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ANNABI-TRABELSI NEILA[1], DALY-YAHIA MOHAMED NÉJIB[2]

[1]Biology Department,
Faculty of Sciences of Gabès Tunisia
[2]Unit of Hydrology and Planktonlogy,
University of Sciences of Bizerta, Tunisia

CENTROPAGES KROYERI EGG PRODUCTION RATE AS A FUNCTION OF LAGOON SUMMER CONDITIONS

SUMMARY

Daily egg production of the neritic calanoid copepod *Centropages kroyeri* was measured from 4 to 23 August 2003 at a site in North lagoon of Tunis and related to summer environmental variables and food availability. Food availability was evaluated by assuming a direct correlation with concentrations of the Chlorophyll *a* (Chl *a*), the particulate organic carbon (POC), and some easily extractable macromolecular compounds such as proteins, carbohydrates and lipids, from the seston. The egg production Rate (EPR) was estimated by incubating mature females with natural filtered seawater.

The EPR of *Centropages kroyeri* ranged from 4.2 (± 2.5) to 8.4 (± 6.2) eggs female^{-1} day^{-1}. This value was positively affected by salinity ($r = 0.501$, $P<0.01$). Among indices of food availability, only seston proteins were positively correlated ($r = 0.840$, $P<0.0001$) with the daily EPR of the species.

RIASSUNTO

È stata valutata la produzione giornaliera di uova in femmine di *Centropages kroyeri* raccolte dal 4 al 23 Agosto 2003 in una stazione di campionamento nella laguna di Tunisi. Il tasso di produzione giornaliero di uova è stato messo in relazione alle variabili ambientali e alla disponibilità di cibo. Quest'ultima è stata valutata assumendo una diretta relazione con la concentrazione di Clorofilla a (Chl *a*), il Carbonio organico pareticolato (POC), e alcune macromolecole facilmente ricavabili dal seston, come proteine, carboidrati e lipidi. Il tasso di produzione giornaliero di uova (EPR) è stato stimato dalle uova ottenute con un incuba mento delle femmine adulte per 24 h in acqua di mare originaria filtrata.

I valori di EPR ottenuti si aggiravano fra 4,2 (± 2,5) to 8,4 (± 6,2) uova / femmina / giorno. Questa variabile era direttamente proporzionale alle va-

riazioni di salinità ($r = 0,501$; $P < 0,01$). Tra gli indicatori di disponibilità di cibo si è trovato che l'EPR era direttamente proporzionale alla concentrazione di proteine nel seston ($r = 0,840$; $P < 0,0001$).

INTRODUCTION

Copepods of the genus *Centropages* occur in most of the world's oceans and are noted for their omnivorous diet, dominated by phytoplankton and other protists (Conley and Turner, 1985; Turner, 1987; Kleppel, 1993). The importance of this genus is well documented in the literature as a food source for other copepod species and fish (Conley and Turner, 1985; Turner *et al*., 1985; Davis, 1987; Turner, 1987, Sell *et al*., 2001).

In the North lagoon of Tunis, the genus is represented by *C. chierchiae* and *C. kroyeri* that usually occur in high abundances in summer from July to September (Annabi-Trabelsi *et al*., 2006). *Centropages kroyeri* Giesbrecht, 1892 is a dominant species of the southwestern Mediterranean coast, where it replaces its congener *C. typicus* (Daly Yahia *et al*., 2004), which dominates off the northern coast of the western Mediterranean basin (Souissi *et al*., 2001; Molinero *et al*., 2005). There are not many works on the reproductive traits of this species and the factors that regulate this process. In general, Copepoda reproduction is highly dependent on food availability and temperature (e.g. Ban, 1994; Hirche *et al*., 1997; Ianora, 1998; Koski and Kuosa, 1999; Huskin *et al*., 2000; Halsbank-Lenk *et al*., 2001; Shin *et al*., 2003; Devreker *et al*., 2005; Ianora *et al*., 2007; Souissi *et al*., 2008, Sun *et al*., 2008).

The aim of the present study was to determine how and to what degree the daily EPR of *C. kroyeri* in the North lagoon of Tunis is affected by temperature, salinity and food quantity as Chloa and POC concentrations, and food quality as seston composition, during summer.

