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Feeding of *Clausocalanus arcuicornis* (Dana, 1849) Order *Calanoida (Copepoda)* in the Coastal Waters of Baniyas City (Eastern Mediterranean)

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Abstract

This study, included the feeding of *Clausocalanus arcuicornis* (Dana,1849) of *crustacean* zooplankton *(Calanoida)*, by studying the structure of the Mandible and the gut content of this previous species to determine Their favorite food. 76 samples have been collected vertically in period between March and October 2021. The samples were also accompanied with different hydrophysical and hydrochemical measurements in three regions that differ from each other with their environmental properties. The number of members of *(C.arcuicornis)* that were studied reached (61) individuals, of which (42) are female and (19) are male. On the other hand, determining the morphology, studying its structure, and knowing the content of the gut of the aforementioned species helped in expanding knowledge about the conditions and strategies of feeding it under the influence of environmental factors. The number of algae species (phytoplankton) that *C.arcuicornis* fed reached (7) species, of which (4) belong to the *Dinophyceae*, (2) species to Bacillariophyceae earth, and (1) only one species to the group *Cryptophyceae*. The highest average number of *Dinophyceae* was (1500), followed by *Bacillariophyceae* (420) individuals, then the group of *Cryptophyceae* (140) individuals.

Keywords: The Feeding; Mandible; Gut Content; Hydrophysical and Hydrochemical Measurements; Feeding Strategies

Introduction

Crustacean zooplankton is a Heterotrophic and is an important component of marine ecosystems [1] through the primary role it plays in the food web [2]. As such, it is a biological structure in which the feeding methods vary [3], which increases the complexity and complexity of the food chain [4]. In addition to that herbivorous group dependent on phytoplankton [5], which creates a balanced biological composition [6]. copepods are major components of marine food chains and operate either directly or indirectly as food sources for most commercially important fish [7], and their oral appendices have evolved to suit the nature and quality of their food [8]. On the other hand, the jaw's leg movement towards the mouth creates a stream of water that raises the pressure inside the mouth, which leads to water entering with food [9], and others are equipped with a special filtration system through which it filters the food particles entering with Water stream [10].

Copepods generally tend to feed on a mixed diet in their natural environment, especially in the first few layers (0-50) m [11], and the survival and success of *copepods* over the years may be due to their ability to determine prey [12], and the selection of the preferred and most abundant food in the surrounding environment [13]. It is worth noting, however, is the ability of many species of *copepodes* to shift from a plant-feeding pattern in the absence of it in the medium to feeding on small animals and vice versa as is the case with *Glausocalanus arcuicornis* [14].

Copepodes are dominant creatures in marine zooplankton [1]. Their diets often include large proportions of Bacillariophyceae that have Silesian structures to protect. Despite this protection, there are many species of *copepodes* that are capable of breaking and shattering these structures with high efficiency even the most supported and protected species [15]. The composition and shape of mandible teeth at *copepodes* also differ by species, and studies using electron microscopy have revealed These teeth are of complex microscopic structures that contain in their composition silica and this explains their ability to destroy the structures of *Bacillariophyceae* [16].

Various environmental factors such as temperature, salinity, dissolved oxygen, pH, and transparency affect marine *copepodes* and their nutritional activity [9], and the concentration and distribution of food particles in the surrounding medium [17].

The Importance of Research and its Objectives

The research aims to study feeding for *C.arcuicornis*, determine the intestinal content of food, and study the shape and composition of its species, under the influence of various environmental factors. The importance of economic research lies through clarifying the environmental and nutritional requirements of the studied species, which constitutes a basic rule that facilitates the prediction of the status of these species in terms of productivity, as they are of economic importance and constitute a major food for fish, *crustaceans* and many other marine creatures.

Materials and Methods

The species collection processes were carried out from the three study areas that were chosen in the coastal waters of the city of Baniyas, which differ from each other in environmental terms, as shown in figure 1, which are

Sanitation area: (A):

35°12′09″N 35°57′08″E

It is located opposite the Baniyas National Hospital, where the sewage of the hospital and the neighborhoods of Al-Morouj flows into a unified liquefaction line (a major sewage line), where its estuary ends in the coastal waters of a city, and this beach is away from the second area (the thermal station area) at a distance of 7 km.

