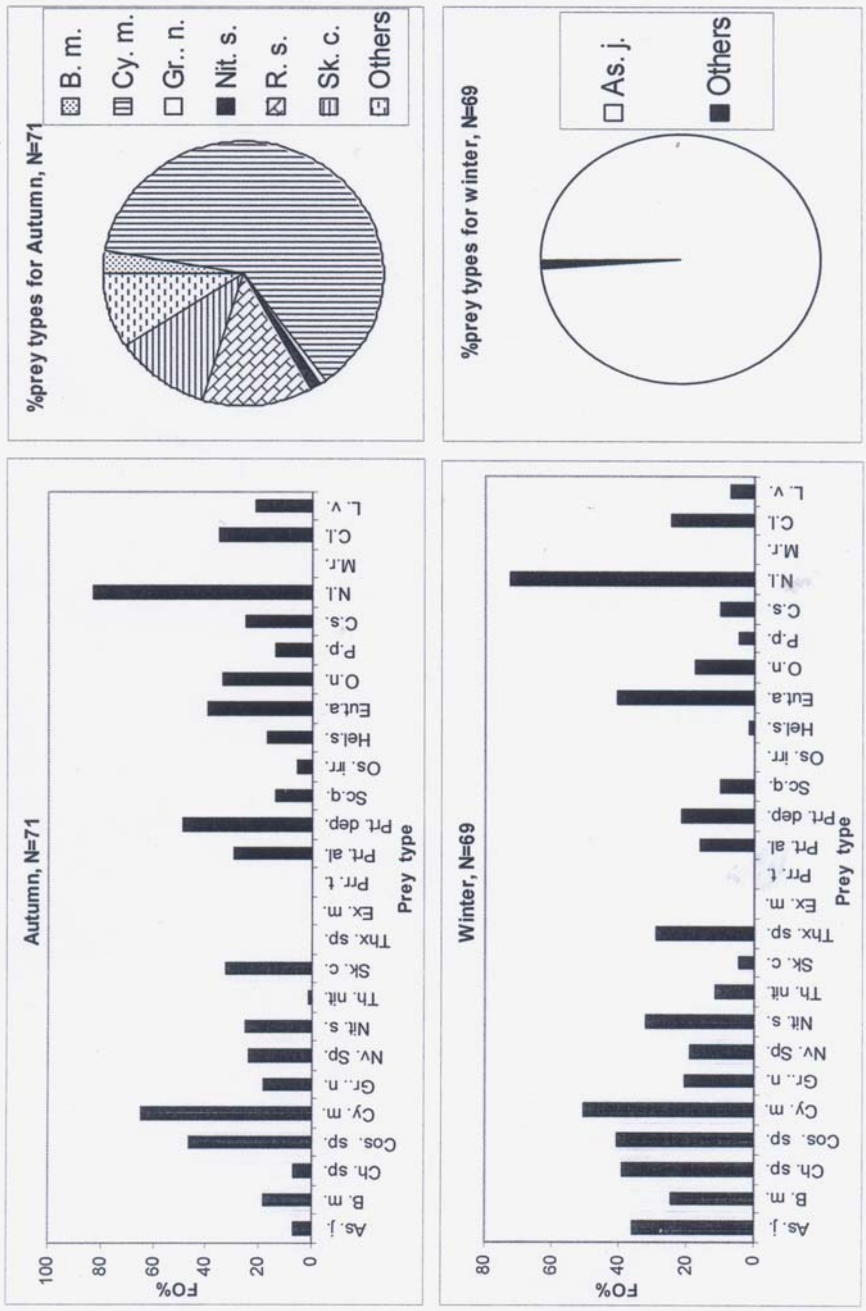

Fig. (3 a): Average percent frequency of occurrence and percent composition of dominant prey types of *Sardinella aurita* diet in Mex Bav during autumn and winter seasons.

