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The Natural Diet of *Apocyclops panamensis* at a Shrimp Farm on the Pacific Coast of Nicaragua

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Roberto Cano, Scarleth Ráudez and Evelyn Hooker (2004) The natural diet of *Apocyclops panamensis* at a shrimp farm on the Pacific coast of Nicaragua. *Zoological Studies* **43**(2): 344-349. Gut contents of 1150 adults of *Apocyclops panamensis* were examined to obtain information on its feeding habits in extensive shrimp ponds during a 16-week period (10 June ~ 5 Sept. 1999). Temporal changes in the relative abundance of ingested algae were studied and compared with the natural phytoplankton assemblage in the pond. The phytoplankton community was comprised of diatoms and blue-green and green algae; total abundance varied between 1.11 x 10^4 and 10.2 x 10^4 cells/ml, of which blue-green algae, such as *Lyngbya limnetica*, *Spirulina nodosa*, and *Anabaenopsis* sp., were the most abundant. During the study period, diatoms made up 89% of the algal cells consumed by A. panamensis. Among the diatoms, *Nitzschia* sp. was most important, while *Navicula* sp. and *Amphora ovalis* were also substantial. The green alga, *Chlorella* sp., accounted for 10.6%; blue-green algae were rarely consumed. http://www.sinica.edu.tw/zool/zoolstud/43.2/344.pdf

Key words: Apocyclops, Copepoda, Nicaragua, Diet.

Extensive shrimp farming in Nicaragua has been very successful among the local peasants, because little management and investment are required. This farming strategy depends on a natural food supply (phytoplankton and zooplankton) as the main source of food for the shrimp species under culture. Thus, the quality and quantity of the natural food resources are very important issues on extensive shrimp farms, because they basically determine the sustainability of this activity. However, most previous studies on zooplankton in such habitats have mainly dealt with its abundance and distribution patterns in coastal areas. Among the components of zooplankton, copepods constitute an important fraction. *Apocyclops panamensis* is a free-living cyclopoid copepod found in a variety of freshwater and brackish water bodies. It has been reported to be a dominant species in the zooplankton community on shrimp farms in Nicaragua (Castellanos 1998). However, little is known about the feeding ecology of *A. panamensis* on local farms, in spite of the great dependence of shrimp farming on a natural food supply. The main purpose of this study was to determine the diet of *A. panamensis* in order to help local shrimp farmers improve their management techniques for extensive culture systems.

MATERIALS AND METHODS

Samples were taken 8 times from 10 June to 5 Sept. 1999. Plankton samples were taken biweekly from 3 sites on a shrimp pond (Fig. 1). Zooplankton was collected using 55 μm plankton net by performing 3 vertical hauls from a depth of 1 m to the surface. To avoid regurgitation, carbonated water was added to each sample (Infante 1978), and the sample was fixed with 6% formalin after 2 min. *Apocyclops panamensis* individuals were identified according to Suárez et al. (1996). Prior to gut content analyses, samples were treated with a sodium hypochlorite solution to render the bodies of the organisms transparent (Infante

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1978). Food items were counted after being identified according to Geitler (1925), Hustedt (1930), Huber-Pestalozzi (1961), Hendey (1964), Cupp (1977), Richman et al. (1980), and Huber-Pestalozzi et al. (1983). Data were analyzed by a qualitative method based on the frequency of occurrence and the percent composition by number. Fragments of digested algae were registered as "fine particles" and expressed as an estimated percentage of the total amount of food in the gut. One hundred fifty specimens of *A. panamensis* were analyzed per sampling date with the exception of the 1st round of sampling, for which only 100 specimens were analyzed. Phytoplankton samples were taken at 0.5 m with a horizontal Van Dorn sampler. Samples were preserved with a 4% Lugol solution and counted according to the sedimentation method of Utermöhl (1958).