MATERIAL AND METHODS

Sampling

The sample collection was carried out daily in the morning from 4 to 23 August 2003 at the S station in the North Lake of Tunis (SW Mediterranean, Tunisia) (Fig. 1). It's a large and shallow (2600 ha, average depth about 1.5m) lagoon with sandy-muddy bottom mainly covered by *Chaetomorpha linum* and *Ruppia cirrhosa* (Trabelsi, 2001). Plankton was collected every day by horizontally towing a standard plankton net (220 µm mesh size). The collected plankton was transferred to the laboratory within 30 min, and adult females were sorted for incubation. In situ measurements of temperature (°C) and salinity (psu) were detected with sensors of a multi-parametric probe.

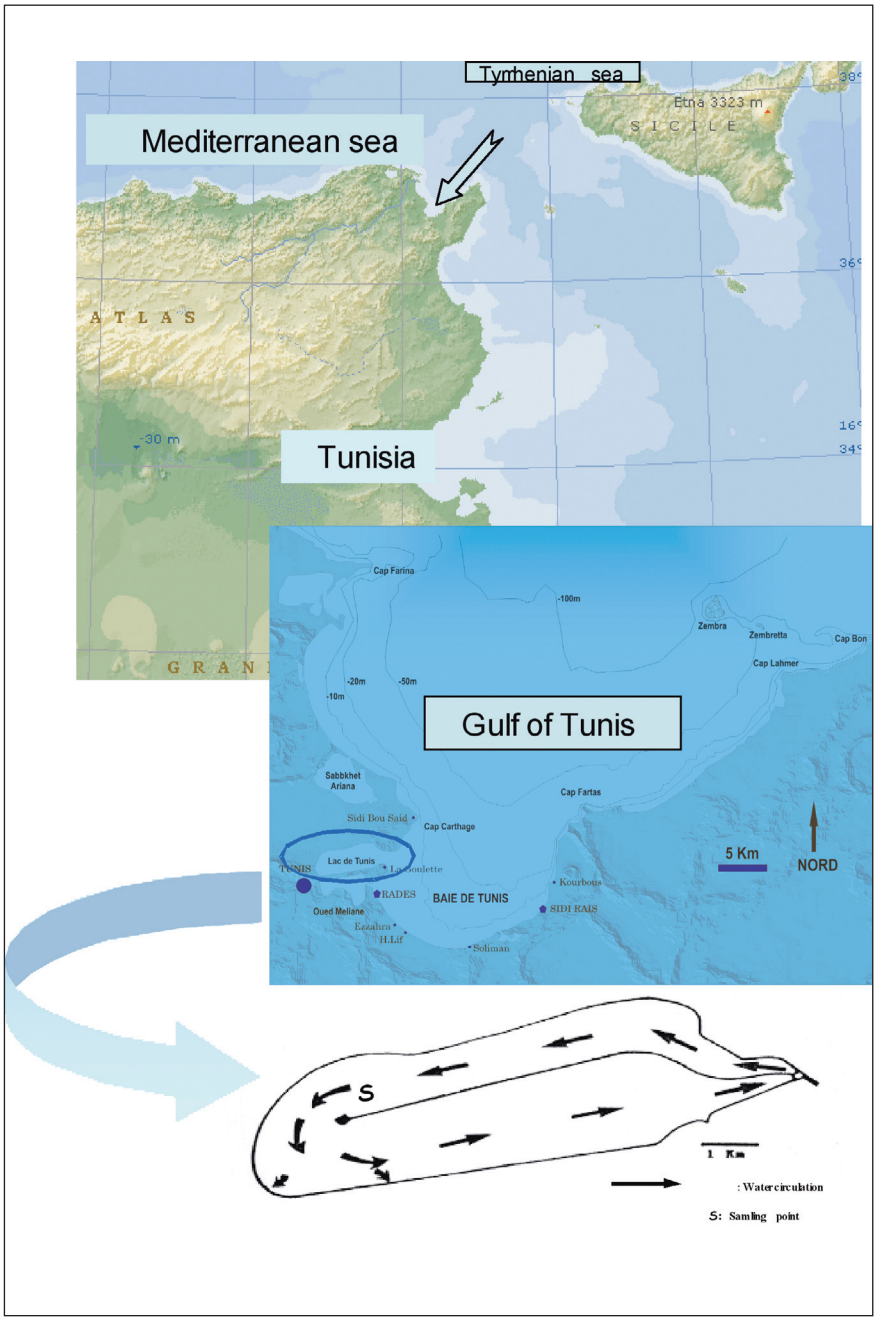

Fig. 1 - Geographical situation of Tunis North lagoon.

