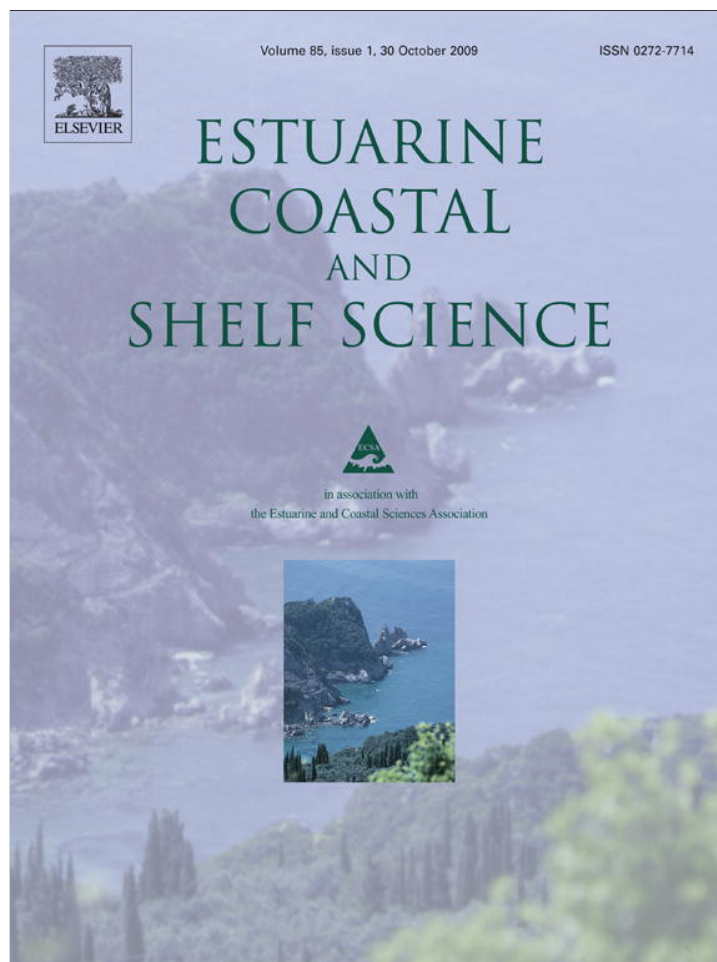


Provided for non-commercial research and education use.  
Not for reproduction, distribution or commercial use.



This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

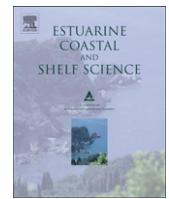
In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier's archiving and manuscript policies are encouraged to visit:

<http://www.elsevier.com/copyright>



Contents lists available at ScienceDirect

## Estuarine, Coastal and Shelf Science

journal homepage: [www.elsevier.com/locate/ecss](http://www.elsevier.com/locate/ecss)

## Temporal variation in abundance and fecundity of the invading copepod *Eurytemora americana* in Bahía Blanca Estuary during an unusual year

Anabela A. Berasategui\*, Mónica S. Hoffmeyer, Florencia Biancalana, Melisa Fernandez Severini, María C. Menendez

Instituto Argentino de Oceanografía (IADO), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Camino La Carrindanga Km 7.5, B8000FWB Bahía Blanca, Argentina

### ARTICLE INFO

#### Article history:

Received 4 December 2008

Accepted 8 March 2009

Available online 14 March 2009

#### Keywords:

*Eurytemora americana*  
abundance and fecundity  
invading copepod  
unusual annual cycle

