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Feeding ecology of the round sardinella, *Sardinella aurita* (Family: Clupeidae) in the Egyptian Mediterranean waters

Fedekar F. Madkour
Marine Science Department, Faculty of Science, Port Said University, Egypt.

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ABSTRACT
The objective of the present study was to analyze the diet composition of the round sardinella, *Sardinella aurita* in the Egyptian Mediterranean off Port Said coast. Gut contents from 100 stomachs/season were examined. The gut fullness index was estimated and the percentage of empty stomachs was expressed as the vacuity index (VI). Diet composition was described using frequency of occurrence (%*F*) and numerical methods (%*N*). The diet of *S. aurita* consisted predominantly of zooplankton (50.1%) followed by phytoplankton (34%) and relatively small quantities of detritus (15.9%). The major prey items were copepodes supplemented by diatoms followed by Protozoa and Chlorophyceae. The type and abundance of ingested prey were related to the plankton composition in the environment in order to determine prey-type selectivity. Diet composition of stomach proved that *Sardinella aurita* has a flexible adaptive strategy appeared obviously from adjusting its diet feeding habits to its specific requirements.

1. INTRODUCTION
The study of the food and feeding habits of fish species remains a subject of continuous research, because it constitutes the basis for development of a successful fisheries management on fish capture and culture (Oronsaye and Nakpodia, 2005). Studies on diet composition are important in community ecology since the use of resources by organisms has a major influence on population interactions within a community (Mequilla and Campos, 2007). Studies of species resources requirements have been used in attempts to understand factors controlling the distribution and abundance of organisms (Ross, 1986). Analysis of stomach contents could provide useful information on positioning of the fishes in the food web of their environment and estimation of trophic levels (Pauly and Christensen, 2000; Post *et al*., 2000). In addition, the quality and quantity of food are among the most important exogenous factors directly affecting growth and indirectly, maturation and mortality of fish, thus being ultimately related to fitness (Wootton, 1990).

Sardine (Family: Clupeidae) is a mid-sized pelagic fish that represents one of the most important commercial fishery resources in the Egyptian Mediterranean Sea. The presence

Corresponding author E-mail: Fedekarmadkour@yahoo.com
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of sardine in front of Nile Delta with high abundance was related to the Nile flood. The abundance and species composition of sardine were greatly altered after the construction of Aswan High Dam. Prior to the damming of the Nile, the average fish catch reached to 35000 tons, where sardine constituted around 50 % of this catch (18000 tons) (El-Zarka and Koura, 1965). After the construction of AHD in 1964, the Egyptian Mediterranean fisheries declined to less than one-fourth and sardine was the most affected fish which was declined drastically to 0.9% of the total fish catch in 1971. This low level was more or less retained till 1979, after which the sardine catch again increased reaching 31.7% of the total catch (Hamza, 2006). According to GAFRD (2007), it was raised to about 52% of the average total catch during the period 1997-2007.

Round sardinella, *S. aurita* Valenciennes, 1847, is considered as an abundant species of the sardine catch which together with *Sardina pilchardus*, and other species make up about 60% of the total fish production in Port Said landing sites (Mehanna *et al*., 2008). In the Egyptian Mediterranean waters, the *S. aurita* spawning period runs from June to September, with its peak in late July to early August, when water temperature reaches the yearly maximum (El-Rashidy, 1987). *S. aurita* being a commercially important fish needs special attention and the study of its food and feeding is important. Several studies have been conducted on its fisheries and biology (Rifaat, 1960; El- Maghraby, 1960; Hashem and Faltas, 1979; Faltas, 1983 and Mehanna *et al*., 2008) but only one on its feeding habits in Alexandria (Abdel Aziz and Gharib, 2007). The aim of the present work was to determine the feeding ecology of *S. aurita* by studying seasonal feeding habits, diet composition and selectivity as a function of prey availability. Also to provide information on the abundance of natural food needed by *S. aurita* at the Egyptian coasts off Port Said. Changes in diet composition through the different growing stages were discussed.