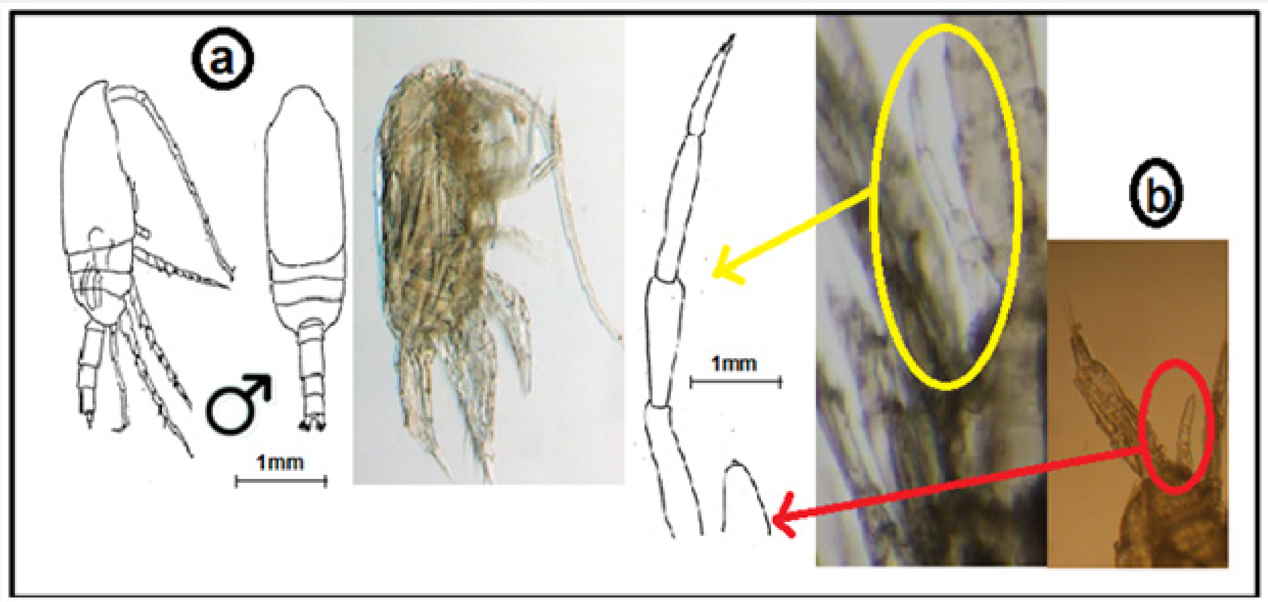

Figure 1: (a) a general shape from the side to the male, (b) p5 of the male.

The Thermal Station Area: (Estuary of hot water): (B):

35°10′13″N 35°55′21″E

This region is located opposite the electrical power station in Baniyas, which is one of the five power stations responsible for supplying the country with electrical energy. The thermal plant is 5 km from the third clean area. The thermal water resulting from the cooling of the station and the steam of the boilers that unite with it is poured into marine waters.

Prince Beach Chalets: (C).

35°09′02″N 35°55′20″E

The Prince Chalets Beach, on which the Prince's Resort and Chalets is located, and this beautiful beach is 1 km from the Archaeological Tower of Al-Sabi site. This beach is a very clean area and not exposed to pollution, and therefore it is a destination for tourism and summer vacation.

Each region is divided into three sites (stations):

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Zone A: Stations: A3-A2-A1.

Zone B: Stations: B3-B2-B1.

Zone C: Stations: C3-C2-C1.

The process of collecting samples of the two species in each site was as follows:

a) The first location: (50-0) m, (50-25) m, (25-0) m.

b) The second location: (100-0) m, (100-50) m, (50-25) m, (25-0) m.

c) The third location: (200-0) m, (200-100) m, (100-50) m, (50-25) m, (25-0) m.

i. Measurements of the main environmental factors such as: (temperature (t), salinity (s), dissolved oxygen concentration, pH, and transparency) were made by using modern advanced devices with calibration paths, including the Hanna Instruments HI9812-5 device.