### ABSTRACT

*Eurytemora americana* has been only reported as invader in Bahía Blanca Estuary, Argentina within the South Hemisphere. There are a few experimental researches under laboratory conditions done with this species and its reproductive behaviour around the world is very scarce. Consequently, it is still not possible to completely understand its population dynamics. In the present study, *E. americana* reproductive temporal behaviour and relationships among abundance, female size, egg production and hatching success were examined in the Bahía Blanca Estuary, during 2007 pulse. In order to determine the potential relationships between these variables and the environmental variables, experimental incubations were conducted in the laboratory simulating natural conditions. Spearman's rank correlation was used to analyze the relationships among all variables. Temporal change of biotic and environmental variables was corroborated by a Mann–Whitney/Kruskal–Wallis non-parametric tests, with significant differences ( $p < 0.01$ ) in all variables throughout the study. Abundance population results showed very high values in relation to those recorded in recent years in Bahía Blanca Estuary. This response could be due to the unusual combination of environmental factors (polar wave with temperatures  $\leq 6^\circ\text{C}$  and a drought period with high salinities, 32.7–36.6) recorded during the studied winter period. Significant positive correlations between abundance and salinity ( $p < 0.01$ ,  $n = 226$ ), and hatching success ( $p < 0.01$ ,  $n = 25$ ) as well as a significant negative correlation between abundance and chlorophyll *a* ( $p < 0.01$ ,  $n = 226$ ) were found. Although *E. americana* shows a k-strategy within its annual pulse, it presented two markedly distinct behaviours depending on temporal environmental variability. From July to early september, when the estuary evidenced high salinity, low temperature and high food availability, *E. americana* showed large females, large clutch size and high hatching success. When environmental conditions became unfavorable from September to October, small females, small clutch size and very low hatching success were observed. The latter is associated with diapause egg laying which ensures population recruitment. According to our findings the particular combination of low temperatures, high salinities and high available food (i.e. variables which each year modulate its pulse) during 2007 winter–spring, favored the great development of *E. americana*. This invading species in its opportunistic role has managed to exploit a vacant niche in the estuary, developing two different behaviours within the k-strategy depending on change in environmental conditions.

© 2009 Elsevier Ltd. All rights reserved.

*Eurytemora americana* (Williams, 1906) is an estuarine copepod native to the northern hemisphere (Kos, 1977) which is generally observed in relatively low abundance (40–1250 ind  $\text{m}^{-3}$ ) in comparison to other copepods like *Eurytemora affinis*, *Eurytemora hirundoides*, *Acartia tonsa* and *Acartia clausi* (Jeffries, 1962; Heron,

1964; Sage and Herman, 1972; Avent, 1998). This species is adapted to cold-intermediate temperatures ( $< 15^\circ\text{C}$ ) and intermediate salinity with values (in Practical Salinity Scale) ranging between 10 and 33 (Avent, 1998) or around an average of 24 or less (Sage and Herman, 1972).

Until now, *Eurytemora americana* has been only reported as invader in Bahía Blanca Estuary within the South Hemisphere (Hoffmeyer, 1994; Hoffmeyer et al., 2000). This copepod develops a planktonic pulse beginning in June and lasting until October,

\* Corresponding author.

E-mail address: [aberasa@criba.edu.ar](mailto:aberasa@criba.edu.ar) (A.A. Berasategui).

during which it coexists with *A. tonsa* and *Balanus glandula* larvae, maintaining a competitive relationship between them (Hoffmeyer, 1994, 2004). After this, *E. americana* disappears from the water column and remains as resting eggs in bottom sediments (Hoffmeyer, 2004). Over approximately the last twenty years *E. americana* has become the most abundant calanoid copepod in the estuary from August to October (Hoffmeyer et al., 2009). Its population density has increased during the last years associated with environmental changes and its dominance over *A. tonsa* population has been observed (Hoffmeyer, 2004; Hoffmeyer et al., 2008, 2009). Partial exclusion of *A. tonsa* in the co-occurring period could be attributed to the fact that *E. americana* (herbivory) assimilates the phytoplankton bloom more efficiently than *A. tonsa* (Hoffmeyer and Prado-Figueroa, 1997). *Eurytemora americana* has presented low abundance (30.33 ind m<sup>-3</sup> at 5–7 °C and 34–35 of salinity) during the 1990–1991 pulse and a higher abundance (6330 ind m<sup>-3</sup> at 10.90 °C and 17.23 of salinity) in the 2002 pulse in the Bahía Blanca Estuary (Hoffmeyer, 2004). Recent research on this population has shown positive significant correlations of abundance of its developmental stages with chlorophyll *a* (Chl-*a*) and salinity as well as negative correlations with temperature and photoperiod (Hoffmeyer et al., 2009).

