

## Feeding of the planktonic shrimp *Lucifer faxoni* Borradaile, 1915 (Crustacea: Decapoda) in the laboratory

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- **Abstract:** Feeding behavior of juveniles of the planktonic shrimp *Lucifer faxoni* Borradaile was studied in the laboratory under light and dark conditions. Newly-hatched nauplii and metanauplii of *Artemia* were used as prey organisms. The feeding rate of *L. faxoni* was dependent on prey size and prey density, but was not obviously affected by light or dark conditions. The capture of the prey tended to increase with longer exposure time to prey. The maximum ingestion rate was 17.28 and 13.40 nauplii.*L. faxoni*<sup>-1</sup>.d<sup>-1</sup>, in the light and in the dark conditions, respectively.
- **Resumo:** O comportamento alimentar de espécimens jovens de *Lucifer faxoni* Borradaile, em laboratório, sob condições de luz e escuro, foi estudado utilizando-se como alimento náuplios recém-eclodidos e metanáuplios de *Artemia*. Neste estudo a taxa de alimentação de *L. faxoni* foi influenciada pelo tamanho e concentração da presa, bem como pelo tempo de contato com a mesma. A atividade alimentar de *L. faxoni* foi maior em condições de luz, quando comparado com as condições de escuro. A taxa máxima de ingestão calculada foi de 17,28 e 13,40 náuplios.*L. faxoni*<sup>-1</sup>.d<sup>-1</sup> para as condições de luz e escuro, respectivamente.
- **Descriptors:** Feeding behavior, Predation rate, Marine carnivory, *Lucifer faxoni*, Zooplankton.
- **Descritores:** Comportamento alimentar, Taxa de predação, Carnivoria, *Lucifer faxoni*, Zooplâncton marinho.

### Introduction

The feeding mechanisms are worth studying in order to answer basic questions about how evolution has shaped feeding behavior and how this behavior will affect community structure and function (Båmstedt, 1988).

Carnivorous feeding of zooplankton may play an important role in the regulation of prey populations (Hopkins *et al.*, 1993), and consequently in determining community structure. Feeding behavior and energetics of carnivorous feeding of zooplankton species have been studied (Lampitt & Gamble, 1982; Yen, 1983; Reeve *et al.*, 1989; Oresland & Ward, 1993).

The planktonic shrimp *Lucifer faxoni* Borradaile is regarded as an important component of the carnivorous

zooplankton in tropical and subtropical neritic waters in the Atlantic. It is abundant and widely distributed in the neritic waters along the eastern coasts of North America (Hopkins, 1966; Bowman & McCain, 1967; Omori, 1977) and South America (López, 1966; Harper, 1968; Jimenez-Alvarez, 1976). In Brazilian coast it is distributed from Pará State to Lagoa dos Patos (Barth, 1963). This species have been found abundantly in Ubatuba, São Sebastião and Cananéia regions (São Paulo State). In these localities, its role in trophodynamic pathways must be important (Vega-Pérez, 1993; 1996), since it constitutes one of the most important food items found in the stomach contents of fishes (Gasalla, 1995; Wakabara *et al.*, 1996).

In general, studies on this species have been concerned mainly with other aspects of its ecology than feeding behavior (Woodmansee, 1966a,b; Harper, 1968; Omori, 1977). Information related to its feeding behavior is limited to Lee *et al.* (1992).

This study was conducted to contribute to our understanding of the feeding behavior of *L. faxoni* under laboratory conditions. The goal is to determine predation rate at different food concentrations using two sizes of prey under different light condition.

## Material and methods

Zooplankton samples and seawater were collected on September 20-23, 1994 off Ubatuba region, São Paulo State, Brazil (Fig. 1). Oblique hauls were made using a 505  $\mu\text{m}$  mesh ring net of 1 m diameter, which was towed between the surface and 12 m depth for 5 min at ship velocity of ca. 1.0 - 1.5 knots. Samples were transferred into plastic containers and transported immediately to the laboratory.

Juvenile females specimens of *L. faxoni* (mean of total length =  $3.84 \pm 0.99$  mm; mean wet-weight =  $239.19 \pm$

$111.90 \mu\text{g}$ ) were sorted with pipette and placed individually in small glass bowls (diameter 9 cm and depth 7 cm), containing approximately 100 ml filtered seawater with salinity 34.00. All specimens were maintained at room temperature of 21.5-27.0°C in starved condition for 6h before the experiments begun.