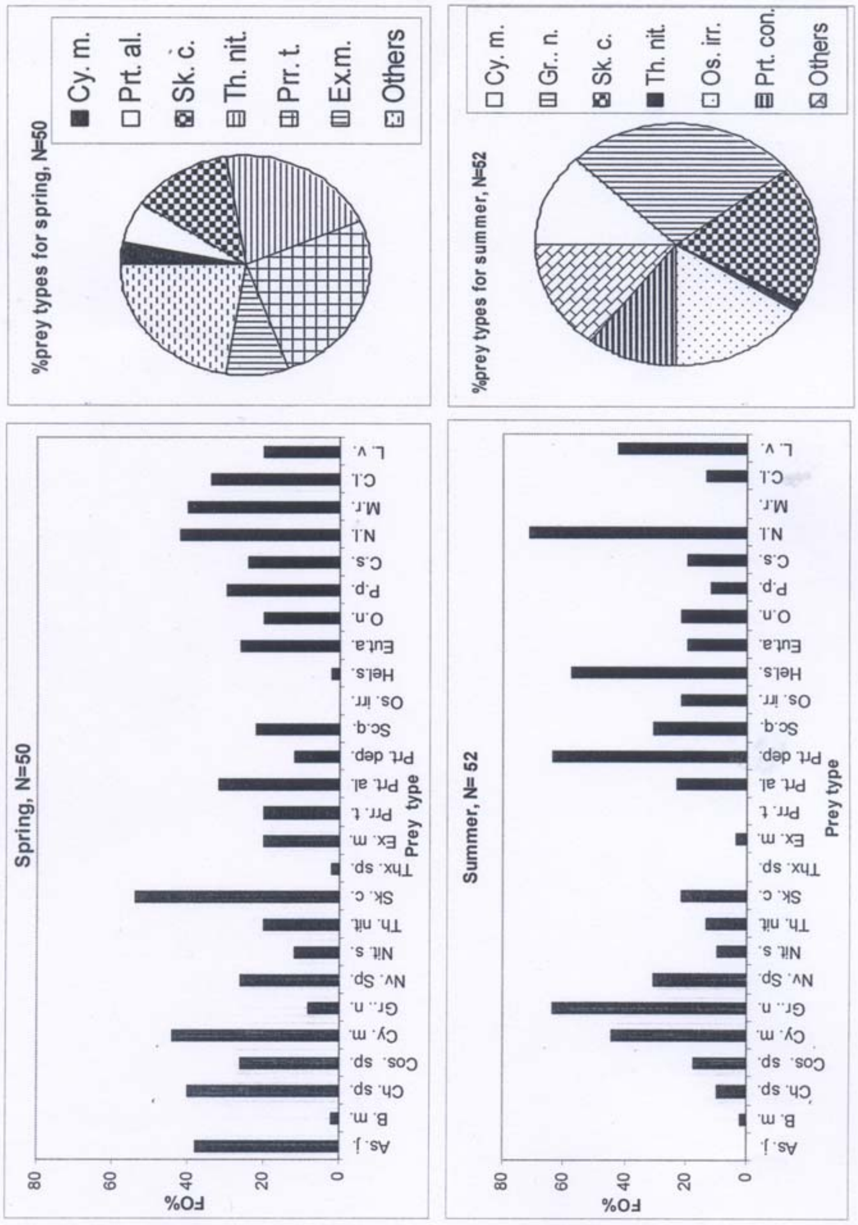

Fig (3 b): Average percent frequency of occurrence and percent composition(%N) of dominant prey types of *Sardinella aurita* diet in Mex Bay during spring and summer seasons.

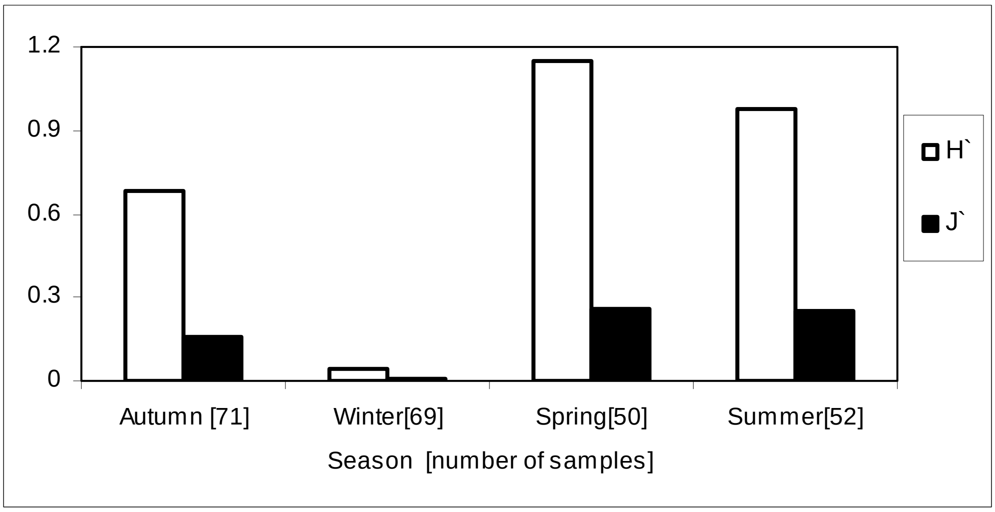

Fig (4): Diversity Index (H`) and Evenness (J`) of food items during different seasons.

In winter the diet consisted of 84 items, 68% (i.e. 57 species) belonging to phytoplankton and 32% (i.e. 27 items) of zooplankton with numerical density of 504640 and 15 organisms /stomach, respectively (Fig 2). Twelve items were the most frequent in the diet, its occurrence ranged between 20 – 73 % of the stomachs (Fig 3a), copepod nauplii occupied the first order (%FO = 73%). *Asterionella japonica* was the most preferable food item (IRI = 3584%), with numerical abundance 99%, and %FO = 36%, while the other prey items were consumed by a very small percentage (1%).The diversity and evenness indices were the least (0.04 and 0.01 respectively).

During spring the diet comprised 75 items, 64% (i.e. 48 species) belonging to phytoplankton and 36% (i.e. 27 items) belonging to zooplankton, with numerical density of 23335 and 1170 organisms/stomach. Ninteen items were the most frequently observed, with occurrence between 20 and 54% (Fig 3b). *Skeletonema costatum, Cyclotella meneghiniana* and nauplii occurred in 54, 44 and 42% of the examined stomachs. Six items displayed considerable counts, *Prorocentrum triestinum* and *Thalasonema nitzschiodes* were the most important items (IRI = 522 and 420%) forming 26 and 21% of the numerical density of the total count of food items, while *Skeletonema costatum* and *Exuviella marina* (IRI=702 and 156%) were represented by 13 and 8%. On the other hand *Protoperidinium alexandrium* and *Cyclotella meneghiniana* (IRI =189 and 150) were less abundant (%N=5.9 and 3.4%).The diversity and evenness indices attained the highest value (1.2 and 0.26, respectively).

In summer the diet was composed of 93 items, 61% (i.e. 57 species) belonging to phytoplankton and 39% (i.e. 36 species) to zooplankton items with numerical density of 9113 and 50 organisms /stomach respectively. Twelve items formed more than 20% of the stomachs examined. %FO for *copepod* nauplii, *Protoperidinium depressum, Grammatophora angulosa* were 71, 64 and 64% respectively (Fig 3b), other prey species were eaten by a relatively small number of fish. *Grammatophora angulosa* and *Skeletonema costatum* were the important prey items (IRI = 1695 and 403% respectively), and constituted by 26.7 and 19% of the diet respectively, *while Oscillatoria irrigua*, *Cyclotella meneghiniana* and *Protoperidinium* *conicoides* (IRI = 337, 548 and 216%, respectively) were less important (%N = 15.9, 12.4 and 10.2% respectively). The other species collectively constituted 14.7% of the diet. The diversity index (0.98) was lower than that in spring, while evenness appeared to be approximately of the same value (0.25) (Fig 4).