2. MATERIAL AND METHODS

2.1 Environmental measures and plankton sampling

The study was conducted at Port Said coast (31º 29' N, 32º 33' E) which receives brackish water inputs from Lake Manzalah (Figure 1). This lake is reported to be relatively eutrophic due to direct release of sewage, industrial and agriculture wastes into it (Hamza, 1985). Samples and measurements were taken seasonally, one in each season: autumn (October 2009), winter (January 2010), spring (April 2010) and summer (July 2010). Temperature was measured using a mercury thermometer, salinity using a refractometer and pH by a digital pH meter. Transparency was measured using a Secchi disc. Dissolved oxygen was determined by Winkler's method (Strickland and Parsons, 1972). Plankton samples were taken by nets of 30 and 100 µm mesh size for phytoplankton and zooplankton, respectively and then preserved in 4% formalin solution immediately. The plankton, phyto-and zooplankton, were identified to the lowest possible genus and counted although convenient higher groupings have been partially adopted for convenience of presentation. One way ANOVA was performed on environmental parameters to evaluate seasonal variations between them using software program SPSS V. 17.

2.2 Fish collection and stomach sampling

Samples of *Sardinella aurita* were obtained seasonally from the fishermen catches using purse seine net at landing sites of Port-Said. Fish samples were chilled in iced blocks immediately before being transported to laboratory for analysis. Total length of each specimen to the nearest centimeter was taken from the tip of the head to the tip of the tail, using a Vernier caliper. Specimens were dissected and the alimentary tracts were removed by section at the point, where the stomach entered the abdominal cavity and immediately before the anus. Both the pyloric and cardiac stomachs were cut open and the main bolus of contents removed. The contents were then placed into

a 5 ml vial and any remaining contents were washed in with 4% formalin solution. The gut contents were agitated to break up the bolus into an even mixture and examined under an inverted microscope. Only specimens with complete structures or with a prominent body part were identified and counted. Fragmented body parts like carapaces, spines, segments, and legs were not included in the analysis and were classified as a digested material.

Fig.1: Map showing the trawling area in front of Port Said Fishing Harbor.

2.3 Food analysis

Gut contents from 100 stomachs/season were examined. The intensity of feeding (fullness index) was estimated on a scale of 0–4 (0 = empty; 1 = 25% full; 2 = 50% full; 3 = 75% full; 4 = completely full) as described by Pillay (1952). The percentage of empty stomachs to the total number of examined stomachs was expressed as the vacuity index (VI). Diet composition was described using frequency of occurrence and numerical methods as described by Hyslop (1980) and Costal *et al.* (1992). In the frequency of occurrence method, the occurrence of food items was expressed as the percentage of stomachs with a certain food item to the total number of stomachs containing food (%*F*). In the numerical method, the number of each food item was expressed as the percentage to the total number of food items found in the stomachs (%*N*).

3. RESULTS

3.1 Environmental variables and plankton availability

Seasonal fluctuations of hydrobiological characters off Port Said waters are shown in Table (1). There were significant seasonal variations in temperature, salinity and water transparency, while seasonal fluctuations in dissolved oxygen and pH readings were insignificant (ANOVA, $P>0.05$). Densities of plankton communities showed bimodal

annual cycles with different peaks duration for phytoplankton and zooplankton. The more pronounced peaks occurred in winter (162498 individual/l) for phytoplankton, and in summer (10923 individual/m^3) for zooplankton. Diatoms appeared as the predominant component of phytoplankton, contributing numerically 71% of the total phytoplankton population throughout the study period, with an annual average of 49570 individual/l. Cyanophyceae and Chlorophyceae came in the second order, giving approximately close annual averages (8237 and 7134 individual/l, respectively). The most dominant phytoplankton species were *Cyclotella meneghiniana*, *Thalassiosira* sp., *Nitzschia closterium*, *Synedra pulchella*, *Anabaena* sp., *Scenedesmus dimorphus* and *Prorocentrum micans*. The recorded zooplankton were subjectively categorized as copepods (Calanoida, Cyclopoida and Harpacticoida), Cladocera, Protozoa, fish eggs and larvae, and others (Chaetognatha, larvae of decapods, cirripedes, molluscs and echinoderms). Copepods were the most important zooplankton group in the investigated area, constituting an annual average of 58.4 % of the total zooplankton during the period of study, with a main peak of 7209 individual/m in summer. Although the copepod density during winter was comparatively low (2923 individual/ m^3) in comparison to the other seasons, it represented about 78% of the total zooplankton in this season. *Centropages*, *Paracalanus*, *Acartia*, *Oithona* and *Euterpina* were the main genera as zooplankton biomass builders.