Laboratory analysis

Particulate organic carbon (POC) was measured by the method used by Cauwet (1975). Total Chl *a* concentrations were obtained spectrophotometrically, according to Lorenzen (1967). Protein concentrations were determined by the method of Lowry *et al*. (1951), as modified by Clayton *et al*. (1988), with a bovine serum albumin standard. Carbohydrate concentrations were determined by phenol-sulfuric acid reduction as described by Dubois *et al*. (1956) and modified by Head (1992). Particulate lipids were extracted in CH_2Cl / methanol (2:1, v/v) (Folch *et al*., 1956) with a known amount of C17 fatty acid added to the sample as internal standard.

Egg production

Mature females of *C. kroyeri* were stored out every day by using a stereomicroscope and a pipette. 15 to 25 females were kept individually in incubation cells with 5 ml of filtered (GF/C Whatmann, 0.45 µm porosity) seawater. It has been demonstrated that incubation in small volumes does not affect egg production (Niehoff *et al*., 1999; Harris *et al*., 2000). The incubation cell was arranged to avoid cannibalism on laid eggs by mothers. It was composed of a spawning chamber up and a egg-collecting chamber down a separation grid with a mesh size of 100 µm. Egg production rates (EPR) were calculated as the mean number of eggs produced per female per day, considering all the females used.

Statistics

The data were analyzed with non-parametric Spearman-rank. The data were considered significant when tests had a probability level of 0.05 or less.

RESULTS

Abiotic conditions

The daily patterns of surface water temperature, salinity, chlo*a* and POC concentrations are presented in Fig. 2 and Fig. 3. Temperature ranged between 26.8°C and 30.4°C, and Salinity ranged between 40 and 44 during the 20 day of study period. Chl *a* concentrations ranged between 0.1 and 0.6 µg l^{-1}. The POC concentrations fluctuated between 246 and 1360 µg l^{-1}.

Biochemical components of the seston

The average concentrations of biochemical components are showed in table 1. Carbohydrates represented the most important fraction of the lagoon seston (58 %). Proteins were detected with small quantities and represented only 14 % of the summer seston in the North lagoon of Tunis.

Table 1 - Arithmetic average concentration range and standard deviation of main organic constituents for suspended particulate matter in the North Lagoon of Tunis.

	average	range	standard deviation
Protein ($\mu g.l^{-1}$)	40.45	27.4-80.8	8.08
Carbohydrate ($\mu g.l^{-1}$)	169.8	106.8-310.3	44.06
Lipid ($\mu g.l^{-1}$)	83.7	28.6-104	14.58

EPR

The EPR of *C. kroyeri* varied between 4.2 (± 2.5) and 8.4 (±6.2) eggs female^{-1} day^{-1} with an average of 6.5 eggs female^{-1} day^{-1} (Fig. 4). The maximum EPR was 30 eggs female^{-1} day^{-1}. The daily percentage of spawning *C. kroyeri* females varied between 50 and 89 % (Fig. 5).

EPR of *C. kroyeri* was positively correlated with salinity ($r = 0.501$, $P<0.01$). Among nutritional parameters, only seston proteins were positively correlated ($r = 0.840$, $P<0.0001$) with the daily EPR of *C. kroyeri*.