The wet weight of food showed inverse relation with the weight of fish, where the lowest average food wet weight (0.17 g) was recorded during autumn and coincided with the highest average weight of fish (average: 26 g). The average food wet weight reached its maximum (average 0.26 g) during spring coinciding with the smallest fish weight (average 15.5 g) (Fig 5).

3.3. Change in food composition with size of fish

The specimens were grouped into five length (S.L.) classes. For the first class (<10cm), the food items were composed of 62 items, 66% (i.e. 41 species) belonging to phytoplankton and 34% (i.e. 21 species) to zooplankton, (Fig. 6), increased to 71 items, 68% (i.e. 48 species) belonging to phytoplankton and 32% (i.e. 23 items) to zooplankton at the second class (10- 10.9 cm), reached its maximum 121 items, 65% (i.e. 79 species) belonging to phytoplankton and 35% (i.e. 42 species) to zooplankton at the third class (11- 11.9 cm). Then decreased again at the sizes 12- 13 and > 13 cm to become 101 and 77 items, 65% (i.e. 66 species) and 75% (58 species) belonging to phytoplankton and 35% (i.e. 35 species) and 25% (i.e. 19 species) to zooplankton items, respectively.

The amount of food was the lowest average (42175 organisms/stomach) in the smallest size (< 10 cm), then increased to reach its maximum average (376780 organisms/ stomach) at size 10- 10.9 cm. (Fig 6). The counts decreased gradually at the next three classes to reach an average 92040 organisms/ stomach at size (> 13 cm). At all sizes the numerical density of zooplankton was less than 1% of the total amount of food.

The diversity index increased with increasing the number of species at all sizes except at size 10- 10.9 cm. (Fig 7). Of the total number of species found at every size class, about 7 – 10 species frequently occurred with more than 20% of the stomachs at every length class, with different numerical densities (Fig 8).

The diatom *Asterionella japonica* was the main prey diet occurred in the stomachs examined of all length classes with %FO from 6 to 43% and %N from 84% to 97%. *Cyclotella meneghiniana* occurred in 44 to 56% of stomachs (%N 1.6 to 11.2%). Other species shared in the diet of each class but with less importance (Fig 8).

The wet weight of food ranged between 0.14 and 0.27 g (Fig 9). It was highest at the smallest size (< 10 cm) and lowest at the size 10-10.99 cm.

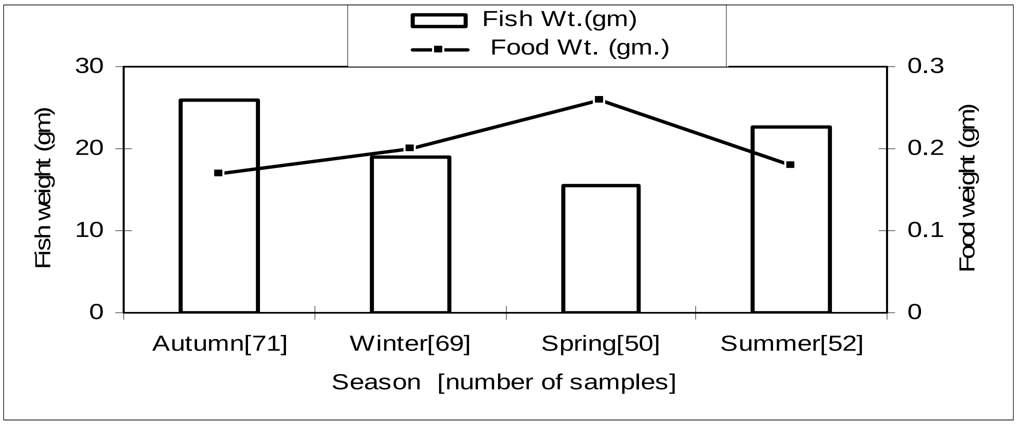

Fig (5): Average fish weight and food wet weight for different seasons.

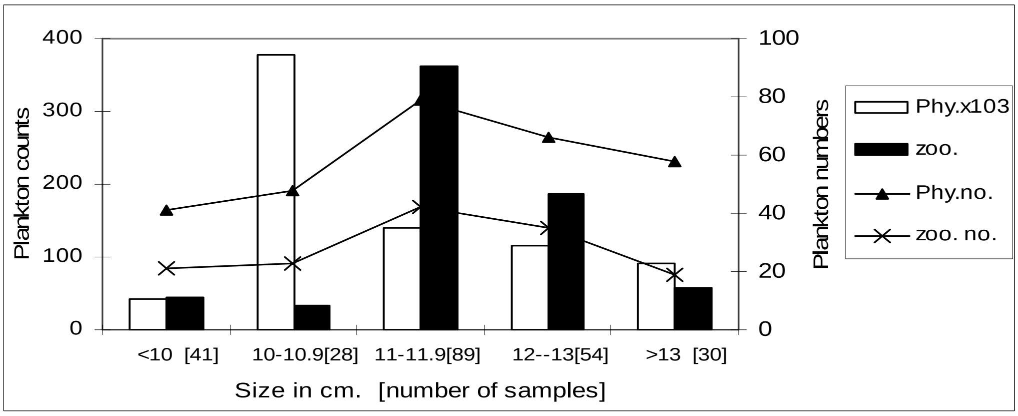

Fig (6): Average plankton count/stomach and numbers of prey items in the stomach against different sizes.