Table 1: Environmental variables, phytoplankton (individual/l) and zooplankton (individual/ m^3) densities at Port Said during autumn 2009-summer 2010.

	Autumn	Winter	Spring	Summer
Temperature (ºC)	21.3	16.2	24.2	28.6
Salinity (‰)	36.6	35.1	37.7	39.1
Secchi depth (cm)	160	130	230	250
Oxygen (mg/l)	6.9	7.1	5.4	5.9
pH	8.2	8.0	8.0	8.3
Total phytoplankton	71128	162498	32994	12539
Diatoms	57614	120249	17157	3260
Cyanophyceae	7824	19499	4620	1003
Chlorophyceae	4268	14625	7258	2383
Dinoflagellates	1422	8125	3959	5893
Total zooplankton	6315	3748	8638	10923
Copepods	3284	2923	3887	7209
Cladocera	708	75	501	1584
Protozoa	145	262	397	568
Fish eggs and larvae	126	157	268	426
Others	2052	330	3585	1136

3.2 Stomach fullness

Out of 400 specimens of *Sardinella aurita* examined, 109 (27.3%) had empty stomachs while 79 specimens (19.8%) had completely full stomachs. The percentage of empty stomachs varied with season as shown in Figure (2). The greatest number of empty stomachs was found in summer, giving the highest vacuity index (VI= 63%) while there were no empty stomachs in spring. Consequently, feeding intensity of *S. aurita* varied seasonally, giving high rate of feeding activity in spring with the highest percentage of completely full stomachs (30%).

3.3 Seasonal diet composition and selectivity

The diet of *S. aurita* consisted predominantly of zooplankton, which accounted for 50.1% of the annual average stomach content, followed by phytoplankton (34%) and relatively small quantities of detritus/unidentifiable material (15.9%). Zooplankton food items could be differentiated into four categories as follows: 1) copepods, mainly calanoids and

cyclopoids, comprised about 37.5%; 2) Protozoa, mainly tintinnids and foraminifera; 3) Cladocera; and 4) fish eggs and larvae (Figure 3). Phytoplankton food items consisted of diatoms (25%), Chlorophyceae (5.9%), Cyanophyceae and dinoflagellates (comprised collectively about 3.1%). Partially digested and digested food, such as fragmented carapaces, legs and antennae of zooplankton, were also present but were not used in the diet analysis.

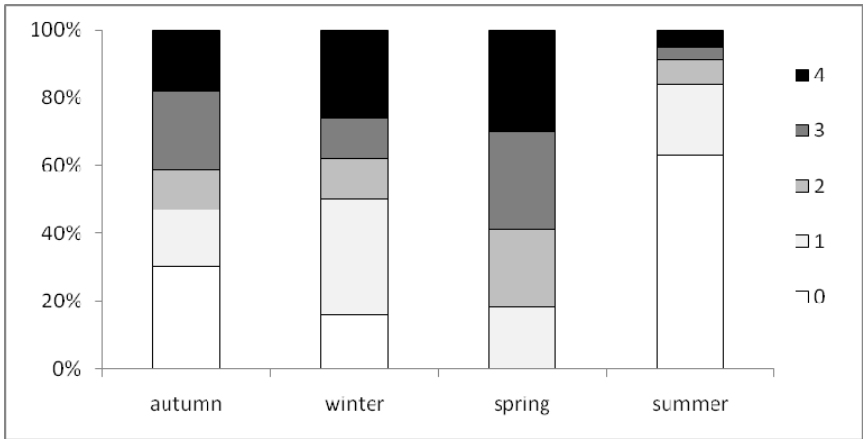

Fig. 2: *Sardinella aurita* from Egyptian Mediterranean off Port Said, 2009-2010. Seasonal variation of feeding intensity, (0 = empty; 1 = 25% full; 2 = 50% full; 3 = 75% full; 4 = completely full).