Three aspects of feeding behavior of *L. faxoni* were studied: (1) influence of prey concentration; (2) effect of prey size; (3) influence of light and dark conditions.

In the feeding experiments newly-hatched *Artemia* nauplii (mean length =  $0.46 \pm 0.036$  mm; mean wet-weight =  $14 \mu\text{g}$ ) and metanauplii (mean length =  $0.62 \pm 0.042$  mm; mean wet-weight =  $17.3 \mu\text{g}$ ) were used as the prey at four different concentrations: 10, 20, 40 and 80 individuals per bowl. These experiments were conducted for 6 h under light and dark conditions.

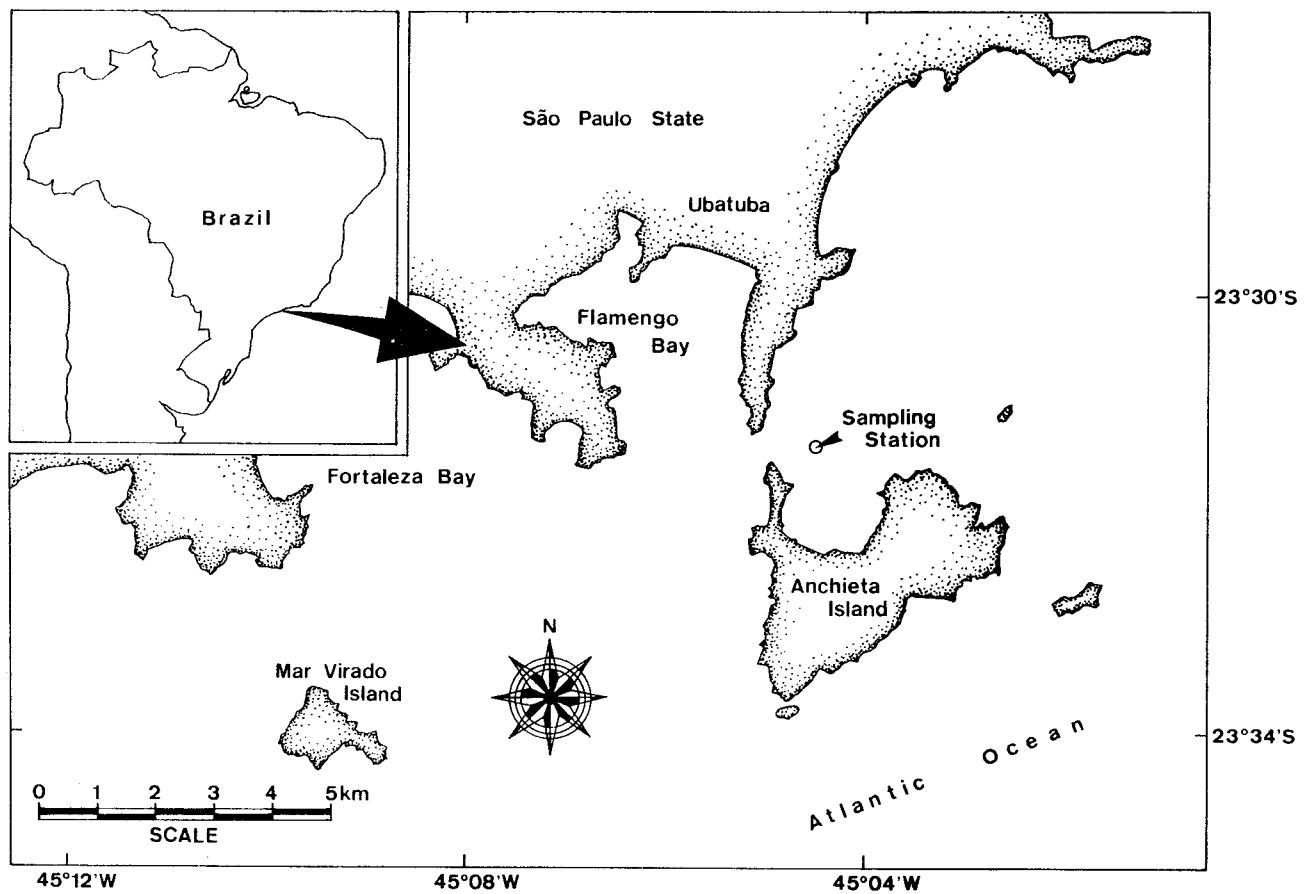


Fig. 1. Map showing the location of the sampling station in Ubatuba region, São Paulo-Brazil.