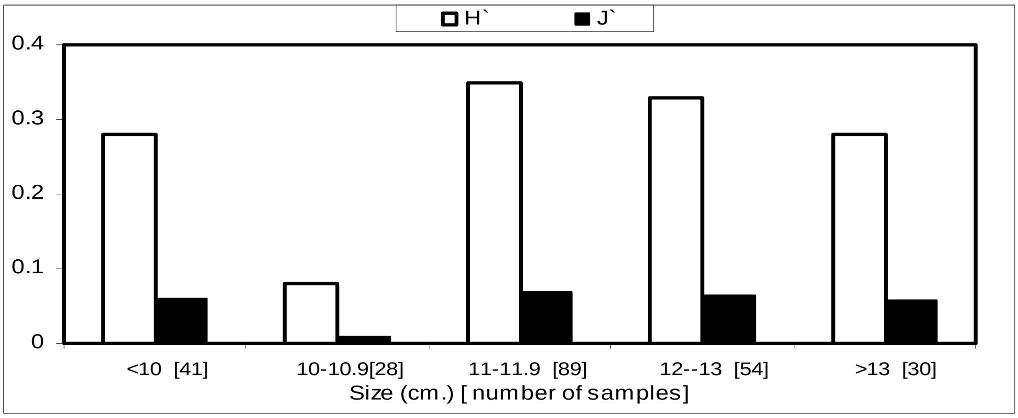

Fig (7): Diversity Index (H`) and Evenness (J`) of food items against different sizes.

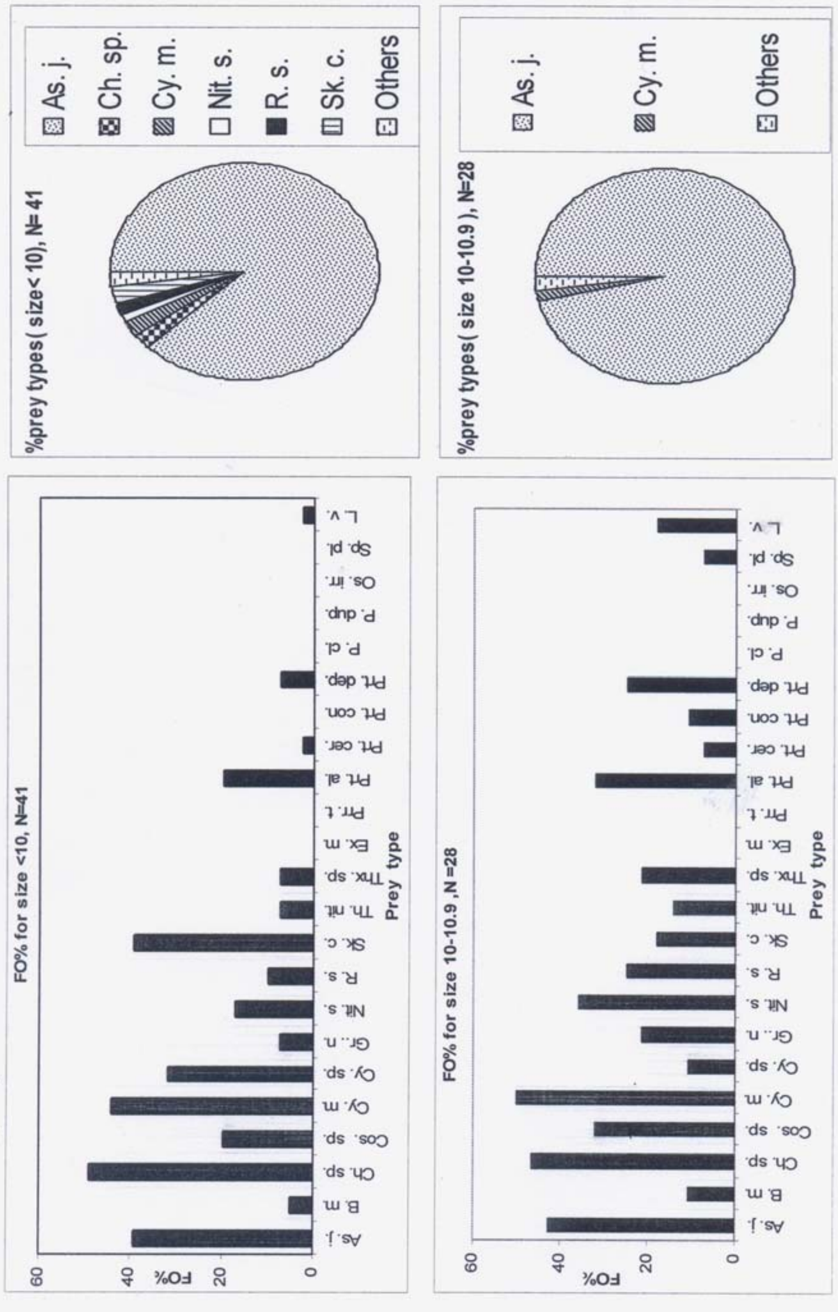

Fig (8 a): Average percent frequency of occurrence of important items of *Sardinella aurita* in Mex Bay for different size groups of the fish,and percent composition of prey types in its diet.