Generation time of *E. americana* is approximately 40 days at 4 °C (Grice, 1970) and its reproductive strategy appears to be similar to that of *E. affinis*. The latter species produces subitaneous eggs during favourable environmental conditions and diapausal during unfavourable conditions (Marcus et al., 1994; Chen and Marcus, 1997; Katajisto, 2006). Preliminary studies performed in Bahía Blanca Estuary provide evidence that, during the population growth period, *E. americana* produces only subitaneous eggs which are ready to hatch in a few days (Berasategui et al., 2009). In contrast, at the beginning of population decline, females start to produce resting eggs (Diodato et al., 2006; Hoffmeyer et al., 2008; Berasategui et al., 2009). Research conducted with *E. affinis* has shown an inverse correlation of temperature with body length and clutch size, with the consequent direct relationship between the last two variables (Hirche, 1974, 1992). Similarly, in a study carried out with *E. americana* females from Bahía Blanca Estuary, body size and volume (biomass) decrease was detected at the end of the population pulse, associated with higher temperatures and less available phytoplankton but the probable relationship with the clutch size was not addressed (Hoffmeyer and Torres, 2001). At present, there are a few experimental researches under laboratory conditions done with *E. americana* (Grice, 1970; Berasategui et al., 2009). In addition, knowledge about its reproductive behaviour around the world is very scarce. Consequently, it is still not possible to completely understand its population dynamics. Taking into account the results of research conducted with *Eurytemora* spp. we predict that (1) egg production, and hatching success vary temporally during the population pulse, and (2) these variables have a direct relationship with salinity and Chl-*a* and an inverse relationship with temperature. To test these hypotheses and reconfirm already established results, we examined the relationship between *E. americana* field abundance, egg production (clutch size), hatching success (hatching percentage) and female size (prosoma length) during the 2007 population pulse in Bahía Blanca Estuary. We also analyzed the possible relationships between these biotic variables and environmental conditions such as temperature, salinity and Chl-*a*. The present paper will contribute to a better understanding of population dynamics of this species and to comprise how such dynamics is affected by environmental variability which constitutes scarcely known matters.

Sampling and measurements were conducted at Cuatros Port from July to October 2007, with an approximate fortnight frequency (nine sampling dates) during the *E. americana* annual pulse (Fig. 1).

Cuatros Port is located in the innermost area of Bahía Blanca Estuary, Argentina (30°30'–39°25'S; 61°15'–63°00'W). On the basis of mainly water dynamics and temperature–salinity variation, in general this estuary is defined as vertically homogeneous (Perillo and Piccolo, 1999; Freije and Marcovecchio, 2004). Water exchange is driven by semidiurnal tides and the estuary receives a low freshwater input from Sauce Chico River and Napostá Grande Stream, with an annual mean discharge of 1.9 and 0.8 m<sup>3</sup> s<sup>-1</sup>, respectively (Piccolo et al., 1990). Subsurface water temperature, salinity and Chl-*a* concentration were monitored to determine their temporal variation. Temperature and salinity were measured (in Practical Salinity Scale) with an HORIBA® multiparameter probe, and subsurface water samples were collected for spectrophotometrically determining Chl-*a* and phaeopigment concentrations according to Lorenzen (1967). Additional subsurface water (0.5–1 m depth) samples were collected for the experimental laboratory incubations. A total of 18 live mesozooplankton samples (two for each sampling date) were collected with a 200-µm mesh plankton net (0.30 m mouth diameter) by means of subsurface horizontal tows. Two series of experiments were conducted in the laboratory. In the first series, live samples were filtered using a 1.7-mm mesh filter to reject macrozooplankton while the mesozooplankton fraction was retained on a 0.2-mm mesh filter. Immediately after this, the concentrated mesozooplankton was put into two plastic containers filled with 5 L of filtered seawater (60-µm mesh) for diminishing density and was incubated for 24 h. Copepod egg production observed in the first 24 h after sampling reflects the in situ egg-laying behaviour (Runge and Roff, 2000). During experiments, we used similar temperature values as those measured in situ. After incubation, samples were preserved in 4% formalin for later determining abundance, egg production (clutch size) and female body size (prosoma length) according to Hoffmeyer and Torres (2001). Thus, during each sampling date, females (10–30) with complete egg sacs and empty oviducts were selected to measure prosoma length and count the number of eggs per sac. A total of 226 females were measured along the study period. In the second series, egg-carrying females were selected from the live mesozooplankton samples and were individually incubated to examine hatching success. Each female was sorted from the sample under a stereomicroscope, washed with 0.45-µm mesh filtered estuarine water and placed on a dish with 100 ml water (<60 µm). Two to four dish replicates were incubated for each sampling date, by suspending the dishes in a culture water bath under simulated in situ temperature and photoperiod conditions. Hatching of initial eggs (15–60 eggs per dish) was monitored with controls every 24–48 h. Estuarine water with natural food (<60 µm) was changed every 48 h and 14–15 h of dark were provided. Hatching percentage was calculated in relation to the initial egg number by: [(No. of nauplii/No. of initial eggs) × 100] according to Runge and Roff (2000). To facilitate counting of nauplii and non-hatched eggs in each control, both were retained in a 60-µm mesh and preserved in 4% formalin. General appearance of non-hatched eggs was also observed. Hatching success was evaluated in a total of 25 experimental units along the sampling period. Mean comparisons of biotic variables between sampling dates were performed by the Mann–Whitney/Kruskal–Wallis tests with Bonferroni's correction. These statistical non-parametric tests were applied because the studied variable data have not been able to meet the normality/variance's homogeneity assumptions. On the other hand Spearman's rank correlation analysis was used to describe and analyze the relationships among all variables.