RESULTS

Phytoplankton Composition and Abundance in the Pond

The phytoplankton community in the pond was made up of 30 taxa, including 17 species of diatoms, 9 of blue-green algae, 3 of green algae, and 1 dinophyte. Total phytoplankton density displayed temporal variations (Fig. 2); mean total cell densities varied from 1.11×10^4 to 10.2×10^4 cells/ml. A cell density peak was recorded on 25 Aug. when *Spirulina nodosa* and *Anabaenopsis* sp. were the main constituents. Throughout the study period, blue-green algae were the most abundant, followed in descending order by green algae and diatoms. Seasonal variations in the major algal groups are presented in fig. 2. At the beginning of the study, the community was dominated by *Lyngbya limnetica*, which was overtaken by *Spirulina nodosa* on the 4th sampling date and then was finally replaced at the end of the productive cycle by the genus *Anabaenopsis*. The contribution of the genus *Chlorella* (Chlorophyta) was also substantial. *Chlorella* was present in the pond phytoplankton during the entire sampling period (4.7×10^3 to 22.6×10^3 cells/ml) with the exception of 6 June, when *Chlamydomonas* (320 cells/ml) was the most abundant species among the green algae. On the other hand, even though lower in numbers, diatoms comprised an important fraction of the phytoplankton community. *Nitzschia* sp., *N. granulata*, and *Navicula* sp. were more abundant during the 1st 2 mo, but were then replaced by *N. longissima* and *N. sigma* during subsequent months.

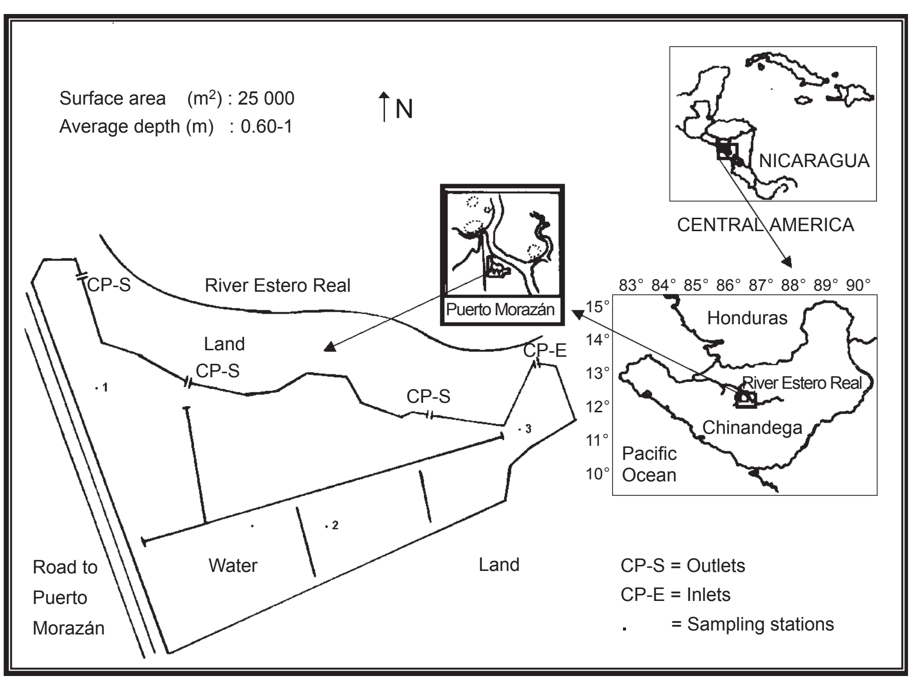

Fig.1. Localization of the study area, and sampling stations on the shrimp farm.

Composition of the Diet

The diet of *A. panamensis* in the shrimp pond was made up of 14 species of algae: mainly diatoms, greens, and blue-greens (Table 1). Only the 4 species of *Nitzschia* sp., *Chlorella* sp., *Navicula* sp., and *Amphora ovalis* were important, as the remaining species appeared only sporadically. Particulate matter was also an important part of the diet, even though we did not quantify it, but it was estimated as a percentage of the total amount of food in the gut content. Diatoms had the highest frequency of occurrence (43%) followed in descending order by green algae (Chlorococcales) and blue-green algae. Among diatoms, the Pennales were found more frequently; *Nitzschia* sp., *Navicula* sp., and *Amphora ovalis* occurred at 28.0%, 8.7%, and 7.2%, respectively. *Chlorella* sp., the only green alga present in the gut, occurred at 15%, while blue-green algae occurred at less than 1%. Compositions of different groups and species in terms of cell numbers are shown in fig. 3. Diatoms represented 89%, green algae 10.6%, and blue-green 0.5% of the total algae ingested. *Nitzschia* sp. comprised the largest proportion of diatoms (69.4%), followed by *Navicula* sp. (8.8%) and *Amphora ovalis* (4.5%). The blue-green algae *Lyngbya limnetica*, *Spirulina nodosa*, and *Merismopedia elegans* contributed very little to the diet, and *Chlorella* sp. was the only green algae consumed by *A. panamensis*. In the case of planktonic algae, there was no relation between the numbers of algal species recovered from gut contents and those available in the pond (Fig. 4). Only a small fraction (8 species) of the total algae species present in the pond was consistently ingested by *A. panamensis*. The composition of the plant component in the gut contents did not exhibit strong seasonal variation. The changes observed were more closely related to the amount of algae ingested, and the preferences exhibited by *A. panamensis* towards a few algal species (Fig. 5). Despite the fact that diatoms constituted a minor group of algae in the shrimp pond, they were usually dominant in the diet throughout the study period. *Nitzschia* sp. was consumed most abundantly by *A. panamensis*, although *Navicula* sp., *N. granulata*, *N. longissima*, and *N. sigma* were present in high concentrations in the pond. *Nitzschia* sp. disappeared from the phytoplankton in Sept., when other diatom species (*N.