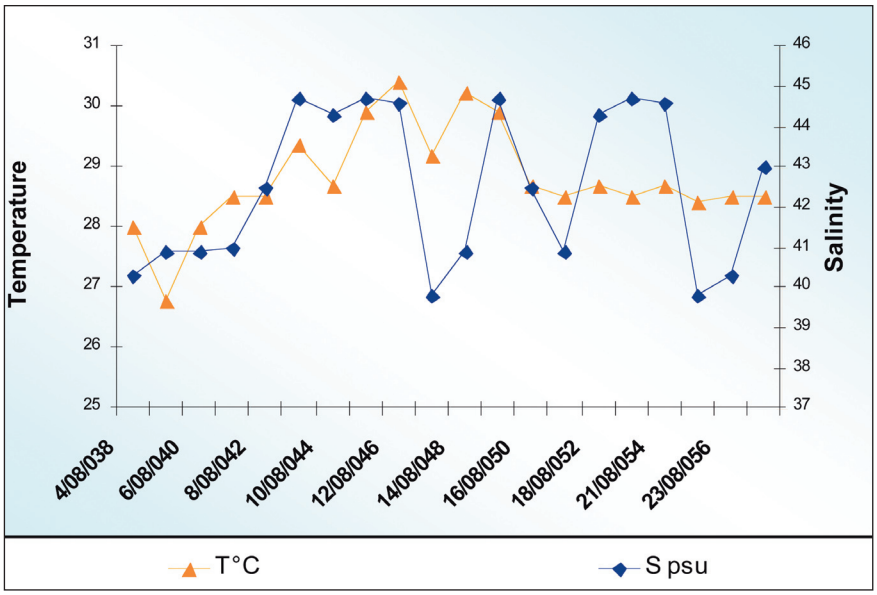

Fig. 2 - Daily patterns of surface water temperature and salinity.

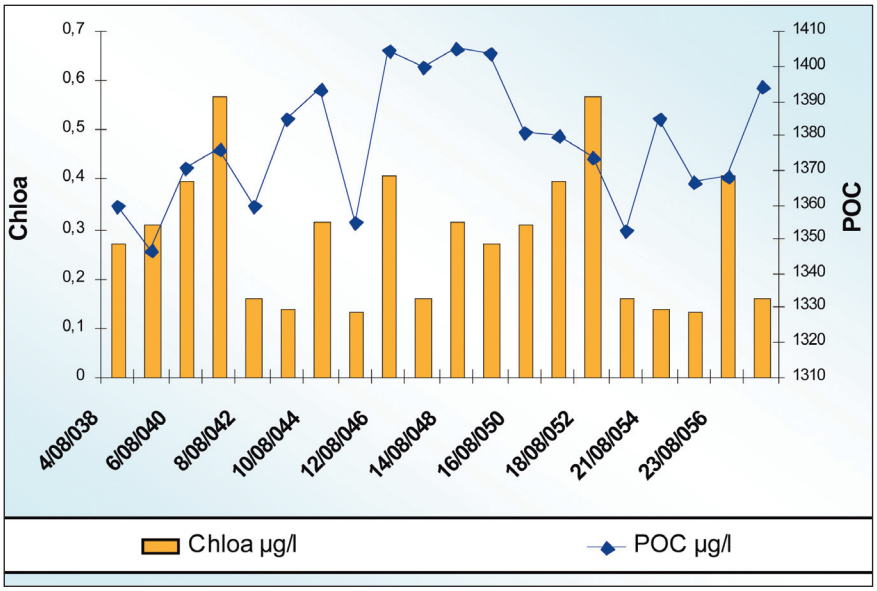

Fig. 3 - Daily patterns of Chl *a* and POC concentrations.