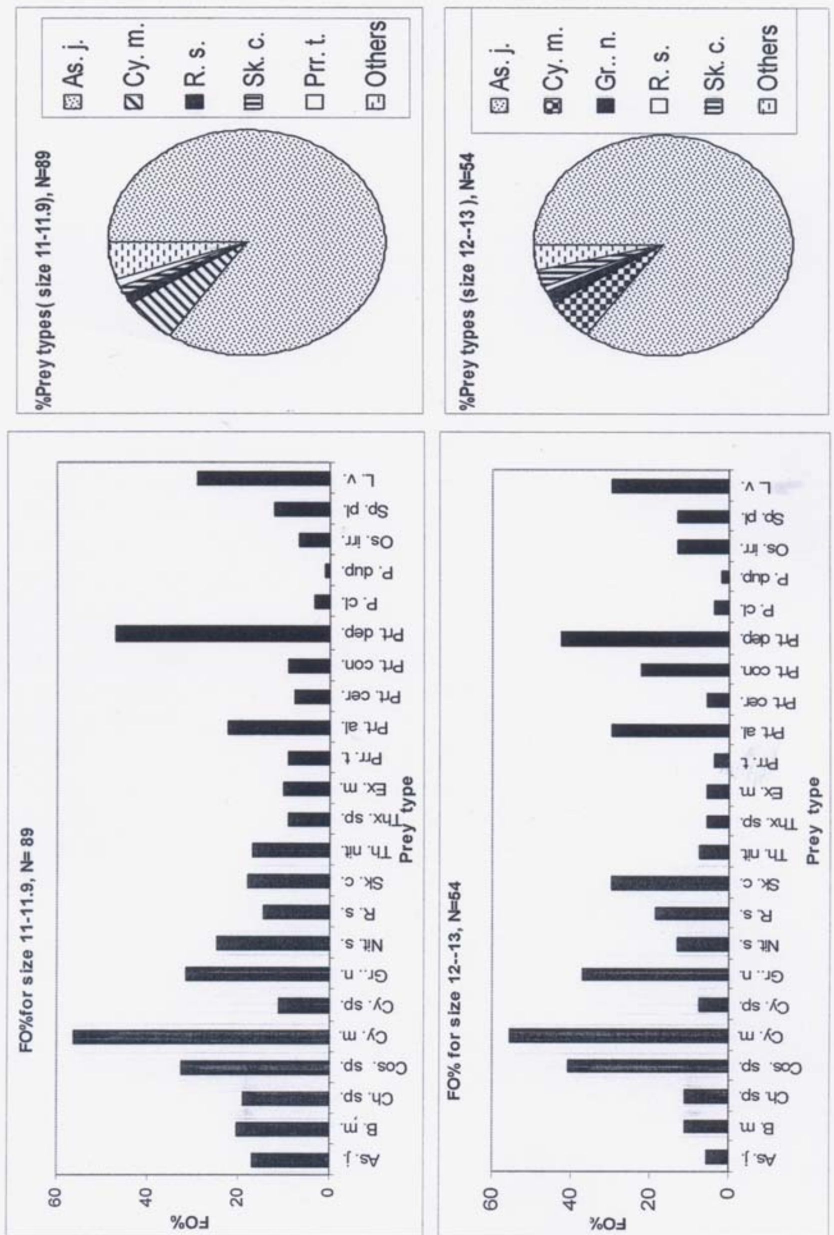

Fig (8 b): Average percent frequency of occurrence of important items of *Sardinella aurita* in Mex Bay for different size groups of the fish,and percent composition of prey types in its diet.

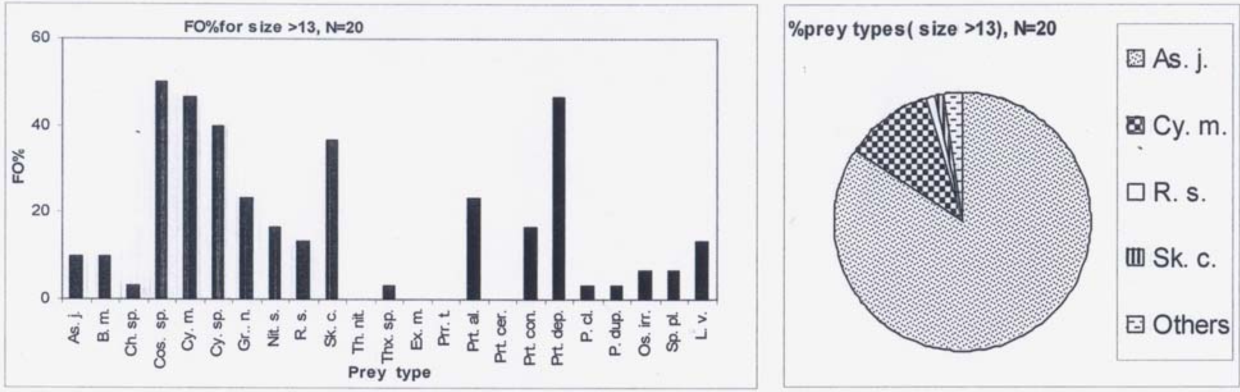

Fig (8 c): Average percent frequency of occurrence of important items of *Sardinella aurita* in Mex Bay for different size groups of the fish,and percent composition of prey types in its diet.

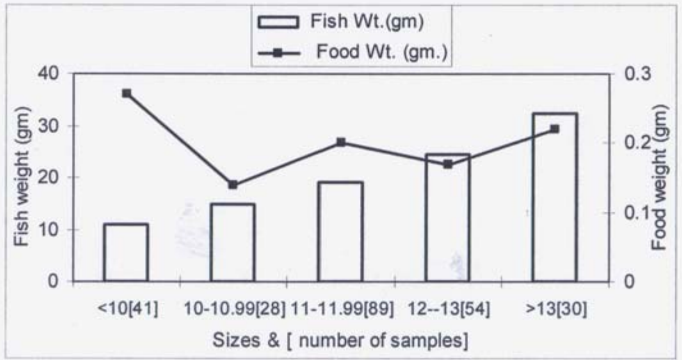

Fig (9): Average fish weight and food wet weight for different sizes.

4. DISCUSSION

The study of trophic ecology is useful and fundamental to an understanding of the functional role of the fish within their ecosystems (Blaber, 1997; Cruz *et al*., 2000). Analysis of stomach contents of *Sardinella aurita* in El Mex Bay showed good correlation with the ambient plankton, where all species found in the stomach content of this fish were previously recorded in the water of El Mex Bay (El- Sherif, 1989, Labib, 1997 and Hussein, 1997), with nearly the same correlation, for example diatoms, the main prey represented by 96% of the diet (average 13 x 10^4 cell/stomach), found in the water of El Mex Bay as the main bulk of phytoplankton community forming 89.6% (i.e. 111.4 x 10^4 cell/ liter) of the total standing crop of phytoplankton (Labib, 1997), Dinophyceae 2.4% in the diet (average 0.33 x 10^4 cell/ stomach) against 3.8% (i.e. 4.7 x 10^4 cell/ liter) in the bay, Chlorophyceae and Cyanophyceae 1% in the diet (average 0.14 x 10^4 cell/ stomach) against 4% (i.e. 5 x 10^4 cell/ liter) of total phytoplankton in the bay. The VI (the vacuity index), which is an inverse indication of feeding intensity, was almost negligible during the present study (only one stomach was empty during February).