ii. To measure salinity and pH, and the Dissolved Oxygen - DO Meter AZ Instrument AZ-8403 to measure the concentration of dissolved oxygen and temperature, while the Seki disk was used to measure transparency, and the global zooplankton collection network with a closing device, with 200μ holes and of the WP2 Closing type, was used. Net in order to obtain the required samples.

iii. I used a submersible lens with a magnification of Specimens of the species *Clausocalanus arcuicornis* preserved in formalin at a concentration of 4% were studied in the laboratories of the Damascus University according to modern international methods, relying on an advanced and modern microscope, a magnifying glass, and using the microscopic needle necessary to extract the mandible.

iv. The following references were relied upon to identify the phytoplankton found in the intestine, Table 1: [18-21] (Alexandra et al., 2010).

Table 1: Changes in the values of environmental factors during the period of emergence of *C.arcuicornis* during the study months.

Depths (m)	0	0-25	0-50	25-50	50-100	100-200
Temperature (°C)	29.15	25.64	20.56	19.87	8.11	7.73
Salinity ‰	36.89	36.54	37.61	37.8	37.84	38.13
(pH)	6.81	7.02	7.43	7.59	7.78	7.90
Dissolved oxygen (mg/l)	5.79	6.21	6.79	6.97	6.98	7.02

Results

Taxonomic status and general description of the species:

Clausocalanus arcuicornis

Taxonomic status

Phylum: Arthropoda

Subphylum: Crustacea

Class: Copepoda

Order: Calanoida

Family: *Clausocalanidae*

Genus: *Clausocalanus* (Giesbrecht, 1888)

Species: *Clausocalanus arcuicornis* (Dana,1849).

Male

The length of the male (0.7-0.9mm) and in terms of its overall appearance is very similar to the female. The front end of the head was round, while the abdomen extended, and the fifth leg of the legs had a four-legged left leg. As for the right hand, it is atrophied [22] figure 1.

Female

The length of the female (1.1-1.2mm), the front end of the head was round, fifth of the legs has a single branch and two parts [22] figure 2.

Feeding of *Clausocalanus arcuicornis*

C.arcuicornis appeared in all study areas and stations, and the total number of individuals studied was (64) individuals, of which (44) are female and (20) male are distributed at different depths, and this explains that this species has wide environmental adaptation. Eurybiont with the values of different environmental factors [23] as shown in Table 1. The largest presence was in the layer with depth (0-50) m [24], due to the large number of nutrients in this layer, as it is the primary productivity layer [25], where the phytoplankton that exists Photosynthesis, The presence of marine currents and wave movement, and the exposure of the layer (0-50) m to significant changes in the values of environmental factors, as well as the Estuary drainage, whose water is loaded with organic materials and nutrients and which flows into station (A1), has made this layer a suitable place for the existence of the species Previous (Hidaka et al.;2016), and this species did not exist in station (B1) at all, and the reason is that this station is the mouth of the hot water resulting from cooling the turbine of the station and the boilers. Previous to bear it or even live in its field.

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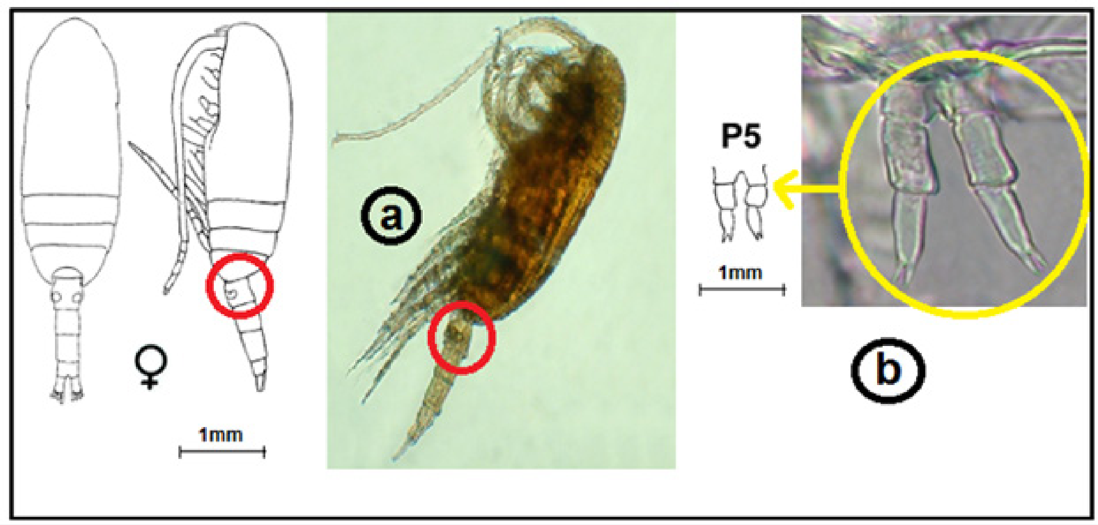