Additional experiments were made to determine the effect of longer exposure time (9 h and 12 h) of *L. faxoni* fed with 20 newly-hatched nauplii prey. During the experiment no molt of *L. faxoni* was observed.

At the end of each experiment, specimens of *L. faxoni* were carefully removed from the bowl, and the number of prey remaining in each bowl were counted. When the prey was partially consumed, i.e. about half of body, it was registered as 0.5 individual. *L. faxoni* specimens were frozen after the experiments to avoid alterations in the length and weight, since the measurements were processed in the period of 48 h.

The relationship between the length of pre-buccal somite and total length of *L. faxoni* was observed by López (1966). Pre-buccal somite was measured, from the tip to the posterior edge, under a stereomicroscope Wild M5 using a micrometer scale. Measurements of wet-weight were made with electronic microbalance (Sauter Co. Ltd., Model D81) by placing a known number of individuals on a aluminium foil.

From length and weight data of *L. faxoni*, the following regression equation was obtained:

$$W = 308.653L^{2.489} \quad (r = 0.883),$$

where W and L are the weight ( $\mu\text{g}$ ) and length (mm), respectively. This equation was used to calculate the weight of a single *L. faxoni*.

Ivlev's equation modified by Parsons *et al.* (1969) was fitted to the mean values of ingestion rates obtained from the experiments to express the functional response of the

*L. faxoni* in terms of nauplii  $L. faxoni^{-1} \cdot d^{-1}$ , and  $\mu\text{g}$  nauplii  $L. faxoni^{-1} \cdot d^{-1}$ :

$$I = I_{\max}(1 - e^{-d(p_0 - p)}),$$

where I is the ingestion rate;  $I_{\max}$  is the theoretical maximum rate of ingestion;  $d$  is the constant;  $p$  is the prey density, and  $p_0$  is the threshold prey density below which no feeding takes place.

For all statistical comparisons, one-way analysis of variance (ANOVA) and Tukey multiple comparison test were applied (Sokal & Rohlf, 1981).

## Results

In laboratory conditions, *L. faxoni* generally ate their prey whole, although sometimes partial consumption has been observed.

Throughout the series of experiments, a large number of *L. faxoni* (82.09%) was observed preying on newly-hatched *Artemia* nauplii and metanauplii, whereas 17.91% of the *L. faxoni* had not ingested prey.

The mean values of individual ingestion rates varied with the prey size, prey density and light/dark conditions (Table 1). The number of prey ingested in the 6h experiments was variable. Nearly 70.92% of *L. faxoni* consumed 1-5 prey items, 9.91% captured 6-11 prey and only 0.70% ingested 13 nauplii (Fig. 2). Higher percentage of capture was verified in light conditions (Fig. 3).

Table 1. Means ( $\pm$ SE) of ingestion rates (express per day) of *L. faxoni* preying upon *Artemia* newly-hatched nauplii and metanauplii.

PREY DENSITY	LIGHT		DARK	
	N	MEAN	N	MEAN
Newly hatched nauplii				
10	8	1.5 (0.420)	9	1.11 (0.587)
20	10	3.15 (0.487)	9	1.87 (0.407)
40	10	2.55 (0.449)	10	2.9 (0.737)
80	10	3 (0.882)	9	2.39 (0.623)
Metanauplii				
10	5	1.9 (0.675)	5	3.8 (0.581)
20	10	3.5 (0.819)	10	1.6 (0.452)
40	7	5.42 (1.822)	9	2.89 (0.827)
80	10	4.5 (1.325)	9	3.78 (0.923)