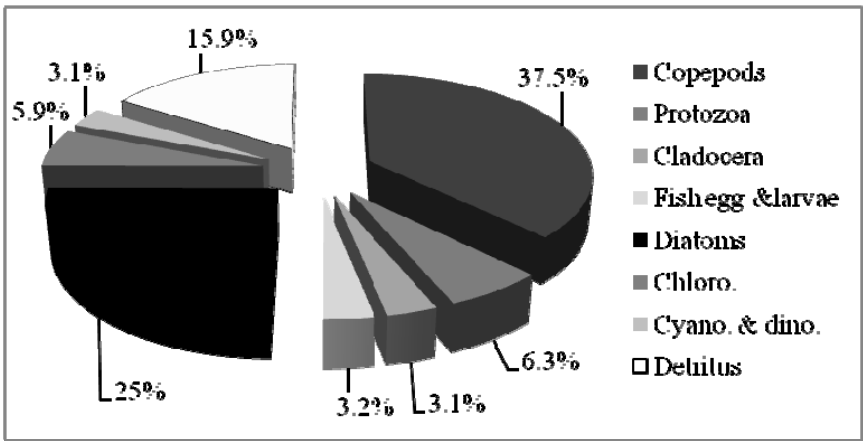

Fig. 3: *S. aurita* from Egyptian Mediterranean off Port Said, 2009-2010. Percentage of annual average of diet composition items.

According to frequency of occurrence method, the major prey items were copepods supplemented by diatoms followed by Protozoa and Chlorophyceae (Figure 4). The percentage frequency of each prey item varied seasonally, with copepods being the main prey item in the diet all the year except in autumn ranging between 91% to 32% of the total food items. Diatoms were the most common in autumn (75%), and declined to be the second common food item for the other seasons. The highest occurrence of Chlorophyceae in the diet of the fish was in autumn (25%) while Protozoa were most frequent in spring (21%). There was only low percentage of the remaining food items that were irregularly found in the stomach contents of *S. aurita*.

The average seasonal numbers of different main food items following the numerical analysis reflected that displayed by frequency method giving a consistent presence of copepods, diatoms and Chlorophyceae in the diet of *S. aurita*

(Figure 5). Copepods particularly calanoids, showed the highest percent contribution to the diet of *S. aurita* in terms of number with the highest value in summer (53.2%). Diatoms and Chlorophyceae recorded the highest value in autumn (34.9% and 11.9%, respectively) while displayed relatively close percentage in other seasons with abundance of diatoms. A large number of phytoplankton genera were consumed by *S. aurita*. Of diatoms, the centric forms particularly *Cyclotella, Thalassiosira* and *Coscinodiscus* constituted the most important diet of *S. aurita* followed by pennates (*Synedra, Nitzschia* and *Navicula*). Of other phytoplankton groups, *Scenedesmus*, *Anabaena* and *Spirulina* were usually represented by a few individuals in each stomach.

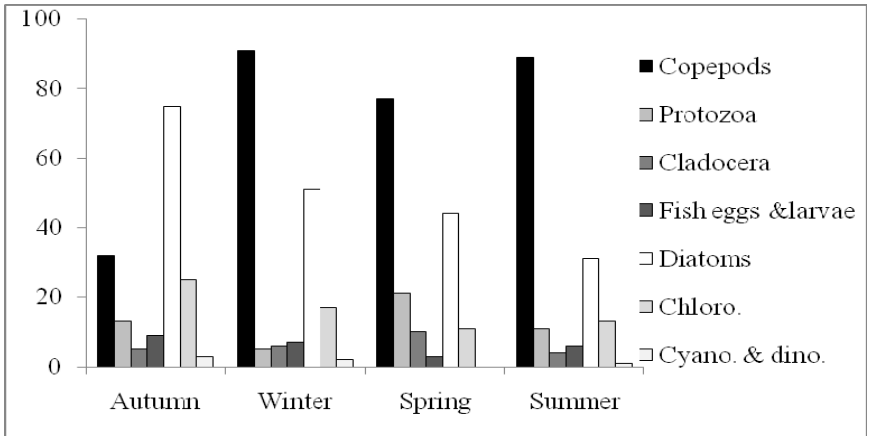

Fig. 4: *S. aurita* from Egyptian Mediterranean off Port Said, 2009-2010. Seasonal variation of food items based on percentage frequency of occurrence as a function of total length (TL, cm).