Table 1. Phytoplankton species and their frecuency of occurrence in the diet of *Apocyclops panamensis*. The volumes calculated for the common organisms in the diet are given

Organisms	Frequency of Occurence (%)	Volume μm^3
Cyanophyta (blue-green algae)	0.9	
Lyngbya limnetica	0.6	27.5
Merismopedia elegans	< 0.1	0.5
Spirulina nodosa	0.3	2.35
Chlorophyta (green algae)	15.1	
Chlorella sp.	15.1	13
Bacillariophyta (diatoms)	43	
Amphora ovalis	7.2	1022
Cyclotella sp.	2.2	194
Cymbella turgida	1.0	33500
Navicula sp.	8.7	607
Nitzschia sp.	28.0	596
Nitzschia longissima	0.2	679
Nitzschia granulata	5.3	5330
Nitzschia sigma	0.6	230
Pleurosigma salinarum	1.1	26000
Tropidoneis lepidoptera	< 0.1	17400

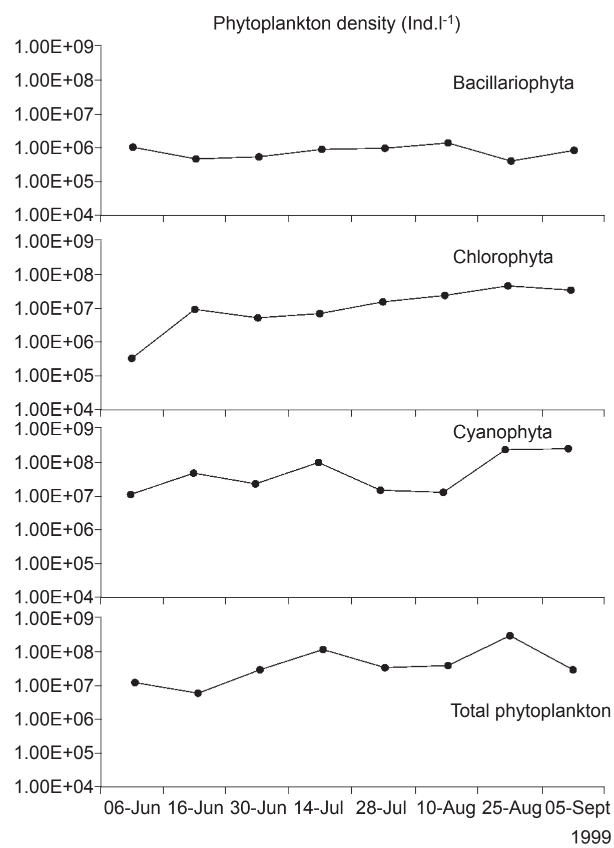

Fig. 2. Phytoplankton densities throughout the growing season of *Litopenaeus*, in the shrimp farming pond.