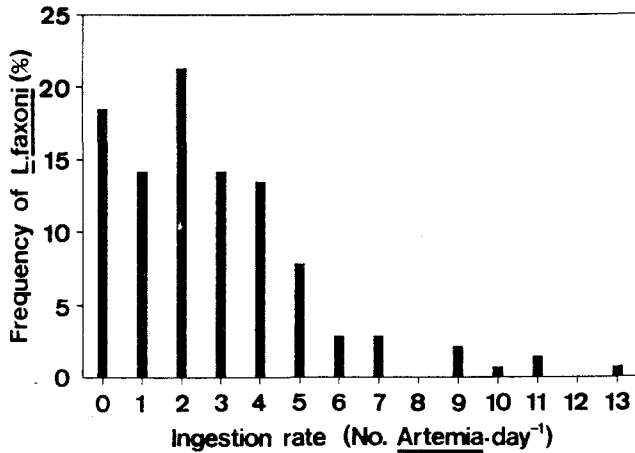


Fig. 2. Frequency (%) and ingestion rate (No. *Artemia*.day<sup>-1</sup>) of *L. faxoni*.

*Lucifer faxoni* showed preference towards ingesting larger prey (metanauplii) than small one (nauplii). The one-way ANOVA analysis applied to the ingestion rate proved significant differences. However, the Tukey multiple comparison test did not prove this difference statistically except for the case when prey density was 10 nauplii.100 ml<sup>-1</sup>.

Interaction effect on prey and predator was evident. Mean ingestion rates of *L. faxoni* increased with prey densities. The rates on nauplii and metanauplii prey approached asymptotic values in both light and dark conditions, as shown in Figure 4. The calculated rate of maximum ingestion was 17.28 and 13.40 nauplii.*L. faxoni*<sup>-1</sup>.d<sup>-1</sup> for light and dark experiments, respectively. These values were equivalent to 252.56 µg wet-weight nauplii.*L. faxoni*<sup>-1</sup>.d<sup>-1</sup> in the light and 175.24 µg wet weight nauplii.*L. faxoni*<sup>-1</sup>.d<sup>-1</sup> in the dark.