Results on temporal variation of salinity, temperature and Chl-*a* showed two clear trends (Fig. 2a). From July to mid-August, low temperatures (5.2–7 °C) and high salinity (32.7–36.6) were recorded. In September, a temperature increase (11.9–15.8 °C) and



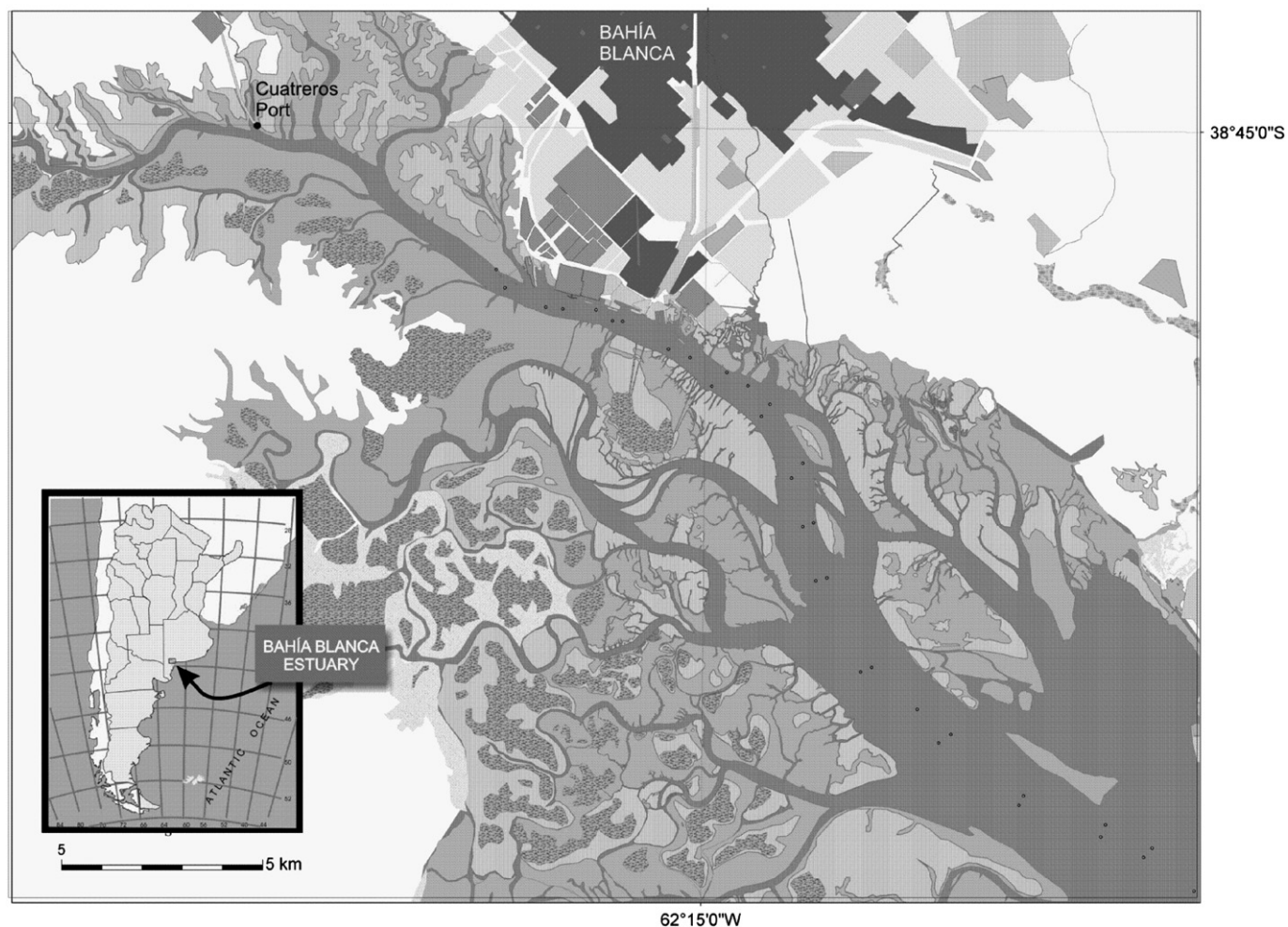


Fig. 1. Map of the Bahía Blanca Estuary, Argentina, with location of the sampling station (Cuatros Port).

a salinity decrease ( $\leq 30$ ) were also observed. Concentration of Chl-a from July to mid-August was generally higher ( $20\text{--}8.07\ \mu\text{g L}^{-1}$ ) than the concentration during October owing to a phytoplankton bloom during that period (Popovich and Marcovecchio, 2008). The population's abundance increased during July to the beginning of September when the maximum value occurred (Fig. 2b). After this, there was a period of population decline until the end of the pulse in October. During the population peak, a maximum of  $17402\ \text{ind m}^{-3}$  was observed, which coincided with the maximum salinity value (37.51), temperatures of approximately  $7\text{--}11.9\ ^\circ\text{C}$  and a decrease in Chl-a ( $< 8.07\ \mu\text{g L}^{-1}$ ). Significant positive correlations between abundance and salinity ( $p < 0.01$ ,  $n = 226$ ), and hatching success ( $p < 0.01$ ,  $n = 25$ ) as well as a significant negative correlation between abundance and Chl-a ( $p < 0.01$ ,  $n = 226$ ) were found (Table 1). Female prosome length decreased during the pulse, but there were notoriously larger prosome sizes ( $1.14 \pm 0.009\text{--}0.95 \pm 0.018\ \text{mm}$ ) during the period of population growth than during the period of population decline ( $0.72 \pm 0.012\text{--}0.67 \pm 0.012\ \text{mm}$ ) (Figs. 2b and 3). The largest sizes coincided with high salinity (32–37.51), high Chl-a ( $> 8.07\ \text{mg L}^{-1}$ ) and low temperature ( $5\text{--}7\ ^\circ\text{C}$ ) conditions as well as with a high hatching success (91–100%) and large clutch size (114–101 eggs per sac) (Fig. 2a,b). Correlations showed the same trends, female prosome length was positively correlated with salinity, Chl-a, clutch size and hatching success but negatively correlated with temperature (Table 1).

Clutch size and hatching success presented high values during the period of population growth and low values in the declining period (Fig. 2c). Both variables were positively correlated with each other and with salinity, also presenting a negative correlation with temperature (Table 1). Chl-a exhibited a positive significant correlation with clutch size and a positive non-significant correlation with hatching success (Table 1). At the end of August, the number of non-hatched eggs increased, reaching 100% in October, at the end of the pulse (Fig. 2c). Although we do not present in this paper egg size measurements, these eggs were larger than those produced at the start of pulse (subitaneous) (Fig. 3). Generally, they were released forming egg masses with sac remains. Kruskal–Wallis test results determined significant differences ( $p \ll 0.001$ ) in all mentioned biotic variables throughout the sampling dates. The latter indicates that there were clear temporal variations of them during the population pulse. The Mann–Whitney–Bonferroni analysis results determined that abundance significantly differed during all sampling dates ( $p < 0.05$ ). In contrast, no significant differences in clutch size, prosome length and hatching success were found within the first and the last sampling dates by which two different behaviours of these variables could be established.