longissima and *N*. *sigma*) were present in large quantities. However, these diatom species were seldom consumed by *A*. *panamensis*. Although blue-green algae dominated the phytoplankton community, *Lyngbya limnetica*, *Merismopedia elegans*, and *Spirulina nodosa* were consumed by *A*. *panamensis* only on rare occasions. On the other hand, there was a relationship between individual algal numbers in gut contents and the algal density among the phytoplankton: the number of algae in gut contents increased with the concentration of algae in the phytoplankton during the 1st 5 sampling dates (Fig. 6). This situation changed during the last 45 days of the study, and no relationship was observed between the amount of algae in the water and the amount recovered from gut contents during that time. Thus, in the period between 6 June and 28 July, on average, 9.5 algae (n = 655) were found, whereas, between 25 Aug. and 5 Sept. (when algal counts were high and dominated by *Anabaenopsis* sp. in the pond) only an average of 1.7 algae (n = 300) were found in each gut. Another important feature about the diet of *A*. *panamensis* was the presence of particulate matter in the gut content. Almost all individuals examined had a high percentage of unidentified particulate matter (detritus and algal fragments), comprising about 50%~80% of the gut content.

DISCUSSION

Apocyclops panamensis gut content analysis indicated that diatoms are an important item of their diet, with a 43% frequency of occurrence.

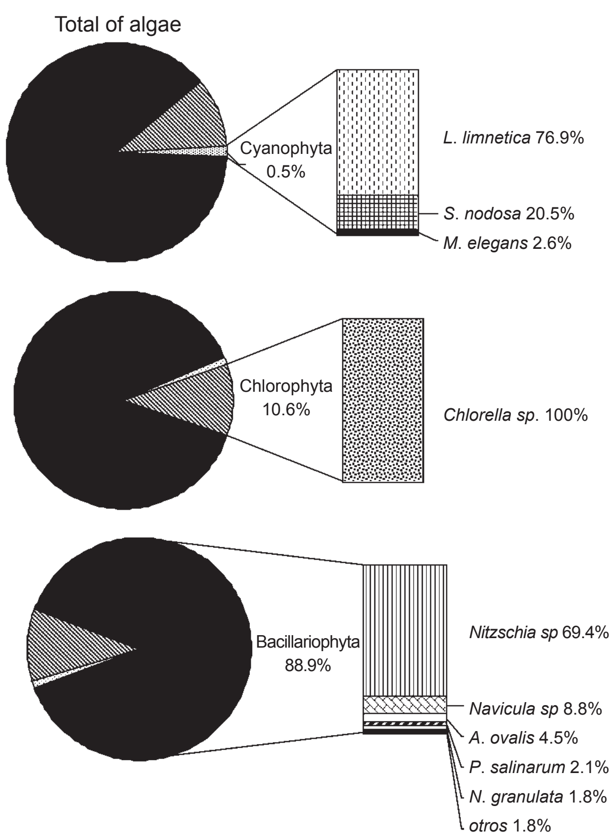

Fig. 3. Relative abundance composition of the main algal groups and species found in *Apocyclops panamensis* guts (n = 1150).

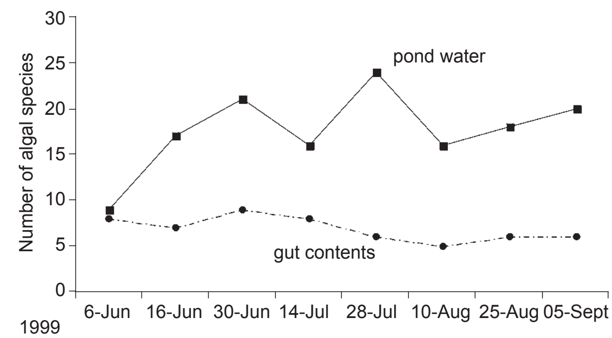

Fig. 4. Number of algal species in the pond water and in the gut contents of *Apocyclops panamensis*.

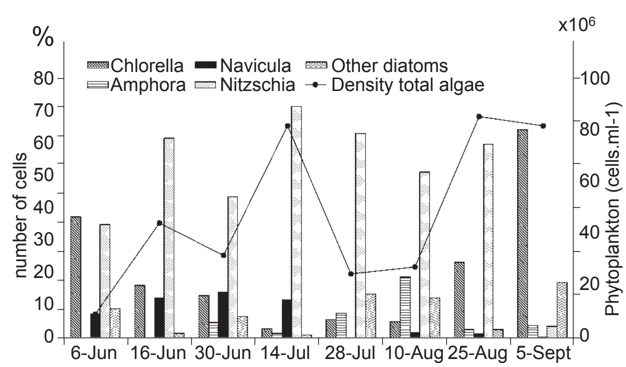

Fig. 5. Seasonal changes in the percentages composition by number of the algae consumed by *Apocyclops panamensis* and the total phytoplankton abundance in the pond.