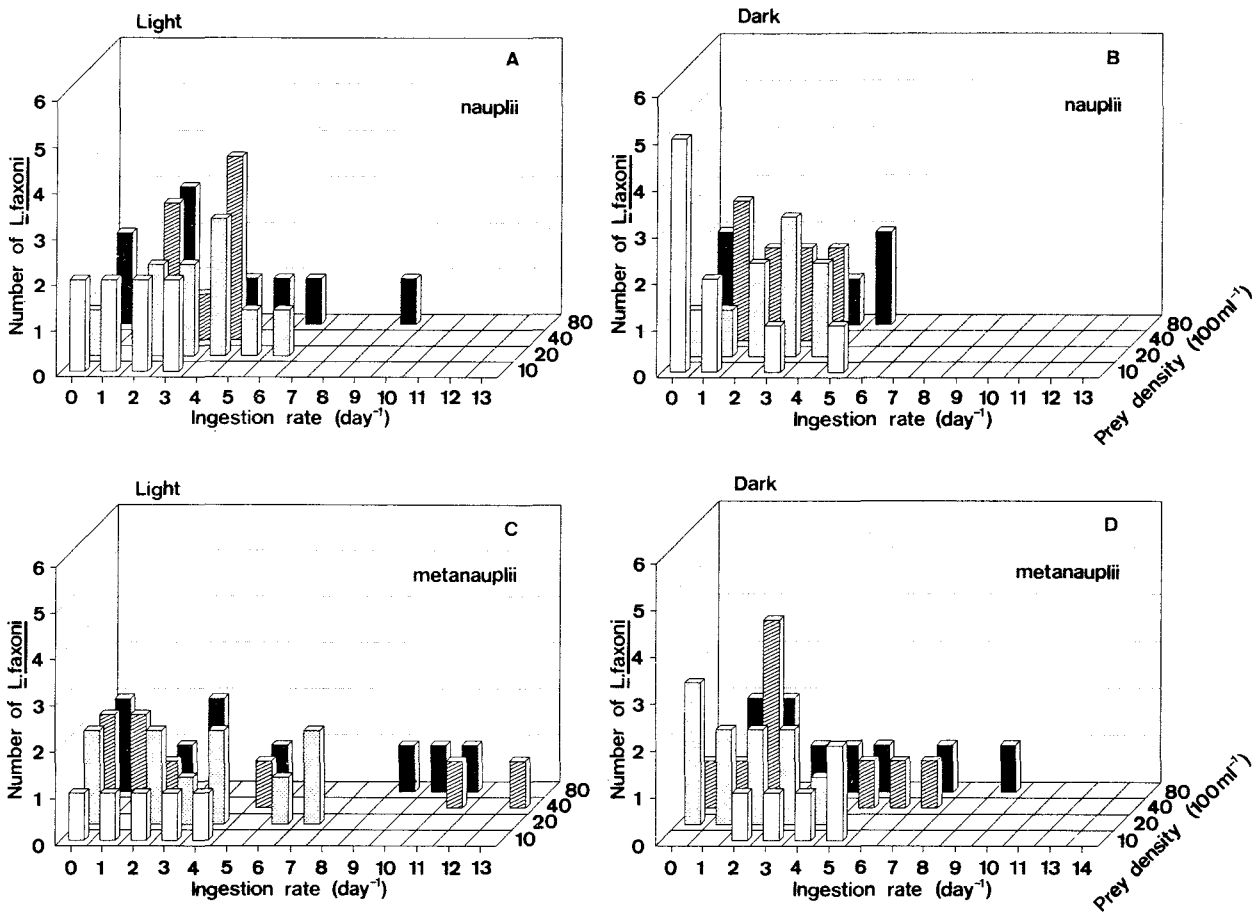


Fig. 3. Ingestion rate (express per day) of *L. faxoni* preying upon *Artemia* nauplii (A, B) and metanauplii (C, D), in light and dark conditions.

