

## THE DIET OF LARVAL SARDINE, *SARDINA PILCHARDUS* (WALBAUM, 1792) IN THE EASTERN CENTRAL ADRIATIC

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### ABSTRACT

In the period from February to April 1990, data regarding the diet of larval (4-24 mm) sardine *Sardina pilchardus* (Walbaum, 1792) in relation to food availability was gathered in the eastern central Adriatic. The most common food organisms in the guts (78-89%) were the developmental stages of copepods (eggs, nauplii and copepodites). Percentage composition of copepod nauplii in the diet decreased with increasing larval size, while copepodites increased. The largest larvae still consumed a high proportion of small food particles. There was no consistent relationship between food availability and feeding success, probably because feeding conditions were generally adequate.

**Key words:** sardine, larvae, feeding, eastern central Adriatic

### INTRODUCTION

The sardine, *Sardina pilchardus* (Walbaum, 1792), is an important commercial fish species in Croatian coastal waters; the annual fluctuations in recruitment are therefore of considerable social and economic consequence.

There are only few papers dealing with the fish larval feeding ecology in the eastern Adriatic (Karlovac, 1962, 1967; Duka, 1963; Regner, 1971; Dulčić, 1993).

It is generally considered that food availability is one of the major factors affecting larval fish survival (Buckley & Lough, 1987) and it has been shown experimentally that food deprivation rapidly increases mortality in sardine larvae (Silva & Miranda, 1992). A knowledge of the diet and prey selectivity of larval sardine is thus required in order to assess food availability in the plankton.

A preliminary description of the diet of sardine larvae, from sampling on a cruise in the central Adriatic in 1952 and 1953, has been given by Karlovac (1967).

The aim of this study is to present a description on the diet of sardine larvae and food availability from sampling in 1990 in the eastern central Adriatic.

### MATERIAL AND METHODS

Sardine larvae were collected in zooplankton sam-

ples taken during sampling from February to April 1990 at the station Stončica near the island of Vis (43°00'N 16°20'E). Sampling was carried out at slow speed (2 knots) with 20 or 40 cm diameter mouth aperture Bongo net tows (200 or 280 µm mesh) fitted with partial-filtering style of cod-ends to minimise sample damage. Sample depth ranged to approximately 70 m or was within about 5 m off the bottom. Water flow through the nets was measured by means of a flowmeter fitted to one side of the nets, and maximum depth sampled was recorded by a depth recorder attached to the sampler frame. Following the haul, the fresh sample was emptied into a glass tray and sardine larvae for gut content analysis were sorted into glass vials containing 4% borax buffered formaldehyde solution. Specimens ranged in size from 4 mm to 24 mm; all are here termed as larvae. Each specimen was measured (standard length) under a dissecting microscope fitted with an eyepiece micrometer, no allowance being made for shrinkage. The complete gut was then detached, opened and all contained organisms counted, identified to the taxonomic level as allowed by their condition, and a proportion measured for length and width. Data were analysed by larval size, separated into three length ranges <10 mm, 10-15 mm, and >15 mm. In total, 1429 larvae were examined, comprising 751 larvae < 10 mm in length, 545 larvae 10-15 mm, and 133 larvae > 15 mm. Incidence