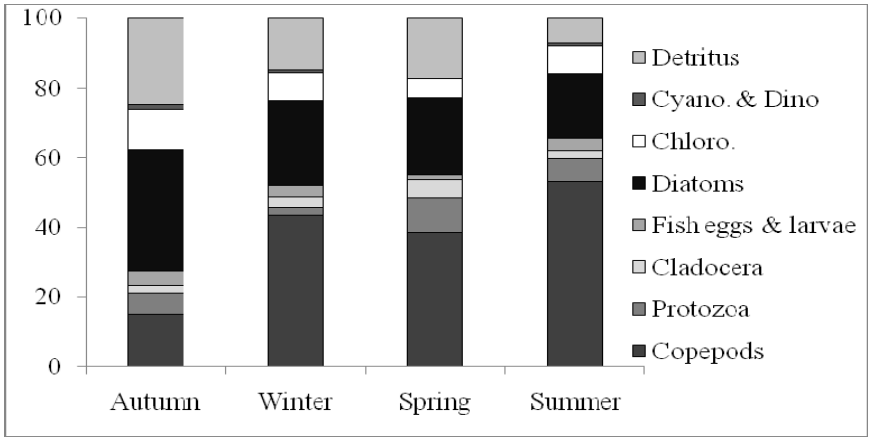

Fig. 5: *S. aurita* from Egyptian Mediterranean off Port Said, 2009-2010. Seasonal variation of food items based on percentage contribution of each food item to the diet as a function of total length (TL, cm).

3.4 Feeding variation with fish size

The total length of collected specimens ranged between 8 to 16 cm. In order to evaluate variations in food habits as a function of size, the specimens were divided into eight classes with 1cm length intervals. As shown in Figure (6), copepods and diatoms were found in all size groups of *S. aurita*. In fish size <11 cm TL, the diet composition was characterized by the predominance of plant origin items (phytoplankton) which collectively did not exceed 45.7%, with a great quantity of diatoms, giving the highest percentage (40%) in size class 6-7cm. Starting from size class 11cm onwards, changes in diet composition

were observed, where the food items of animal origin began to increase with increasing fish size. Copepods constituted the main animal origin items forming the highest percentage (86.3 %) in size class15-16cm. The length classes of 8-12 cm TL were characterized by the occurrence of high percentage of detritus (up to 25%) which decreased as fish length increased.

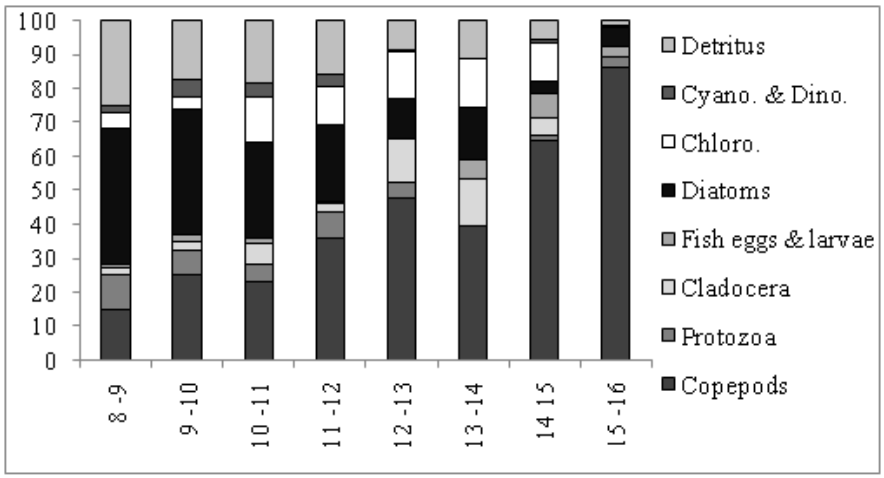

Fig. 6: *S. aurita* from Egyptian Mediterranean off Port Said, 2009-2010. Variation of food items based on percentage contribution of each food item to the diet for the different size classes.