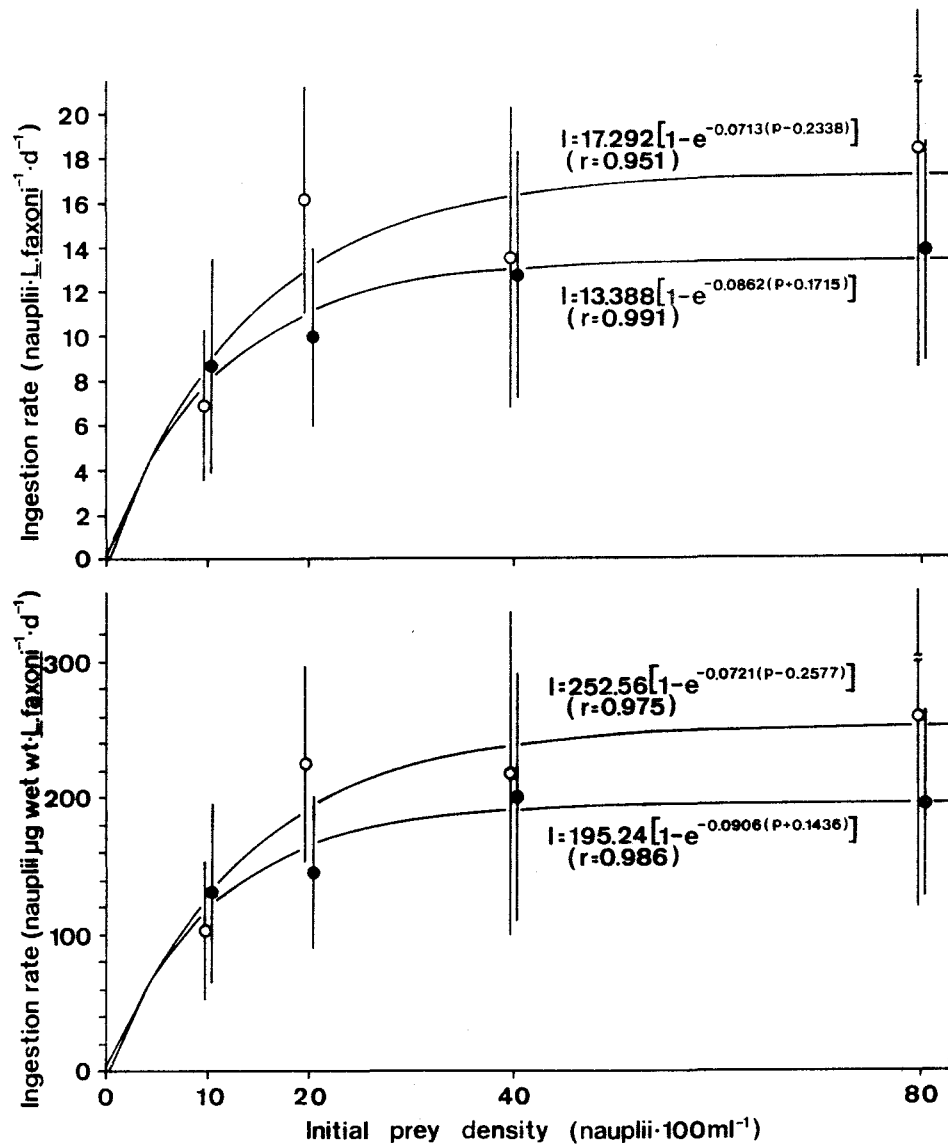


Fig. 4. Ingestion rate of *L. faxoni* on different prey density (Ivlev's function), in light(o) and dark(●) conditions.

The other experiments made to determine the effect of longer exposure time (9 h and 12 h), utilizing 20 *Artemia* nauplii, showed that the capture tended to increase with longer exposure time to prey (Fig. 5). Tukey multiple comparison test showed the differences in the 6 h and 9 h experiments under light conditions were statistically significant. For the other trials, the differences were not statistically significant.

In all experiments the mean ingestion rate was higher in the light conditions, although they were not statistically significant ( $p < 0.05$ ).

## Discussion

In laboratory conditions, *L. faxoni* generally ate their prey whole, but the partial consumption was also observed.

These feeding behavior has been reported in other crustaceans such as the prawn *Crangon crangon* (Gibson *et al.*, 1995).

The number of prey ingested by *L. faxoni* in the laboratory was highly variable ranging from 0 to 13 *Artemia* nauplii. Nearly 17.9% did not feed. The reason for this large variation could be due to the physiological state of *L. faxoni* since feeding can vary due to stress of collection and acclimation period (Chow-Fraser, 1986).

Prey size is one of the several factors affecting prey encounter rate and the predator ability and willingness to capture and ingest prey (Oresland & Ward, 1993). In this study, *L. faxoni* preyed more efficiently on *Artemia* metanauplii than on newly-hatched nauplii. The difficulty in capturing the nauplii may be due to the inability of this