Tsikliras *et al.* (2005) indicated that in the northeastern Mediterranean the species feeds mainly on zooplankton and crustaceans and according to the classification based on TROPH, round *Sardinella* is an omnivorous species with preference to animal prey (Stergiou& Karpouzi, 2002). Similar feeding habits have been reported for round *Sardinella* in other areas, with the percentage composition of diet varying with area and season (Nieland, 1982; Wang & Qiu, 1986; Moreno & Castro, 1995).

The relatively high numbers of prey items/stomach may be attributed partly to the high diversity of the available food in El-Mex Bay in all seasons, where the annual record was 159 phytoplankton and 121 zooplankton species in El Mex Bay and more than 70% of these numbers recorded seasonally (El-Sherif, 1989 and Hussein, 1997).

Although the fish diet in winter was diversified consisting of 84 items, *Asterionella japonica* was the main prey item, constituting more than 99% of the fish diet by count, and the other 83 species were represented by (1.0%), (i.e. 5047 organisms/ stomach). In the coastal areas around Alexandria *Asterionella japonica* flourished during winter, less abundant during other seasons (Hussein, 2000). An increase in the diversity of *Sardinella aurita* diet is consistent with niche theory which stipulates that when a "preferred" prey is abundant, breadth of diet is more limited than during seasons when such prey are scarce (Wotton, 1990). *Sardinella aurita*, therefore, seems to feed on other prey when *Asterionella japonica* is scarce. During the other three seasons *Sardinella aurita* preyed on diatoms, particularly *Cyclotella meneghiniana* and *Skeletonema costatum*, the two species formed collectively 16.4% to 73.3%.

The present results showed an increase in feeding intensity during winter (average 504660 organisms/ stomach), when *Asterionella japonica* the main prey item was found in high concentration in the neritic waters of El Mex Bay (El Sherif, 1989). The extreme abundance of *Asterionella japonica,* the preferable food for the fish would encourage it to eat huge amounts for more energy input to meet its requirements for positive growth. The intensity of feeding decreased during summer (9160 organisms/ stomach), associated with the spawning period for this fish during May – August (Faltas, 1983), while it was moderate during autumn and spring with average counts (23 and 24 x 10^3 organisms/stomach, respectively). The changes in feeding intensity was paralleled with changes in the biotic environment, when the composition of the diet during autumn and winter consisted of more than 95% diatoms, while during spring the diet was shared between diatoms and Dinophycaea, %N = 46% for each, but during summer the diet consisted of diatoms, 61%, Dinophycaea, 16% and Cyanophycaea, 18%). Labib (1997) and Hussein (2000) found that the main peak of diatoms in the coastal areas around Alexandria and in El Mex Bay occur during late autumn and winter. While the highest abundance of Dinophycaea and Cyanophycaea in El Mex Bay was recorded during spring and summer (El Sherif 1989, and Labib, 1997). Seasonal differences in diet composition may be due to the capability of the species in adjusting its diet on the seasonally oscillating prey abundance (Nieland, 1982).

Although zooplankton peak in El Mex Bay was recorded during autumn and spring (Hussein, 1997) the numerical percentage of zooplankton in the diet did not exceed 0.6% and 4.5% in both seasons respectively. Copepod nauplii and *Euterpina acutifrons* were numerically of minor importance in the diet of the fish analyzed in this study, even though they were found in 69 and 33% of the stomachs examined and were significantly dominant in El Mex Bay all year (Hussein, 1997). Despite their low numbers in the diet of the fish, their duty value could not be ignored on account of their size and weight.

Faltas (1983) found that the principle prey items of *Sardinella aurita* were decapods, fish larvae, isopods, amphipods, and polychaetes which were frequently found in the stomachs (%FO 74, 15, 25, 27 and 3%, respectively), with %N = 34, 10, 4, 5 and 2% respectively. He noticed also that gastropod veligers and algae with %FO = 80% formed 42% of the diet, while cirriped larvae and Copepoda with %FO = 14 and 9% formed 3% and 1% of the diet respectively and thus could be considered of low importance in the diet. Faltas (1983) concluded that *Sardinella aurita* is a particulate feeder, and owing this to the gear used for capturing (purse- seine) and light. The differences between the present results and Faltas (1983) may be due to the environmental variations, which probably affect the availability of different food items (Pitt, 1973). Tsikliras *et al*. (2005) indicate that *Sardinella aurita* in the northern Aegean Sea is omnivorous, opportunistic feeder, feeds mainly on zooplankton and crustaceans. In Senegal waters *Sardinella aurita* is an omnivore with preference to plant material (Nieland, 1982). It seems that *Sardinella aurita* has a flexible adaptive strategy resulting from its demographic plasticity (Cury and Fontana, 1988).

The increase of wet weight of food during spring was due to the increase of zooplankton in the stomachs (%N = 4.8%), while during the other seasons there was no relation between the wet weight and the amount of food because of the different amounts of digested food (Detritus) during different seasons.

The diversity index and evenness were very low during winter due to the dominance of one species (*Asterionella japonica*, with %N = 99%), the diversity index increased during spring and summer because many species shared the dominance of the diet, but during autumn the value decreased with the increase of *Cyclotella meneghiniana* count (> 50%) of the diet. An index of diversity will vary from a minimum, when all the individuals present in a community belong to a single species, to a maximum when each individual belongs to a different species (Zar, 1984).