Figure 2: (a) a general shape from the female side, (b) p5 of the female.

Discussion

It was found through the study, which was compatible with many international studies, table 2, that *C.arcuicornis* is herbivorous [26] as shown in table 3, and perhaps the most important food for him is (Dinophyceae) [27,28], knowing that by studying the intestinal content of figure 3 for individuals of the previous species within the layer (50-0) m, it was observed that there are several species of food and this explains that the previous species resort to mixed food [29] and feeding on more than one species due to the high availability of food within them [30], This is illustrated in table 3, whereas at large depths (200-100 m), it resorted to the use of only one species of food, according to what is available in the medium and most likely from *Bacillariophyceae* [31]. The reason is that these depths Light does not reach it, and phytoplankton does not exist to carry out photosynthesis, and consequently, it is poor layers of food, in which species resort if there is dependence on food available in the medium [7].

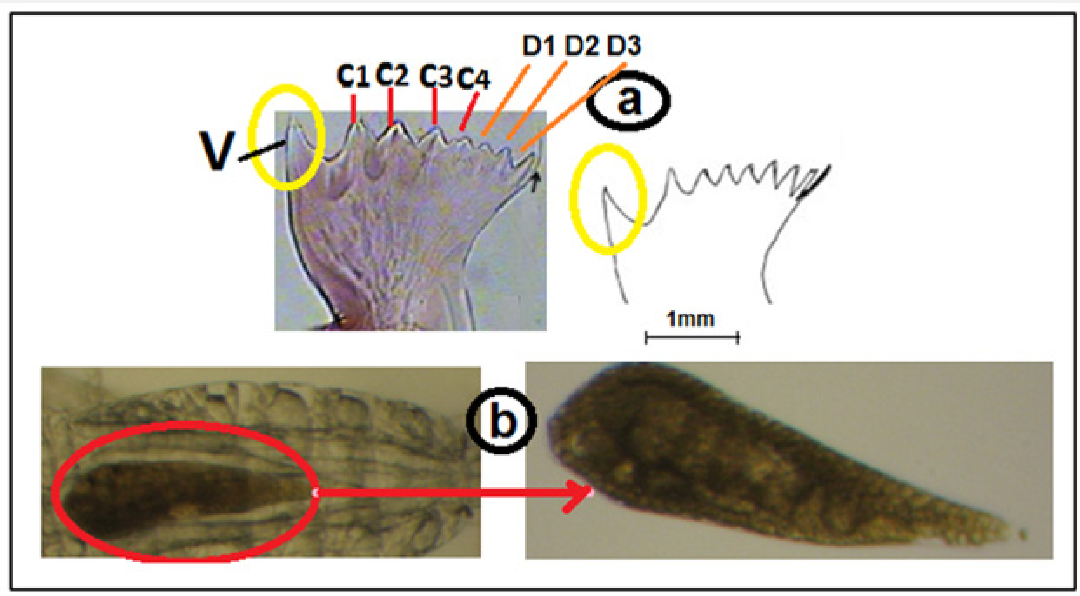

Figure 3: (a) mandible structure, Mandibular Gnathobasis V: Ventral Teeth. C1-C2-C3-C4: Central Teeth. D1-D2- D3: Dorsal Tooth. (b) general view of the gut.

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Table 2: Some global studies that are compatible with the current study.