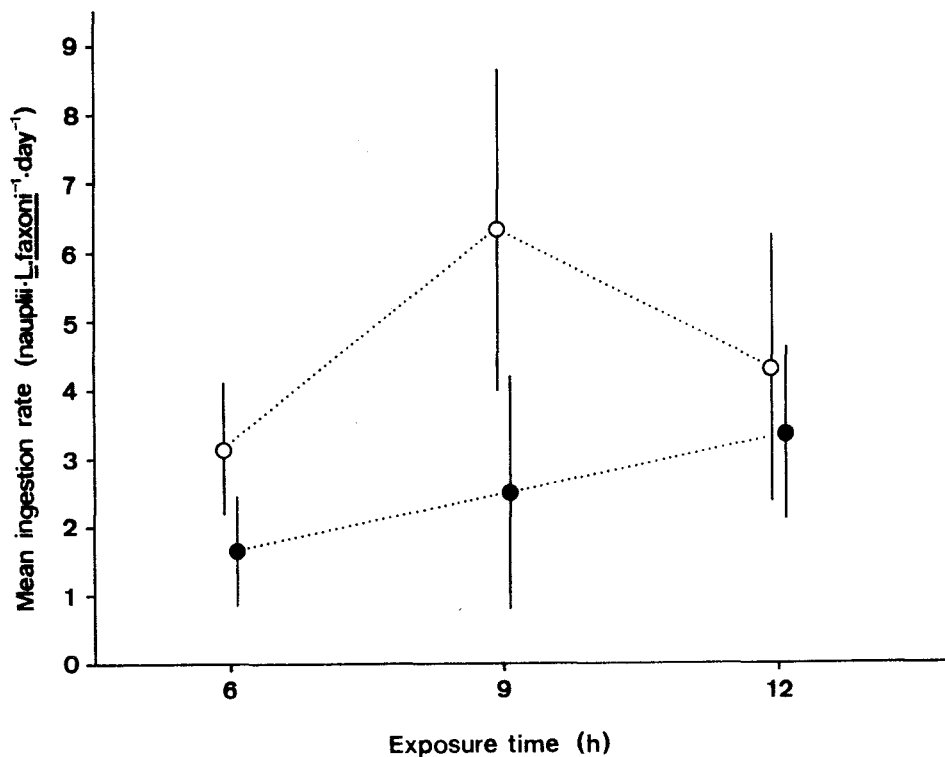


Fig. 5. Mean ingestion rate (express per day) of *L. faxoni*, with relation of exposure time to newly-hatched *Artemia* nauplii, in light(o) and dark(●) conditions.

species to manipulate smaller prey, as reported for other prawns (Wassenberg & Hill, 1993; Gibson, 1995). Another possible explanation for this result is that *Artemia* metanauplii are able to swim more actively than nauplii and then, they would be detectable at a greater range. This is probably because of the disturbances caused by the beating of the swimming appendages or by the prey's presence in the swimming current of the predator (Landry, 1978; Ohman, 1988).

Another factor which affects the ingestion rate is the abundance of food (Valiela, 1984). In this study, higher prey densities resulted in higher ingestion rate, but the relationship curve was asymptotic. Lee *et al.* (1992) showed that the ingestion rate of adult females of *L. faxoni* increased with increasing food density, and it did not appear to saturate at higher food concentration (100 nauplii.l<sup>-1</sup>) in the laboratory condition.

The ingestion rate was slightly higher in the light conditions than dark condition, it was not significantly different, however, between light and dark experiments, indicating that perceptions of prey may occur without visual cues. Besides visual perception, the detection of prey for the *L. faxoni* would be a chemo- or mechanoreception process. Although at present little is known about the

relative importance of chemo- and mechanoreception in predator recognition.

In this study longer exposure time of predator to the prey tended to increase the number of *Artemia* captured by *L. faxoni*. These results confirm that food will be successfully captured when the feeder is exposed longer to the presence of its food (Andrews, 1983).

The information obtained in this study confirms that further field and laboratory studies on feeding rate of *L. faxoni* are required for better understanding the potential contribution of this species to the marine secondary production in the studied region.