The diet differences among size classes are probably due to the energy requirements, which vary according to the developmental stage. Indeed, during ontogeny, fish often change their diet (Karpouzi & Stergiou, 2003). The observed increase in prey number with *Sardinella aurita* size (till size11.9cm) indicates increasing preference of small sizes for diversified food items, then at sizes (12-13 and >13 cm), the selectivity of food increased and the number of prey items decreased. The numerical density of food reached its maximum at the second size class (10-10.9 cm), probably coincided with maturation of reproductive organs to reach maturity stage. Faltas (1983) found that the length at first spawning was 11.5 cm for this species. Although zooplankton counts were relatively small as compared to phytoplankton at all sizes (33- 363 org/ stomach), yet, its presence seemed to be essential at various sizes as a protein source for growth and maturation, the increasing counts at size class (11- 11.9 cm) insure its importance for maturation of sexual organs. The diversity index was the lowest at the second size class due to the dominance of *Asterionella japonica* (%N = 97%), also the wet weight was the lowest at the second size class due to the lowest zooplankton density at this size (33 organisms/ stomach). While the lowest food density was recorded at the smallest size followed by the highest wet weight may be due to the high weight of detritus.

Asterionella japonica was the most important food item eaten by *Sardinella aurita* of all size groups (%N ranged from 84 to 97%). However, *Cyclotella meneghiniana* and *Skeletonema costatum* represented by small percentage at all sizes. Other food items were scarce. This coincides with Faltas (1983) who noticed small variations in the types of food items of *Sardinella aurita* at different sizes.

Analysis of stomach contents of other species of *Sardinella* , as *Sardinella gibbosa* and *S. longiceps* showed that the fish feed mostly on phytoplankton, copepods and nematodes (Nyunja *et al.*, 2004), while the diatom *Fragilaria oceanica* has been suggested as the favorable food for *S. longiceps* (Mohantz *et al*., 2005). Preliminary observations on food and feeding habits showed that copepods and other crustacean items are preferred food for *Sardinella fimbriate* (Bennet, 1967). Recent study by Emmett *et al.* (2005) showed that nearshore sardines typically consumed more phytoplankton and copepods while offshore sardines consumed more euphausiids.

5. CONCLUSION

In the study area, *Sardinella aurita* proved to be a filter feeder planktivorous fish mainly herbivorous, with diet composed of more than 95% phytoplankton, while zooplankton items were numerically less important in its diet.

The food of *Sardinella aurita* consisted mainly of diatoms (>95%), during autumn and winter; while diatoms and Dinophyceae shared the dominance (46% for each) during spring. But during summer the diet consisted of a collection of diatoms (61%), Dinophyceae (16%) and Cyanophyceae (18%).

Asterionella japonica was the main food item for all different sizes, particularly during winter, while *Cyclotella meneghiniana* and *Skeletonima costatum* shared the dominance with other food items during the other seasons.

REFERENCES

Bacheler, N.M., Neal J.W., Noble R.L.: 2004, Diet overlap between native bigmouth sleepers (*Gobiomorus dormitor*) and introduced predatory fishes in a Puerto Rico reservoir. *Ecology of freshwater fish,* **13**: 111- 118.

Bennet, P.S.A.: 1967, Some observations on the fishery and biology of *Sardinella fimbriata* (Val.), at Vizhhhingam. *Indian J. Fish* , **14 (1&2)**: 145- 158.

Blaber, S.J.M.: 1997, Fish and fisheries of tropical estuaries (367pp). London: Chapman and Hall.

Bradford, J. M.: 1972, Systematic and ecology of New Zealand central east plankton sampled at Kaikoura - New Zealand Oceanographic Institute, No. **54**.

Cruz, E.V.H.; Abitttia,C.L.A.; Campos,D.L. and Galvan,M.F.: 2000, Trophic interrelations of the three most abundant fish species from Laguna San Ignacio, Baja California Sur, Mexico. *Bulletin of Marine Science***.** **66**, 361-373.

Cury, P. and Fontana, A.: 1988, Competition et strategies demographiques compares de deux especes de Sardinelles (*Sardinella aurita* et *Sardinella maderensis*) des cotes ouest- africaines. *Aquatic living resources*, **1**: 165- 180.

Dodge, J.D.: 1982, Marine dinoflagellates of the British Isles, Her Majesty's Stationery Office, London, 303 pp.

Dorner, H., Wagner, A.: 2003, Size – dependent predator- prey relationships between perch and their fish prey. *Journal of fish biology,* **62**: 1021- 1032.

Dussart, B.: 1969, Tome 2 cyclopoides et Biologie N. Boubee edit. Paris 1- 292.

Edmondson, W.T.: 1959, Fresh water biology, 2nd ed. John Wiely and Sons Inc, New York and London. **20**, 1248 pp.

El- Maghraby, A.M.: 1960, The biology of the Egyptian Sardine. Preliminary account of the biology of *Sardinella eba* Cuv. and Val. Notes and Memoires No. 58, Alex. Inst. Hydrob.

El Nayal, A.A.: 1935, Egyptian freshwater algae,. *Bull. Sci. Cairo,* **4**, pp. 1- 106.

El Nayal,A.A.: 1936, Contribution of our knowledge of the freshwater algae of Egypt *Bull. Sci. Cairo,* **1(9),** pp. 1-31.

El- Sherif, Z.M.: 1989, Distribution and ecology of phytoplankton in El-Mex Bay (Egypt). *Bull. Inst. Oceanogr. Fish. , A.R.E.* **15(2)**: 83-100.

Emmett, R.L.; Brodeur,R.D.; Miller,T .W.; Pool,S.S.; Krutzi,K.;Bentley,B,J. and Mccrae,J.: 2005, Pacific sardine (*Sardinops sagax*) abundance, distribution, and ecological relationships in the Pacific Northwest. *Ecology.* Vol.**46**: 122-143.

Faltas, S. N.: 1983, Study of purse- seine fisheries in Egyptian Mediterranean waters with special reference to the biology of sardine in the catch. M.Sc. Thesis, Faculty of Science. Alex. Univ., 194 pp.

FAO.: 2000, The state of world fisheries and aquaculture 1999. Food and Agricultural Organisation of the United Nations, Rome.

Hashem, M.T. and Faltas, S.M.: 1979, Fisheries investigation of the sardine gill net at El- Mex region, near Alexandria. Inst. Oceanogr. And Fish., Rep. Fish. Inv. Sardine and other pelagic Fish. Alex. ,28 pp.

