Egg production of *Calanus euxinus* in the Black Sea: effects of chlorophyll concentration

Murat Telli[1] and Şengül Beşiktepe [2]

e121436@metu.edu.tr, sengul@ims.metu.edu.tr
[1]Middle East Technical University, Biology Dept., Ankara, Turkey
[2]Middle East Technical University Institute of Marine Sciences P.O.B. 28, 33731 Erdemli/İçel Turkey

Abstract- The effects of chlorophyll-a (chl-a) concentration on egg production rates of *Calanus euxinus* were examined in the Black Sea during October 2000 and May 2001. Chl-a concentration was used as an index of food quantity. Egg production rates varied between 0.07 and 7.34 eggs female^{-1} d^{-1} in October 2000, and between 1.82 and 7.02 eggs female^{-1} d^{-1} in May 2001. Egg production rates of *C. euxinus* were lower than those reported for the other species of *Calanus* from the other regions, but our results are identical to the egg production rates reported earlier for *C. euxinus* in the Black Sea. Depth integrated chl-a (from depth of the fluorescence minimum to the surface) concentrations ranged from 13.21 to 35.73 mg m^{-2} in October and from 9.44 to 23.97 mg m^{-2} in May. Egg production rates did not correlate well with chl-a concentrations. Thus, egg production rate of *C. euxinus* appears to be independent of the chl-a concentration in October 2000 and May 2001 in the Black Sea.

Keywords-Black Sea, *Calanus euxinus*, egg production, growth rate, feeding Rate

Introduction

Calanus euxinus is one of the most dominant copepod species in terms of biomass among the mesozooplankton of the Black Sea. It accounts for over one-third of the total zooplankton biomass and its maximum concentration always exceeds 250-500 ind. m^{-3} (Vinagradov *et al.* 1992). Calanus *euxinus* occurs in the aerobic zone of the Black Sea for all seasons and reproduces throughout the year (Sazhina 1996; Beşiktepe 2001). In spite of long history of the investigation of the Black Sea zooplankton, the reproductive patterns of the zooplankton have been poorly studied (Sazhina 1996; Arashkevich *et al.* 1998). The main objective of this study was to quantify egg production rates of *C. euxinus* and examine the effect of food availability on egg production of the copepod, and then estimate growth rate of the *C. euxinus* in the Black Sea. An additional goal was to describe the diel egg-laying pattern of the copepod.

Material and Methods

Data were obtained during two cruises carried out in the southern Black Sea in October (6-17) 2000 and May (23-27) 2001 (Fig. 1). Temperature, salinity and *in situ* fluorescence profiles were taken using a Seabird CTD and Chelsea fluorometers attached to it. Water samples for determination of chl-a concentration

at chosen depths were analized with a Hitachi F-3000 Model spectrofluorometer by using the fluorometric method of JGOFS (1994).

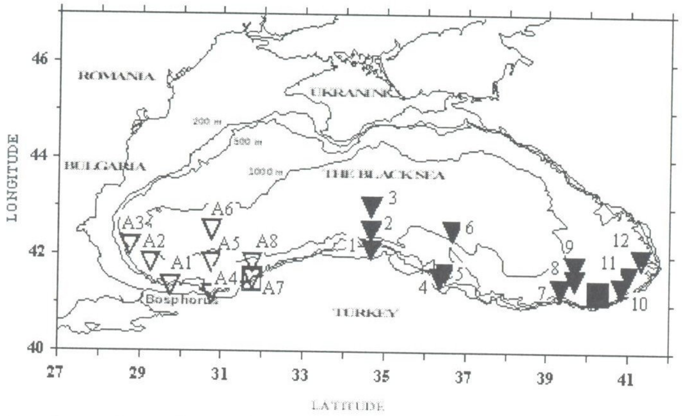

Fig. 1. Locations of sampling stations in October 2000 (filled triangles) and in May.2001 (empty triangles), rectangles illustrates the locations of Egg Laying Time experiments' stations.