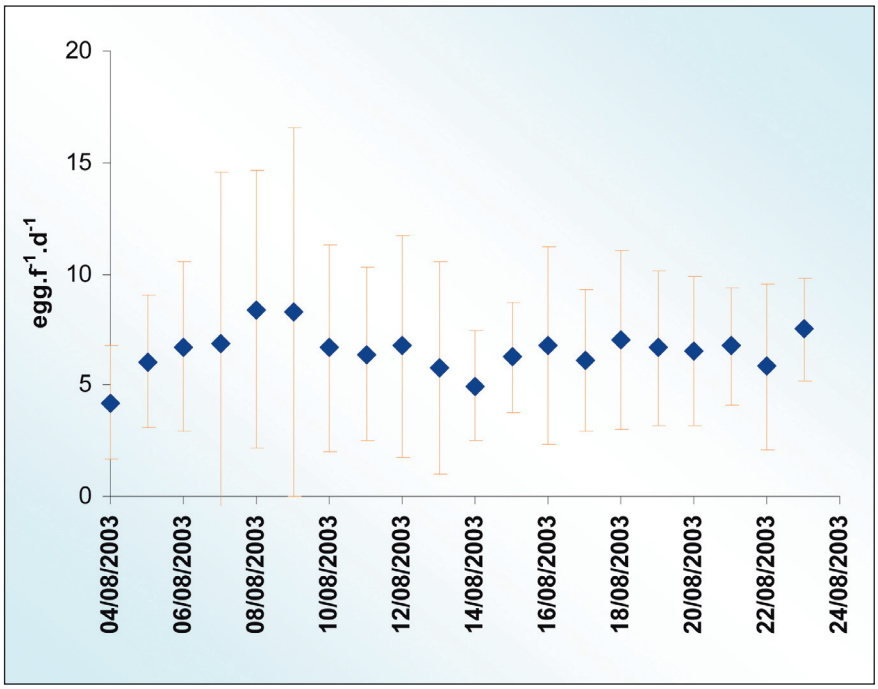

Fig. 4 - Daily EPR of *Centropages kroyeri* in the North lagoon of Tunis between 4 August to 23 August 2003.

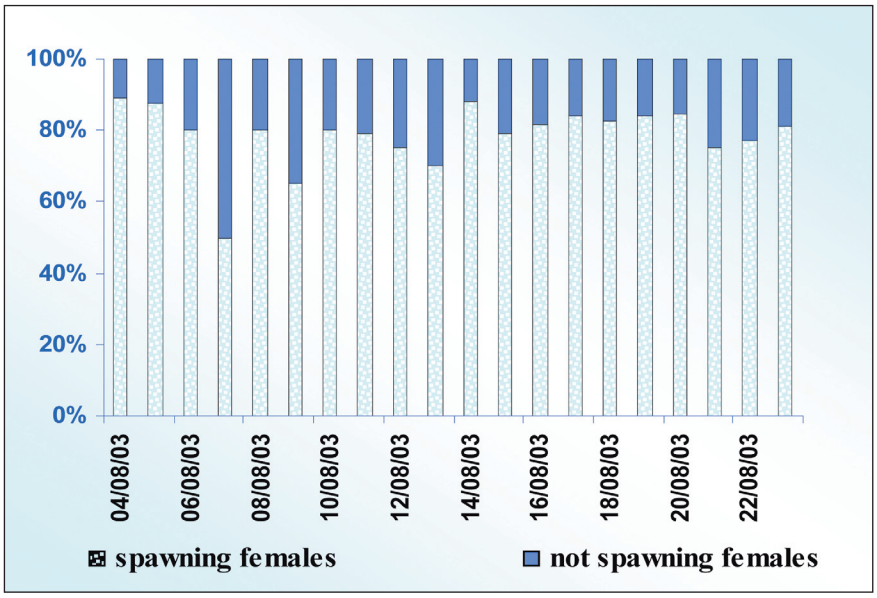

Fig. 5 - Daily percentage of spawning females of *Centropages kroyeri* in the North lagoon of Tunis between 4 August to 23 August 2003.

DISCUSSION

Except for a paper concerning the ultrastructure of its reproductive morphology (Corni *et al.*, 2000) and another about its reproductive traits (EPR and hatching success) in Bizerte Channel (SW Mediterranean Sea, Tunisia) (Souissi *et al.*, 2008), the reproduction of *C. kroyeri* is one of the less studied among species of the genus *Centropages*. The EPR of *C. kroyeri* in the present paper (North lagoon of Tunis) showed a similar range with values reported for the same species in Bizerte Channel (Souissi *et al.*, 2008). Here, during summer, that value varied between 3.2 and 13.1 eggs f^{-1} d^{-1}. Compared to the autumn, winter and spring EPR of other *Centropages* species (see Table 2), summer daily EPR of *C. kroyeri* in Tunisian water is low. According to Liang *et al.*, (1994) *C. abdominalis* is the most successful Copepoda in cold seasons by displaying the highest reproductive rate under low temperature among calanoid species. Ianora and Buttino (1990) showed that an inverse relationship between individual egg production rates and adult abundance, with maximum egg production rates from autumn to spring, when population abundances were low and minimum rates in summer, corresponding to an increment in adult female numbers.