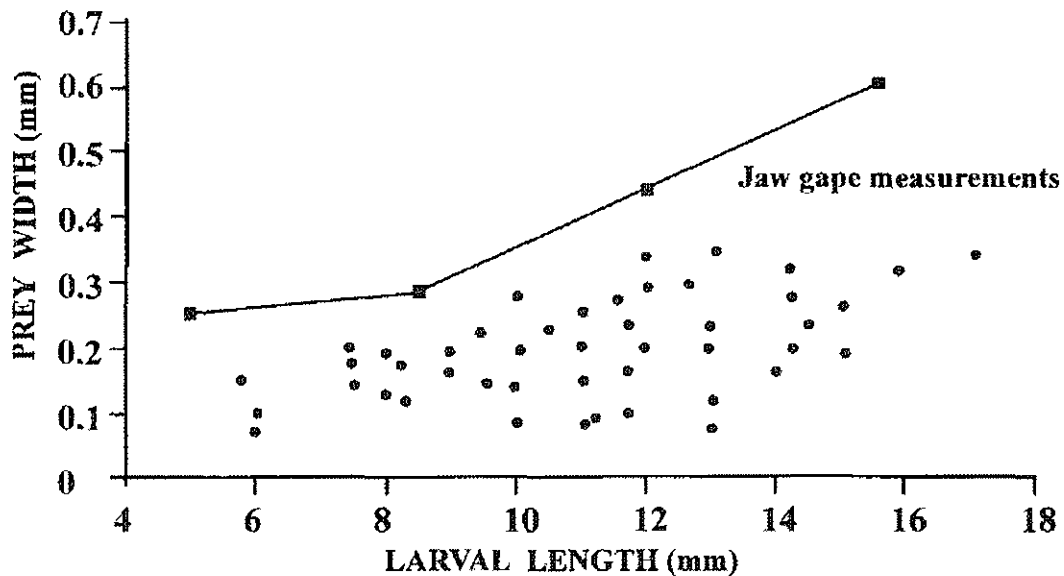


Fig. 1. Width of prey consumed plotted against the length of *Sardina pilchardus* larvae in the eastern central Adriatic. Jaw gape measurements are from Blaxter (1969).

Sl. 1: Širina konzumiranega plena v primerjavi z dolžino larv mediteranske sardele *Sardina pilchardus* v vzhodnem srednjem Jadranu. Meritve razpona čeljusti po Blaxterju (1969).

of larval feeding was calculated as the percentage of larvae in which food was observed, irrespective of food occurrence in the guts was calculated as the percentage of larvae in which at least one specimen of the target organism was observed.

Estimates of food availability in the plankton were obtained from microzooplankton sampled concurrently with 10-cm diameter mouth aperture bongo nets (53  $\mu$ m mesh), fitted on one side with a flowmeter and attached to the towing wire above the main nets. These samples were also preserved in 4% formaldehyde solution and counted for the organisms identified from the gut contents analysis as being most important in the diet of sardine larvae (*i.e.* copepod eggs, nauplii and copepodites with cephalothorax length <0.9 mm).

## RESULTS

Food organisms were generally located at the distal end of the hind-gut, sometimes protruding from the anus. Food was found in the fore-gut only on two occasions. The majority of food items taken by the three size ranges of larvae were the copepodite (9-44%), nauplii (30-61%) and egg (8-12%) stages of copepods (Tab. 1). Copepodites were normally observed only as their remaining exoskeletons, making it difficult to discriminate between the developmental stages of superficially similar genera such as *Paracalanus*, *Pseudocalanus* and *Clausocalanus*.

This was the most common copepodite group in the

diet, especially in larvae >15mm in length (30-35% of composition). Nauplii were numerically the most common organism in the diet, their percentage composition dropping, with increased larval size. The largest and most frequently encountered copepod eggs (approximately 180  $\mu$ m in diameter) were of *Calanus helgolandicus*, copepodites of which were taken in low numbers (approximately 1.5-2% of composition) from >10 mm larvae. These are freely-spawned eggs and hence were ingested individually. Other copepod eggs could be separated into discrete size groups and were probably from individual copepod species, but because of the high copepod species diversity in the area of investigation, they could not be positively identified. Eggs were usually present in the absence of female copepods, suggesting they were free-spawned rather than carried eggs. Very rarely were the egg membranes disrupted due to digestion. The unidentified invertebrate eggs were most probably of euphausiids or chaetognaths. Tintinnids made up 5.5% of the diet in <10 mm larvae, although this value was inflated due to the smaller number of larvae containing high numbers of these organisms. Other identifiable zooplankton organisms had a general low incidence in the diet (1-2%). The only phytoplankton, which was identifiable, was sparse dinoflagellate, *Peridinium* spp. Unidentifiable remains constituted a substantial proportion (9-14%) of the food, usually consisting of amorphous material which may have also contained some phytoplankton remains.