Copepod samples were collected with a Hansen net (mouth opening 70 cm, mesh size 300 μm) via vertical hauls from the depth of 16.2 density layer to the surface. After that, females were sorted under a stereomicroscope within a few hours. The groups of 10 adult females were transferred to 2 l translucent bottles containing 56 μm filtered seawater from the fluorescence maximum. 3 replicate bottles and two control bottles with no added copepods were set up. The experimental bottles were kept on deck in an incubator with sea surface water running through. The incubations were performed under the natural light cycle for 24h. At the end of experiments contents of the bottles were preserved with 4% buffered formaldehyde. Eggs were counted under a stereomicroscope to estimate daily egg production rate of females. To describe the diel egg-laying pattern of *C. euxinus*, two sets of experimental bottles were prepared for the experiments. One set of the bottles was incubated at daytime and the other was incubated at nighttime period during 12h and at the end of experiments eggs were counted.

Results

Sea surface temperature was ~ 20 °C in October and ~ 16 °C in May and a well-developed seasonal thermocline was present during the both cruise. Fluorescence values decreased markedly below the thermocline in both cruises. The total chl-a concentrations were coincident with the relative fluorescence values in October and May. Chl-a concentration was in the range of 9 and 37 mg m^{-2} in both cruises.

In October 2000, daily egg production rates based on the 24 h experiments ranged from 0 to 7.34 ± 2.16 eggs female^{-1} day^{-1} (Fig. 2-a). Average egg production rate for the Southern Black Sea was 1.69 ± 2.31 egg female^{-1} day^{-1}. In May 2001, daily egg production rates ranged from 1.82 ±1.14 to 7.02 ± 2.21 egg female^{-1} day^{-1} (Fig. 2-b). Average egg production rate was 3.86 ± 1.93 egg female^{-1} day^{-1}. Egg production rates of *C. euxinus* in May were significantly higher than those in October (Mann-Whitney Rank Sum Test, $P \leq 0.001$).

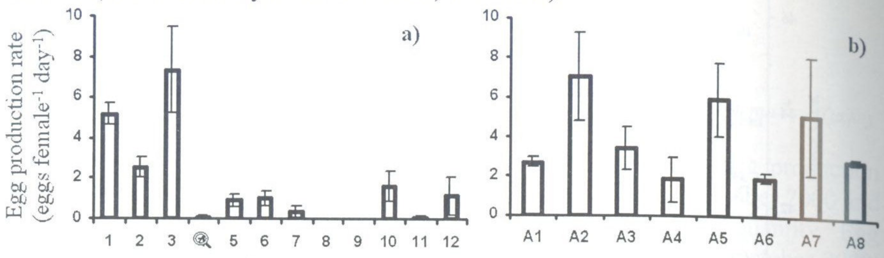

Fig. 2. Egg production rates of *Calanus euxinus* in October 2000 (a) and May 2001 (b).

Fig. 3 shows the relationship between chlorophyll-a concentration and egg production rates. Chl-a concentration (estimated by depth integrated chlorophyll-a concentration, 0-50 m) was used as an index of available food source in the study. There are no significant relationships between egg production rates and depth integrated chlorophyll-a concentrations in October 2000 and May 2001 (Spearman Rank Correlation, $P > 0.05$).

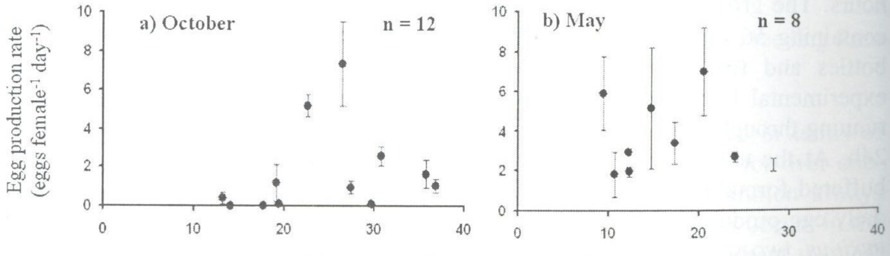

Fig. 3. The relationship between egg production rates (egg female^{-1} day^{-1}) of *Calanus euxinus* and depth integrated chlorophyll-a concentrations (0-50 meters) in October 2000 (a) and May 2001(b).