Hendey, N.I.: 1964, An introductory account of the smaller algae of British Coastal Waters, Part5, Baccilariophyceae, Minist. Agric. Food Invest. Ser., London.

Heurck, V.H.: 1896, Atreatise on theDiatomaceae. William Westy and Son, **28**, Essex, Strand, W.C. 559pp.

Hussein, M.M.: 1997, Distribution of zooplankton assemblages in El- Mex Bay, Alex. Egypt. *Bull. Inst. Oceanogr. Fish,* **23**, 217-241.

Hussein, N.R.: 2000, Ecological and physiological studies on phytoplankton in some coastal areas around Alexandria. Ph.D. Thesis, Faculty of Science, Alexandria University, Egypt, 282 pp.

Hutchinson, G.E.: 1967, A teratise of Limnology. Vol.11. Introduction to lake biology and limnoplankton. John Wiley (edit.), New York, 1115 pp.

Karpouzi, V.S. and Stergiou, K.I.: 2003, The relationships between mouth size and shape and body length for 18 species of marine fishes and their trophic implications. *Journal of fish biology,* **62**: 1353-1365.

Khunnah, M.C.: 1967, Chlorococcales. The Indian Council of Agricultural Research, New Delhi. Job Press Privare Ltd., Kanput 363 pp.

Labib, W.: 1997, Eutrophication in Mex Bay (Alexandria, Egypt). Environmental studies and statistical approach. *Bull. Inst. Oceanogr. Fish,* **23**, 49-69

Laroche, J. L.: 1982, Trophic patterns among larvae of five species of sculpins (family: Cottidae) in a Marine estuary. *Fishery Bulletin NOAA,* **80**: 827- 840.

Malt, S. J.: 1983, Fiches d'identification du zooplankton. Fiches Nos. 169/ 170/ 171, Crustacea, Copepoda (Cyclopoida).

Conseil Permanent international pour L´ Exploration de la Mer, Charlottenlund Slot- Denmark.

Marshall, S.M.: 1969, Protozoa. In: Fiches d'identification du zooplankton, Eds. J.H. Fraser and V.K. Hansen. Sheets 117- 127. Conseil Permanent international pour L´ Exploration de la Mer, Charlottenlund Slot- Denmark.

Mohanty, P.K.; Khora, S.S.; Panda, U.S.; Mohapatra,P.M.: 2005, An overview of Sardines and Anchovies fishery along the Indian Coasts. Dep. Marine Science, India, pp.12.

Moreno,T.and Castro,J.J.: 1995, Community structure of the juvenile of coastal pelagic fish species in the Canary Islands waters. *Scientia marina,* **59**: 405-413.

Nieland, H.: 1982, The food of *Sardinella aurita* (Val.) and *Sardinella eba* (Val.) of the coast of Sengal. Rappots et process verbaux des reunions conseil international pour l'exploration de la mer, **180**: 369-373.

Nyunja,L.A.; Mavuti, K.M. and Wakwabi,E.O.,: 2004, Trophic ecology of *Sardinella gibbosa* (Pisces: Clupeidae) and *Atherinomorous lacunosus* (Pisces :Athherinidae) in Mtwapa Creek and Wasini Channel, Kenya. *Western Indian Ocean J. Marine Science* **1(2),**p. 181-189.

Park, M., and Dixon, P.S.: 1976, Check- list of British marine algae, Third revision, *J. Mar. Biol. Ass. U.K.,* **56**, pp. 527- 594.

Peragallo, H., and Peragallo, M.: 1897-1908, Diatoms Marines de France et des Districts maritimes voisins, I-III (Text and plates), pp. 1-491, Tempere Crez-Surloing.

Pitt, T.K.: 1973, Food of American Plaice (Hippoglossoides platessoides) from the Grand Bank, Newfoundland. *J. Fish. Res. Board Can.* **30**: 1261-1273.

Post D.M., Conners M.E., and Goldberg D.S.: 2000, Prey preference by a top predator and the stability of linked food chains. *Ecology*, **81**: 8-14.

Rifaat, A.: 1960, Sardine Fisheries in the United Arabic Republic (Southern Region). In: Proc. World Sci. Meet. Biol., Sardines and related sp., F.A.O., Experience Paper, 21.

Rose, M.: 1933, Copepods peladiques, Faune de France, **26**: 1- 374, La Chevalier, Paris.

Said, M.A.; El-Deek,M.S.; Mahmoud,Th.H. and Shriadah, M.M.A.: 1991, Physico-chemical characteristics of different water types of Mex Bay of Alexandria, *Bull. Inst. Oceanogr.,& Fish.A.R.E.* **17(1):** 103-116.

Sournia, A.: 1986, Atlas du phytoplankton marine. Vol., **1**. Cyanophycees, Dictyochophycees, Dinophycees et Raphidophycees, Ed. Du CNRS, Paris, 219 pp.

Stergiou, K.I.and Karpouzi, V.S.: 2002, Feeding habits and trophic levels of Mediterranean fish. *Review in fish biology and fisheries,* **11**: 217-254.

Tregouboff, G., and Rose, M.: 1957, Manuel de planctonologie mediterraneene, Paris, Ed., du., C.N.R.S., 2nd Vol., 587 pp.

Tsikliras, A.C., Torre, M. and Stergiou, K.I.: 2005, Feeding habits and trophic level of round *Sardinella* (*Sardinella aurita*) in the northeastern Mediterranean (Aegean Sea, Greece). *Journal of Biological Research* **3**: 67- 75.

Wang, J. and Qiu, S.: 1986, On the feeding habit of *Sardinella aurita* Val. In south Fujian-east Guangdong coastal waters. *Taiwan strait,* **5**:86-93.

Wotton, R.J.: 1990, Ecology of Teleost Fishes. Chapman and Hall, London.

Zar, J.D.: 1984, Biostatistical Analysis. Prentice-Hall, Englewoods cliff, NJ.