**Tab. 1: Percentage food composition and incidence of sardine larvae in the eastern central Adriatic.****Tab. 1: Delež v prehrani in pogostost pojavljanja v prehrani larv mediteranske sardele v vzhodnem srednjem Jadranu.**

	% Composition			% Incidence		
	< 10 mm	10-15 mm	> 15 mm	< 10 mm	10-15 mm	> 15 mm
<i>Calanus helgolandicus</i>	-	1.4	1.9	-	3.3	4.1
<i>Para(Pseudo)</i>	1.5	6.3	30.0	2.8	9.7	25.1
<i>Clausocalanus</i> spp.						
<i>Acartia clausi</i>	1.2	7.8	1.9	0.8	11.6	4.3
<i>Centropages</i> spp.	-	0.3	-	-	0.6	-
<i>Oithona</i> spp.	2.1	4.2	4.0	2.8	7.6	8.2
<i>Oncaea</i> spp.	-	0.8	2.1	-	1.8	4.3
Unidentified copepods	4.2	13.8	4.0	7.4	16.0	12.3
Copepod eggs (~55µm dia)	0.2	0.7	-	0.5	0.7	-
Copepod eggs (~73µm dia)	5.9	1.9	-	8.4	1.2	-
Copepod eggs (~92µm dia)	-	0.9	-	-	0.7	-
Copepod eggs (~110µm dia)	-	0.6	-	-	1.4	-
<i>C. helgolandicus</i> eggs (~183µm dia)	2.3	8.7	7.9	3.2	6.9	16.8
Copepod nauplii	61.0	42.4	30.1	60.5	50.4	45.9
Unidentified invertebrate eggs	0.7	1.3	2.1	1.5	2.6	4.3
Euphausiid calyptopis	0.1	0.2	-	0.5	0.7	-
<i>Evadne</i> sp.	-	-	2.2	-	-	4.4
<i>Limacina</i> sp.	0.2	-	-	0.6	-	-
Gastropod larvae	-	0.3	-	-	0.7	-
Lamellibranch larvae	0.2	-	-	0.6	-	-
Tintinnid	5.6	-	-	0.6	-	-
Rotifer	0.3	-	-	0.6	-	-
<i>Peridinium</i> sp.	0.2	-	-	0.6	-	-
Unidentified remains	14.5	9.0	13.9	28.2	18.5	24.9
Total feeding larvae				217	157	24
Mean no. organisms/feeding larvae				1.9	2.2	2.1

A similar pattern in the incidence of food items in the diet was observed as for the composition of the diet. The incidence of copepodites increased with larval size, constituting 9.1% of the diet in larvae <10 mm in length, 34.6% in 10-15 mm larvae and 44% in larvae >15 mm in length. The largest copepodites (*Calanus helgolandicus*) were restricted to the largest larvae. While incidence of nauplii remained high in the diet of larger larvae, their importance in the diet (*i.e.* proportion of the gut contents) was reduced, indicating that larger larvae fed on smaller numbers. *Calanus helgolandicus* eggs were mostly consumed by larvae >10 mm in length and also formed a greater proportion of the diet of these

larger larvae. In Figure 1 an example of the change in size of food particles with increasing larval size is presented, with measurements from food items taken by sardine larvae, together with sardine jaw gape measurements from Blaxter (1969). With increase in larval size the maximum width of food particles increased. There was no direct relationship between width of food consumed and larval size, due to larger larvae continuing to feed on a high proportion of small particles such as copepod eggs and nauplii.

Food was found in larvae at all times of the day, but with a clear reduction between 00.00 and 04.00 hours (Fig. 2). During the period of darkness, occasional completely undigested organisms were found, suggesting they had newly ingested. There was increased feeding incidence following dawn, around 06.00 and 08.00 hours; and again in the afternoon, between 14.00 and 18.00 hours. At most times a lower percentage of larvae >15 mm had food in their guts than smaller larvae. As an indication of the intensity of feeding at different times of day, the mean number of food items per feeding larvae is plotted in Fig. 3. The mean numbers of particles per larva was mostly <2 for all larval lengths. The number of particles showed little diurnal variation in larvae <15 mm. The greater variation in larvae >15 mm may be related to the smaller number of this group examined. The prominent peak at 20.00 - 2.00 hours was due to an individual larva >15mm in length containing many *Para (Pseudo) Clausocalanus* copepodites. Microzooplankton analysis showed little difference in availability of suitable food during cruise. Copepod nauplii were the most abundant organism (3.4-18.2/l), followed by copepodite stages (2.5-69.2/l).

## DISCUSSION

Karlovac (1967) indicated (without percentage food composition and incidence) that major food of sardine larvae in the eastern central Adriatic is zooplankton (*Oithona*, *Calanus*, copepod nauplii, Gastropod - larvae and Tintinnidae), while phytoplankton occurs in very small proportions. This is in agreement with our results obtained for the same area of investigation.