During the present study, only salinity was positively correlated with the EPR of *C. kroyeri*. High temperatures (26.8°C to 30.4°) seem to not affect

directly the fecundity of *C. kroyeri* in the North lagoon of Tunis. Razouls (1981) described the effects of temperature and salinity on EPR of *C. typicus*. She reported maximum EPR (80 eggs female^{-1} day^{-1}) at 15 °C, and minima EPR (54 eggs female^{-1} day^{-1}) either at 20 °C and 12 °C (23 eggs female^{-1}). According to Ianora *et al*., (2007) *C. typicus* shows a valuable fecundity between 10 and 24 °C, with an optimum around 20 °C, where the EPR stays between 50 and 100 eggs female^{-1} day^{-1}, depending on both short-term and long-term food conditions, the latter via the size of the females. Halsband-Lenk *et al*. (2002) found that *C. typicus* was able to tolerate a wide range of temperatures, from 2 to 30 °C, explaining its wide distribution range from the subarctic to the tropics. These Authors compared North Sea and Mediterranean populations of *C. typicus* and found that optimal temperature for spawning was around 20 °C. The highest temperatures at which both Atlantic and Mediterranean populations could spawn was 25 °C, and the lethal temperature for adults was above 30 °C. A small salinity fluctuation (from 37 to 41 psu) during 24 h promoted increased egg production rates at all three temperatures (12, 15 and 20 °C) tested (Razouls, 1981). Smith and Lane (1985) also recorded egg productions in the laboratory under varying temperature conditions. EPR at 15 °C was higher than at 10 °C, and rate of egg production was found to be independent of adult female size when food and temperature were constant.

Table 2 - EPR of *Centropages* species.

Species	EPR (maximum: eggs fem^{-1} day^{-1})	Period of study	Localities b	Authors
C. abdominalis	37 ± 22	May	the northern Gulf of Alaska	(Slater and Hopcroft, **2005)**
C.abdominalis	31.6	November-May	Fukuyama Harbor, the Inland Sea of Japan	(Liang et al., 1994)
C.furcatus	13.3	February - March	Bahía Magdalena, México	(Gómez-Gutiérrez *et al*., 1999)
C. typicus	100	January–December	Gulf of Naples	Ianora and Buttino (1990)
C. typicus	54.0	February	Gulf of Naples	(Carotenuto et al., 2006)
C. typicus	33.5	January–December	Ligurian Sea	(Halsband-Lenk et al., 2001)

In the present study, the food concentration in term of seston proteins, was shown to be the main correlated factor with EPR of *C. kroyeri*. This suggests that the fecundity of *C. kroyer*i is typically food-dependent in the studied period. We can infer that *C. kroyeri* EPR was supported by availability of non-phytoplankton food in summer conditions (low values of Chloa concentrations), confirming an already known attitude of *Centropages* genus to utilize a wide variety of food. *C. typicus* is mostly carnivorous or omnivorous, feeding on a wide spectrum of preys both phytoplankton sized

organisms (from 3-4 µm equivalent spherical diameter of *Isochrysis galbana* to large diatoms), and animal preys such as ciliates, appendicularia, eggs and nauplii of copepods, up to yolk-sac fish larvae larger than 3 mm length (Calbet *et al*., 2007). Mixed diets induced EPR higher than single-species diets, suggesting that omnivory may be the best feeding strategy for *C. typicus* (Bonnet and Carlotti, 2001; Carlotti *et al*., 2007; Ianora *et al*., 2007). The phytoplankton biomasses are scarce during warm season, and the proportion of protists in total food sources is relatively higher in the same period. Therefore, the food availability for copepods should consider the quantity and quality of food sources simultaneously (Youn and Choi, 2007). While *Centropages* species have different ranges of EPR, in general, when operating with their in situ conditions, the egg production rates of the various species in this genus appear to respond similarly to physical parameters (temperature and or salinity) and food concentration.

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