Diurnal differences in egg production rates of *C. euxinus* are shown in Fig. 4. Female showed strong nocturnal egg laying behavior. Mean egg production was 0.2 at nighttime and 0.01 egg female^{-1} h^{-1} at daytime in October and it was 0.6 at nighttime and 0.06 egg female^{-1} day^{-1} at daytime in May.

Discussion

The egg production rate of *C. euxinus* in this study were weakly related to in situ food concentration determined as chl-a concentration in October 2000 and May 2001. Although, the lack of relationship between egg production and chl-a

concentration have been reported for someother copepod species in a few studies (Saiz *et al.* 1999; Gutiérrez and Peterson 1999), a statistically significant relationship between egg production and *in situ* chl-a concentration was observed by many scientists (Richardson and Verheye 1998; Camphell and Head 2000; Durbin *et al.* 1983). In the present study, the lack of relationship may due to the small range of chl-a concentration values found during the sampling periods. Also, it should be considered that since production of eggs is energetically expensive, sufficient nutritional energy is essential for the female to meet energy expenditure of egg production. Previous studied have shown that size and the chemical composition of phytoplankton such as protein and specific fatty acids could greatly affect the egg production of copepods (Kleppel *et al.* 1998; Jónasdóttir 1994; Runge 1985).

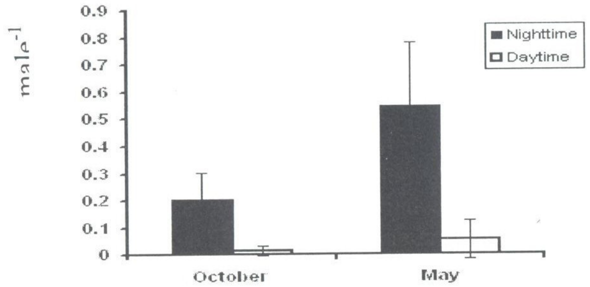

Fig. 4. Diel changes in egg production rates of *Calanus euxinus* in October 2000 and May 2001.

Calanus euxinus showed strong nocturnal egg-laying behavior in the Black Sea. That result is common finding for *Calanus sp.* in the field (Marshall and Orr 1972). However a few studies have been directed to understand what triggers the egg-laying behavior. Durbin *et al.* (1983) found a significant, positive correlation between the daily egg production rate of *A. tonsa* and food availability during 24 to 48 h bottle experiments. However Stearns *et al.* (1989) found no evidence suggesting that pigment concentrations may trigger the nocturnal egg laying in *A. tonsa* during 2 field experiments. While there are experimental results that propose an endogenous rhythm in egg-laying and feeding behavior (Stearns *et al.* 1989). *C. euxinus* showed nocturnal feeding (Beşiktepe *et al.* 1998) and nocturnal egg-laying behavior (present study) in the Black Sea. It should be studied in detail whether a diel feeding rhythm in this species directly controls the diel timing of egg laying or there is an independent endogenous rhythm in egg production rate other than an endogenous rhythm in nocturnal feeding behavior.

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Refrences

Arashkevich E., Svetlichny L., Gubareva E., Besiktepe Ş., Gucu A.C. and Kideyş A.E. (1998) Physiological and ecological study of *Calanus euxinus* (Hulseman) from the Black Sea with comments on its life cycle. In NATO Science Series. 2. Environmental series Vol: 47. Ivanov, L. I., Oguz, T., Ecosystem Modeling as a Management Tool for the Black Sea, 351-365. Kluwer Ac. Pub. Printed in Netherlands.

Beşiktepe Ş., Kideyş A.E., Ünsal M. (1998) *In situ* grazing pressure and dial vertical migration of female *Calanus euxinus* in the Black Sea. *Hydrabiologia,* **363**: 323-332.