The low proportion of sardine larvae which contained food in their guts is typical both for clupeid larvae examined from preserved plankton samples and for other larval fish with straight intestinal tracts (Dekhnik, 1974). The latter (1980) found that 23.7% of herrings and 26.0% of sprat larvae contained food, compared with a mean of 64.3% for all other non-clupeid species.

The tendency of clupeids to evacuate food in response to the trauma of sampling is well documented (Kjelson *et al.*, 1975; Hay, 1981). Food may also be evacuated when live larvae are placed in preservative (Blaxter, 1965) but, in survey material, clupeid larvae are invariably dead when retrieved from a plankton

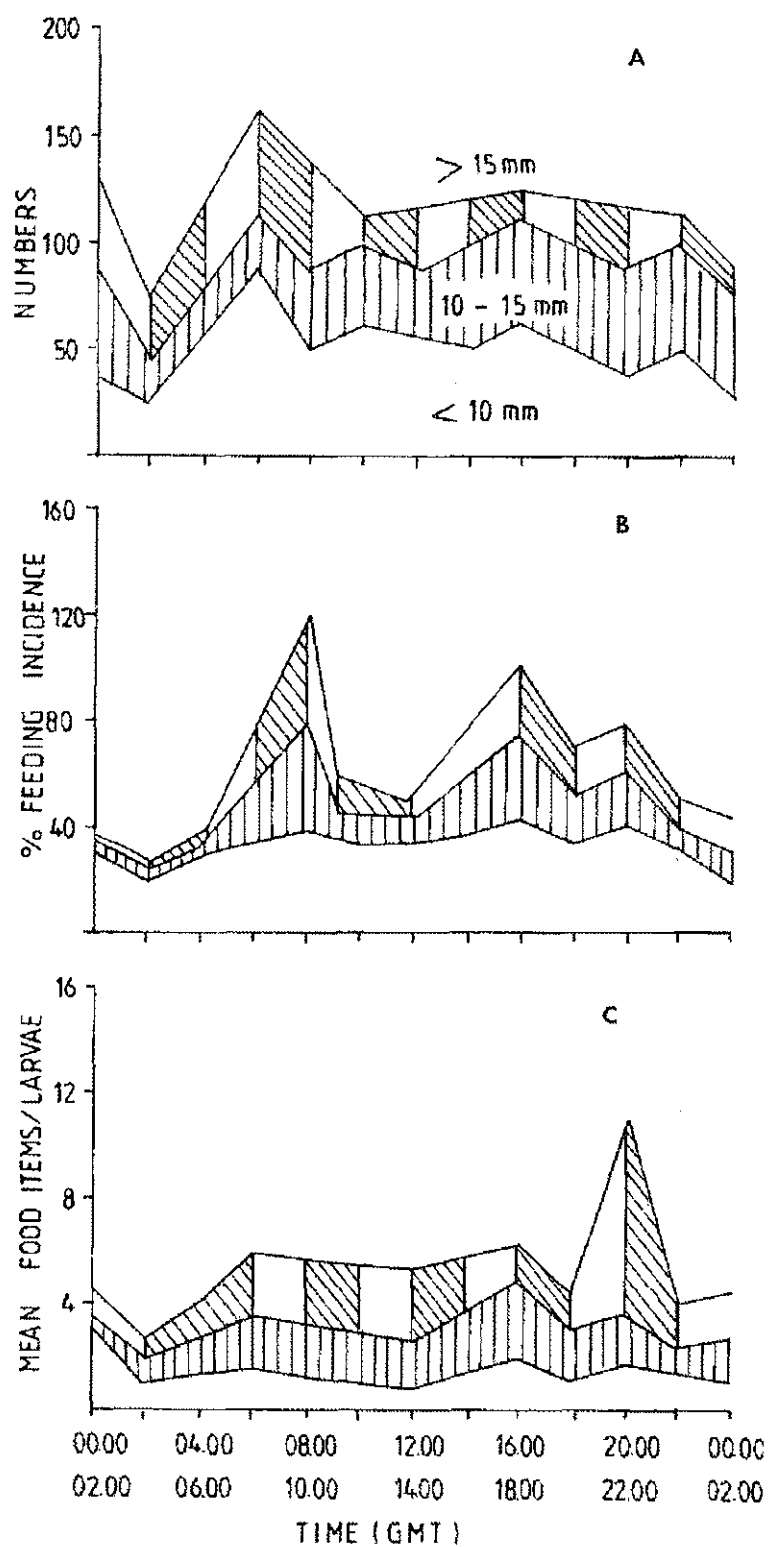


Fig. 2. Number of larvae examined - A), B) Percentage feeding incidence, and C) Mean number of food items per feeding larva by 2-hour intervals over the 24-h period. All values are cumulative.