History	Researcher	Study Title
2004	And G. A. PaffenhoFer	Relation of behavior of copepod juveniles to potential predation by omnivorous copepods: An empirical-modeling study.
2004	Ricardo Giesecke H.E. González	Mandible characteristics and allometric relations in copepods.
2013	Peter Tiselius Enric Saiz Thomas Kiørboe	Sensory capabilities and food capture of two small copepods, *Paracalanus parvus* and *Pseudo-calanus sp.*
2015	Jan Michels Stanislav N	Mandibular gnathobases of marine planktonic copepods
2020	Abigail S. Tyrell Houshuo Jiang Nicholas S. Fisher	Copepod feeding strategy determines response to seawater viscosity.

Table 3: the species of phytoplankton that formed the food of *C.arcuicornis* during the study months.

Species	Taxonomic status	Depth (m)	Average number of individuals in the gut
Ceratium contortus	*Dinophyceae*	15-25 0-25 25-50	289
Ceratium palmatus	*Dinophyceae*	0-25 25-50 50-100	413
Ceratium reflexus	*Dinophyceae*	15-25 0-25 25-50 50-100	478
Ceratium lunula	*Dinophyceae*	0-25 25-50 50-100	320
Dinophyceae			1500
Skeletonema costatum	*Bacillariophyceae*	15-25 0-25 25-50 100-200	184
Bacteriastrum furcatum Shadbolt	*Bacillariophyceae*	15-25 0-25 25-50 100-200	236
Bacillariophyceae			420
Rhodomonas salina	*Cryptophyceae*	15-25 0-25 25-50	140
Cryptophyceae			140

It was found through the current study that the layers with depths (50-0) m, (50-25) m and (15-0) m are the richest layers for the phytoplankton species on which *C.arcuicornis* feeds, especially *Dinophyceae*, and the reason for this is due to the presence of light. And for the high and appropriate temperature compared to the deep layers where there is no lighting and the temperature decreases, and thus phytoplankton, which is the main food of the studied species, is unable to exist and live at those depths [27]. *Dinophyceae* recorded the highest value, as the average number of (1500) individuals within the gut were at the species mentioned above, as in table 3, compared with the rest of the groups. He made its species the main food of the studied species, followed

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by the *Bacillariophyceae* (420) individuals in the gut, then the *Cryptophyceae* (140) individuals, table 3 and this is consistent with [26].

It was observed through studying the gut structure of *C.arcuicornis* that its preferred species as a suitable food is *Ceratium reflexus*, and it was found that in the shallow layers it resorts to feeding on a number of species at the same time, including the two species *Ceratium palmatus* and *Ceratium reflexus*, where the temperature is high and the salinity is low [25] and occasionally feeding on *Skeletonema costatum*, *Rhodomonas salina*, *Ceratium lunula*, while it resorts to feeding on one species only, such as *Bacteriastrum furcatum* Shadbolt, in the deep layers due to low temperature and high salinity [30]. Thus, environmental factors, especially temperature and salinity, play an important role in changing the feeding conditions and strategies of the species. The study was studied and adapted to the quantity and quality of food available in the surrounding medium [25]. *C.arcuicornis* diets include large proportions of *Bacillariophyceae* that possess protective silicic structures, and despite this protection, the former species is able to break and destroy these structures with high efficiency even the most supported and protected species of *Bacillariophyceae* [14], and returns the reason for this is the mandible shape of the teeth (4,3), which has short sharp edges that are used for grinding *Bacillariophyceae* and the rest of the phytoplankton species.

According to many international studies, table 2, which was done using an electron microscope, mandible teeth show a nano particular structure containing a little amorphous silica and a large percentage of crystalline silica that is spread in the form of a network of micro-ketinic fibers [9]. It is also likely that these fibers will serve as the mainstay during the feeding process [26], and the ventral tooth (V) Figure 3 is the most important tooth in mandible at *C.arcuicornis* and at the rest of the copepods, especially *Calanoida*, which is the most important teeth varies according to species, on the other hand (MxI) plays an important role in this species in preserving and holding food particles and preventing their exit as a prelude to their entry and push into the body of the organism [30].

The (MxP) also play an important functional role for the previous species in particular and for copepods in general, through their movement with the presence of water currents in collecting food particles from the surrounding medium and surrounding them well and pushing them towards the inside of the body [25].

Conclusion

From the above we find that *C.arcuicornis* plays with the rest of the *copepods* a major role in marine food webs, as they form the link between phytoplankton on the one hand and secondary consumers [32-37].

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