4. DISCUSSION

This study provides more insights into the feeding habits of *Sardinella aurita* at Port Said, which was observed from samples obtained during the four seasons of 2009-2010. *S. aurita* was infrequently found to abstain from feeding, thus food was present in most of the examined guts (72.7%). The relatively low percentage of occurrence of empty stomach was due to the availability of food material for this species as appeared from the density of plankton in the water samples (Table 1). Presence of occasional empty stomach may be due to regurgitation or digestion of food items in fish stomachs as the fish struggled for escape from the nets. The vacuity index (VI) was high in summer which has been reported as spawning season for *S. aurita* in the southeastern Mediterranean (Pawson and Giama, 1985; Wassef *et al*., 1985). This may be explained by the fact that during spawning, the fish had fully occupied abdominal cavity with the ripe gonads and empty stomach. The synchronization of the period of poor feeding activity with spawning season has been reported for other fish species (Joadder, 2007; Shalloof and Khalifa, 2009). In contrast to our result, Tsikliras *et al.* (2005) found that the index VI was low in the spawning season and they explained their finding as fish need more energy input in spawning season to meet the requirements of reproduction.

Diet composition of *S. aurita* revealed that they usually feed at the surface as indicated by their planktonic stomach contents. Occasionally, they may feed at bottom, in which case their guts were almost filled with silt and sand/ unrecognizable detritus. The presence of unrecognizable detritus or "marine snow" in the diet of *S. aurita* has been noted for this species in other areas (Nieland, 1982) and for other related species such as the Indian oil sardine *S. longiceps* (Kumar and Balasubrahmanyan, 1989). The importance of "marine snow", with its organic content and associated microorganisms, has been noted in the diet of many pelagic species (Gaughan and Mitchell, 2000).

Apart from detritus, an annual average of the diet composition shows the zooplankton–phytoplankton ratio in the food

as 3: 2. Similar feeding habits have been reported for round sardinella in northeastern Mediterranean (Stergiou and Karpouzi, 2002). They classified it, according to their TROPH, as an omnivorous, filter feeder species with preference to animal prey, whereas it was classified as an omnivore with preference to plant material in other areas (Nieland, 1982). A wide variety of planktonic organisms were consumed by *S. aurita* but copepods and diatoms were their main dietary component, making about three quarter of the food; whereas all other items contribute collectively only one-fourth (Figure 3). The present result reveals that *S. aurita* has a preference for copepods that were most numerous in the diet during all seasons except in autumn. This could be attributed to its ability to select its prey based on its large size, regardless of the abundance of smaller alternatives. For instance, high diatom densities in water samples collected in winter (120249 individual/l) did not correlate with a corresponding higher number for this abundant item in the diet of *S. aurita*. Instead, copepods predominated in the stomach contents even though they were found in lower numbers in the environment. Furthermore, the highest consumption of copepods coincided with spawning season of *S. aurita* in summer and this may be because copepods swim longer and more consistently than diatoms making them easier to capture, providing maximum energy gain per unit of handling time and increase the ability of fish to use most of their energy reserves for spawning (Nunn *et al*., 2007). Sometimes, the target species change its feeding strategies and lack the selectivity. This was obvious when *S. aurita* switched from its preferred prey to feed on items lower in the food web (e.g. phytoplankton and detritus) when copepods availability was low during autumn due to the prevailing of upwelling conditions at that time, enriching water by these items.

Round sardinella showed a flexible adaptive strategy that appeared obviously from its diet, with its feeding habits being adjusted to the specific requirements of the species. Thus, diet composition varied with size classes probably due to the energy requirements, which vary according to the developmental stages. For fish >11cm in length, copepods were the main and most preferred prey that increased in importance as the fish grow in size. The diet comprised entirely these prey in the largest group of the specimens examined (15–16cm TL). The preference of larger sizes of *S. aurita* for copepods may be due to its ability to select larger prey. Kahilainen (2004) mentioned that particulate-feeding planktivores are size-selective predators and can visually detect, locate, and attack a single zooplankton individual. During ontogeny, fish often change their diet, being able to exploit sequentially a series of prey sizes, ranging from phytoplankton and small zooplankton to much larger prey (Wootton, 1990).

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