Sl. 2: Število pregledanih larv - A), B) Pogostost pojavljanja v prehrani, in C) Povprečno število plena na larvo v dveurnih intervalih v obdobju 24 ur. Vse vrednosti so kumulativne.

sampler, so that it is unlikely that further food expulsion will occur on preservation. In this study, food was generally found in the hind-gut and towards the anus, suggesting that food was being defecated rather than regurgitated. The proportion of clupeids evacuating their food may be determined also by sampling methodology (Hay, 1981). Conway *et al.* (1991) found that 58% of net-caught samples of the sprat *Sprattus sprattus* contained food.

As larval fish grow they require and consume increasingly larger prey (Theilacker & Dorsey, 1980), and a similar observation was recorded in the present study. While there was an increase in maximum size of prey, there was little increase in the numbers of prey. The mean number of particles per gut of feeding larvae was consistently low, generally <2, which may partially be a result of defecation related to sampling and thus not a true reflection of feeding intensity. Blaxter (1969) found that the greatest number of food particles found in sardine larvae in laboratory experiments was only 3. A substantial proportion of small particles was consumed by larger larvae. Feeding of larger larvae on relatively small organisms such as nauplii is inefficient, since they will contribute relatively less to the food biomass than a smaller number of large particles. The situation for copepod eggs may be less significant, since a substantial proportion of the smaller eggs may have been taken in-

cidental as egg sacs attached to adult females. In the present study, *Calanus helgolandicus* eggs formed only 2.3% of the diet of <10 mm larvae and, surpassingly, a higher percentage in larger larvae (>15 mm in length), suggesting some element of selection. The resistance of copepod eggs to digestion by larval fish (Conway *et al.*, 1994) may be to prevent substantial contribution being made by them to larval nutrition. In laboratory experiments with sardine larvae Blaxter (1969) observed a feeding incidence of approximately 10% for day-light hours, falling to 0% at night and rising rapidly to round 30% in the early morning. The feeding incidence values in this study are considerably higher than these, but with a similar superimposed diurnal cycle, corresponding to observations on other clupeid larvae (Blaxter & Hunter, 1982). The occurrence of occasional, obviously freshly ingested food in the guts of sardine larvae during the dark period suggests that some feeding may occur using senses other than vision (Govoni *et al.*, 1983).

Food concentrations in the range of 5-24 particles/l, as measured in this study, are typical of integrated values down the water column in many areas where fish larvae are abundant (*e.g.* in the Irish Sea, Coombs *et al.*, 1992); higher concentrations occur at discrete depths due to vertical stratification and aggregation in layers.

## PREHRANJEVANJE LARV MEDITERANSKE SARDELE *SARDINA PILCHARDUS* (WALBAUM) V VZHODNEM SREDNJEM JADRANU

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### POVZETEK

V obdobju med februarjem in aprilom 1990 je avtor zbiral podatke o prehranjevanju larv (4-24 mm) mediteranske sardele *Sardina pilchardus* (Walbaum, 1792) v vzhodnem srednjem Jadranu glede na razpoložljivost hrane. Najpogostejši organizmi v prebavnem traktu larv (78-89%) so bili ceponožci v različnih stadijih razvoja (jajca, navpliji in kopepoditi). Odstotni delež v prehrani navplijev se je s povečevanjem velikosti larv manjšal, delež kopepoditov pa večal. Delež majhnih delcev hrane v prebavnih traktih največjih larv je bil še vedno visok. Med razpoložljivostjo hrane in prehranjevalnim uspehom ni bilo kakega doslednega razmerja, brzokone zaradi primernih prehranjevalnih razmer.

**Ključne besede:** sardele, larve, prehranjevanje, vzhodni srednji Jadran

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