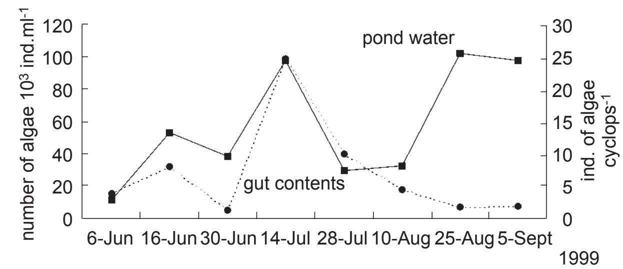

Fig. 6. Algal density of the water pond and in the number of cells recovered from the guts of *Apocyclops panamensis*.

Although the percentage of occurrence does not reveal the true importance of various food items in the diet of *A. panamensis*, it does provide an indication of the proportion of a particular food item which is consumed. Among diatoms, *Nitzschia* sp. presented the highest percentage composition per number of *A. panamensis* gut contents, thus a certain selectivity was shown towards this specific food item. The high ingestion of diatoms by *A. panamensis* could be related to the size and nutritional value of the species consumed. The nutritional value of diatoms is related to their rich content of highly unsaturated fatty acids, the permeability of their perforated silicate walls to digestive enzymes, the appropriate size of their cells walls, and their lack of associated toxins (Chamberlain 1995). Most of the diatoms observed in the gut contents were small, with an average size of 5.6 x 31 μm; this could possibly explain why larger diatoms like *N. granulata*, *N. sigma*, and *N. longissima*, were seldom consumed, even though they were present in high densities in the pond water. The low densities of diatoms in the pond may have been a result of the extensive grazing by *A. panamensis* on certain species of the diatom community. The green alga, *Chlorella*, was consistently ingested by *Apocyclops*; however in the majority of the animals examined, this alga was found to be undigested. Most *Chlorella* cells ingested retained their green color after passing through the gut. According to Chamberlain (1995), green algae are more difficult to digest than diatoms because of their cellulose walls. Blue-green algae were not important items in the diet of *A. panamensis*, and even though their numerical abundance was very high among the plankton, they were rarely consumed. *Apocyclops panamensis* did not consume *Anabaenopsis* sp., but small amounts of *Lyngbya limnetica*, *Spirulina nodosa*, and *Microcystis aeruginosa* were found in the gut of a few animals. These results are consistent with those found by other authors in which zooplankton seldom choose blue-green algae as a food source because of their size and the toxicity of some species (Strangenberg 1968, Porter 1977, Porter and Orcutt 1980). Other authors (De Bernardi et al. 1981, Holm et al. 1983) have reported that cladocerans consumed and utilized only certain blue-green algae (*Aphanizomenon* and *Microcystis*) in culturing experiments. Many copepods also avoid the blue-greens (Alcaraz et al. 1980, Richman et al. 1980, Price et al. 1983) as a food source. In other cases, blue-green algae were only consumed in the absence of the preferred algal species; for example, *Lyngbya limnetica* was the only blue-green algae ingested in large amounts by the copepodid, *Thermocyclops crassus*, when the proportions of *Nitzschia* sp. considerably decreased in Lake Valencia, (Infante 1981). In this study, *A. panamensis* shifted towards *Chlorella* when the level of *Nitzschia* sp. decreased in the pond.

Upon comparing the gut analysis results with the abundance of specific phytoplankton species in the pond, a positive relationship was found between the amount of algae ingested and the abundance of phytoplankton. The abundance of *Nitzschia* sp. in the gut clearly demonstrated that this diatom is preferred by *A. panamensis*. It is also evident that there was a considerable reduction in the amount of plant material ingested by *A. panamensis* at the end of the study period, when the phytoplankton presented the highest densities and was numerically dominated by the blue-greens. These results illustrate that less than 45.0% of the specimens of *A. panamensis* fed on diatoms, 15.0% on chlorophytes, and 1.0% on blue-greens. The high percentage of particulate matter (50%~80%) in the gut contents indicates that *A. panamensis* probably feeds on other food items not identified in this study, and only a small fraction of the phytoplankton (small algae) is consumed.

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