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## References

- Andrews, J. C. 1983. Deformation of the active space in the low Reynolds number feeding current of calanoid copepods. *Can. J. Fish. aquat. Sci.*, 40:1293-1302.
- Båmstedt, U. 1988. Ecological significance of individual variability in copepod bioenergetics. *Hydrobiologia*, 167/168:43- 59.
- Barth, P. 1963. Estudos sobre *Lucifer reynaudi* como indicador de águas tropicais. *Notas Tecn. Inst. Pesq. Mar.*, Rio de Janeiro, 12:1-16.
- Bowman, T. E. & McCain, J. C. 1967. Distribution of the planktonic shrimp *Lucifer* in the western North Atlantic. *Bull. mar. Sci.*, 17:660-671.
- Chow-Fraser, P. 1986. Effect of collection and acclimation period on grazing rates of limnetic zooplankton. *Hydrobiologia*, 137:203- 210.
- Gasalla, M. A. 1995. Organização trófica da ictiofauna do Saco de Mamanguá, Parati, Estado do Rio de Janeiro. Dissertação de Mestrado. Universidade de São Paulo, Instituto Oceanográfico. 145p.
- Gibson, R. N.; Yin, M. C. & Robb, L. 1995. The behavioural basis of predator-prey size relationship between shrimp (*Crangon crangon*) and juvenile plaice (*Pleuronectes platessa*). *J. mar. biol. Ass. U.K.*, 75:337-349.
- Harper Jr, D. E. 1968. Distribution of *Lucifer faxoni* (Crustacea: Decapoda: Sergestidae) in neritic waters off the Texas coast, with a note on the occurrence of *Lucifer typus*. *Contr. mar. Sci. Univ. Tex.*, 13:1-16.
- Hopkins, T. L. 1966. The plankton of the St. Andrew Bay system, Florida. *Publs Inst. Mar. Sci. Univ. Tex.*, 11:12-64.
- Hopkins, T. L.; Lancraft, T. M.; Torres, J. J. & Donnelly, J. 1993. Community structure and trophic ecology of zooplankton in the Scotia Sea marginal ice zone in winter (1988). *Deep-Sea Res.*, 40:81-105.
- Jimenez-Alvarez, M. P. 1976. Distribuição vertical e estágios de desenvolvimento de *Lucifer faxoni* Borradaile (Crustacea) ao largo de Santos. Dissertação de Mestrado. Universidade de São Paulo, Instituto de Biociências. 54p.
- Lampitt, R. S. & Gamble, J. C. 1982. Diet and respiration of the small planktonic marine copepod *Oithona nana*. *Mar. Biol.*, 66:185- 190.
- Landry, M. R. 1978. Predatory feeding behavior of a marine copepod, *Labidocera trispinosa*. *Limnol. Oceanogr.*, 23:1103-1113.
- Lee, W. Y.; Omori, M. & Peck, R. W. 1992. Growth, reproduction and feeding behavior of the planktonic shrimp, *Lucifer faxoni* Borradaile, off Texas coast. *J. Plankt. Res.*, 14:61-69.
- López, M. T. 1966. Biología de *Lucifer faxoni* Borradaile, 1915, en Cananéia, Brasil (Crustacea, Decapoda, Luciferidae). *Bolm Inst. oceanogr.*, S Paulo, 15:47-54.
- Ohman, M. D. 1988. Behavioral responses of zooplankton to predation. *Bull. mar. Sci.*, 43:530-550.
- Omori, M. 1977. Distribution of warm water epiplanktonic shrimps of the genera *Lucifer* and *Acetes* (Macrura, Penaeidea, Sergestidae). In: PROC. SYMP. WARM WATER ZOOPLANKTON. Unesco/NIO, 1977. p. 1-12.
- Oresland, V. & Ward, T. 1993. Summer and Winter diet of four carnivorous copepod species around South Georgia. *Mar. Ecol.-Prog. Ser.*, 98:73-78.
- Parsons, T. R.; Lebrasseur, R. J.; Fulton, J. D. & Kennedy, O. D. 1969. Production studies in the strait of Georgia. Part II. Secondary production under the Fraser River plume, February to May, 1967. *J. expl mar. Biol. Ecol.*, 3:39-50.
- Reeve, M. R.; Syms, M. A. & Kremer, P. 1989. Growth dynamics of a ctenophore (*Mnemiopsis*) in relation to variable food supply. I. Carbon biomass, feeding, egg production, growth and assimilation efficiency. *J. Plankt. Res.*, 11:535-552.
- Sokal, R. R. & Rohlf, F. J. 1981. *Biometry*. San Francisco, W. H. Freeman & Co. 859p.
- Valiela, I. 1984. *Marine Ecological Process*. New York, Springer-Verlag. 546 p.
- Vega-Pérez, L. A. 1993. Estudo do zooplâncton da região de Ubatuba, Estado de São Paulo. *Publção esp. Inst. oceanogr.*, S Paulo, 10:65-84.

- Vega-Pérez, L. A. 1996. Estudo do zooplâncton da plataforma interna da região de São Sebastião. In: Oceanografia da Plataforma Interna da Região de São Sebastião. Relatório FAPESP nº 3. 664p.
- Wakabara, Y.; Flynn, M. N. & Tararam, A. S. 1996. Consumption and selection of superbenthic crustaceans by small-sized fishes in a lower salt marsh system. Rev. bras. oceanogr. (Submitted).
- Wassenberg, T. J. & Hill, B. J. 1993. Diet and feeding behavior of juvenile and adult banana prawns *Penaeus merguensis* in the Gulf of Carpentaria, Australia. Mar. Ecol.-Prog. Ser., 94:287-295.
- Woodmansee, R. A. 1966a. Daily vertical migration of *Lucifer* (Decapoda, Sergestidae). Egg development, oviposition and hatching. Int. Revue ges. Hydrobiol., 51:689-698.
- Woodmansee, R.A. 1966b. Daily vertical migration of *Lucifer* planktonic numbers in relation to solar and tidal cycles. Ecology, 47(5):847-850.
- Yen, J. 1983. Effects of prey concentration, prey size, predator life stage, predator starvation, and season on predation rates of the carnivorous copepod *Euchaeta elongata*. Mar. Biol., 75:69-77.

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