Beşiktepe Ş. (2001) Dial vertical distribution, and herbivory of copepods in the southwestern part of the Black Sea. *J. Mar. System* **28**: 281-301.

Campbell R.W. and Head J.H.E. (2000) Egg production rates of *Calanus finmarchicus* in the North Atlantic: Effects of gonad maturity, female size, chl. concentration, and temperature. *Can.J.Aquat. Sci.*,**57**: 518-529.

Camphell R.G., Runge J.A. and Durbin E.G. (2000) Evidence for food limitation of *Calanus finmarchicus* production rates on the southern flank of Georges Bank during April 1997. *Deep-Sea Res. II.* **48**: 531-549.

Durbin E.G., Durbin A.G., Smayda T.J., and Verity P.G. (1983) Food limitation of production by adult *Acarcia tonsa* in Narragansett Bay, Rhode Island. *Limnol. Oceanog.*, **28** (6): 1199-1213.

Gutiérrez J.G. and Peterson W.T. (1999) Egg production rates of eight calanoid copepod species during the summer 1997 off Newport, Oregon, USA. *J Plankton Res.*, **21** (4): 637-657.

Harris R.P., Irigoien X., Head R.N., Rey C., Hygum B.., Hansen B.W., Niehoff B., Harms B.M., Carlotti F. (2000) Feeding, growth and reproduction in the genus *Calanus. ICES J. Mar. Sci.*,**57**:1708-1726.

Hirst A.G. and Lampitt R.S. (1998) Towards a global model of *in situ* weight-specific growth in marine planktonic copepods. *Mar. Biol.*, **132:** 247-257.

JGOFS. (1994) Protocols for the join Global Ocean Flux Study (JGOFS) Core Measurements, Manual and Guides 29, UNESCO, 170 pp.

Jónasdóttir S.H. (1994) Effects of food quality on the reproductive success of *Acarcia tonsa* and *Acarcia hudsonica*: laboratory observations. *Mar. Biol.*, **121**: 67-81.

Kiørboe T., and Sabatini M. (1995) Scaling of fecundity, growth and development in marine planctonic copepods. *Mar. Ecol. Prog. Ser.*, **120**: 285-298.

Kleppel G.S., Burkart, C. A. and Houchin, L. (1998) Nutrution and regulation of egg production in the calanoid copepod *Acarcia tonsa. Limnol. Oceanog.*, **43** (5): 1000-1007.

Marshall S.M.and Orr A.P. (1972) The biology of a marine copepod. Springer-Verlag, Heidelberg/New York 195pp.

Poulet S.A., Ianora A., Laabir M. and Klein B.W.C.M. (1995) Towards the measurements of secondary production and recruitment in copepods. *ICES J. Mar. Sci.*, **52**: 359-368.

Richardson A.J, Verheye H.M. (1998) The relative importance of food and temperature to copepod egg production and somatic growth in the southern Benguela upwelling system. *J Plankton Res.*, **20** (12): 2379-2399.

Runge J.A. (1985) Relationship of egg production of *Calanus pasificus* to seasonal changes in phytoplankton availability in Puget Sound, Washington. *Limnol. Oceanog.*, **30** (2): 382-396.

Saiz E., Calbet A., Irigoien X., and Alcaraz M. (1999) Copepod egg production in the western Mediterranean response to food availability in oligotrophic environments. *Mar.Ecol.Prog.Ser.*, **187**:179-189.

Sazhina L.I. (1996) Fecundity of Black Sea copepods in 1992. *Oceanol,* **34** (4): 516-522

Stearns D.E., Tester P.A. and Walker R.L. (1989) Diel changes in the egg production rate of *Acarcia tonsa* and related environmental factors in two estuaries. *Mar. Ecol. Prog. Ser.*, **52**: 7-16.

Vinogradov M.E., Arashkevich, E. and Iichenko, S. V. (1992) The ecology of the *Calanus ponticus* population in the deeper layer of its concentration in the Black Sea. *J Plankton Res.*, **14** (3): 447-458.