The results of this study demonstrated higher abundance values of *E. americana*, than those recorded in the last years (Fig. 4a), in Bahía Blanca Estuary (Hoffmeyer, 2004; Hoffmeyer et al., 2008, 2009). Furthermore population peak values found in this study

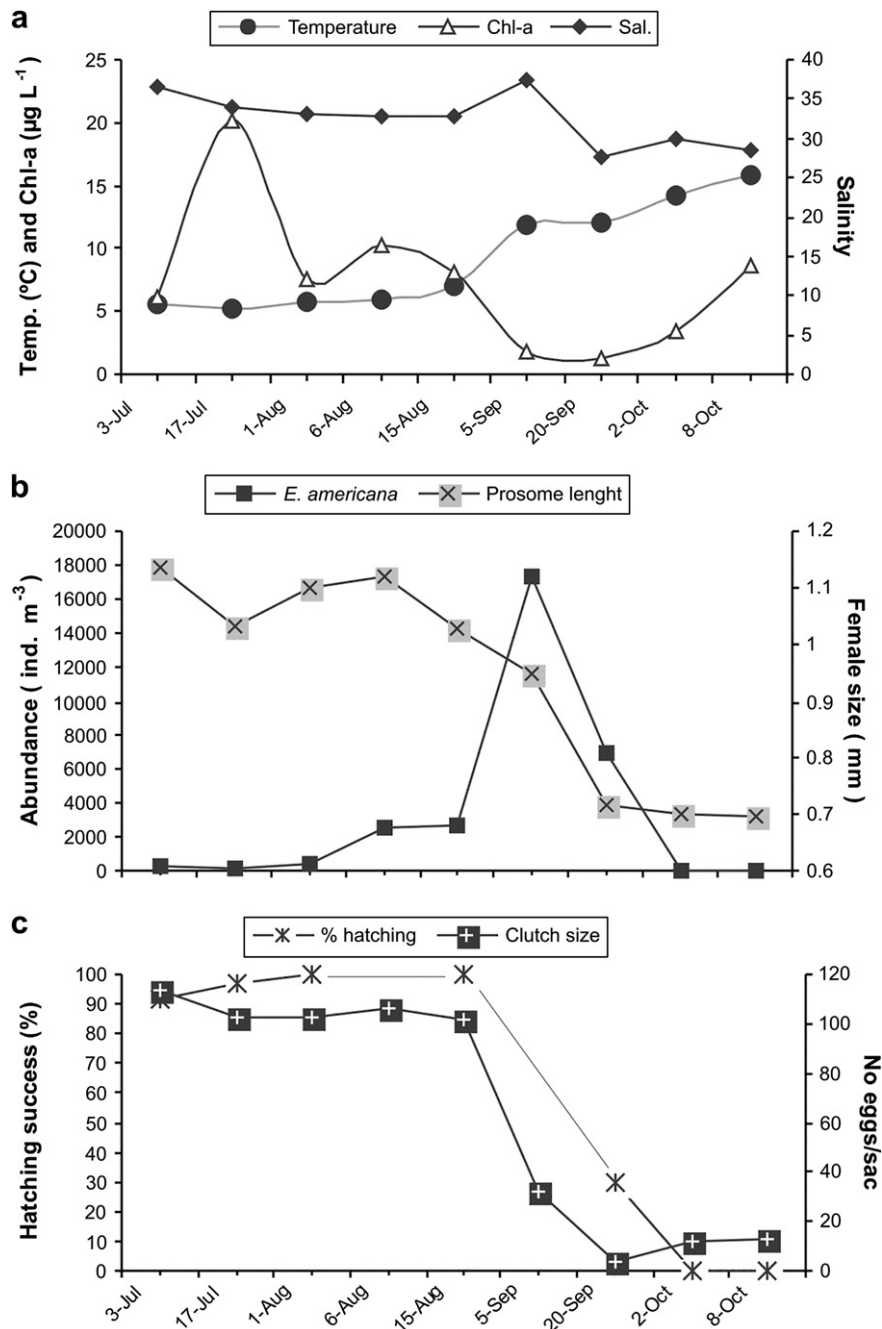


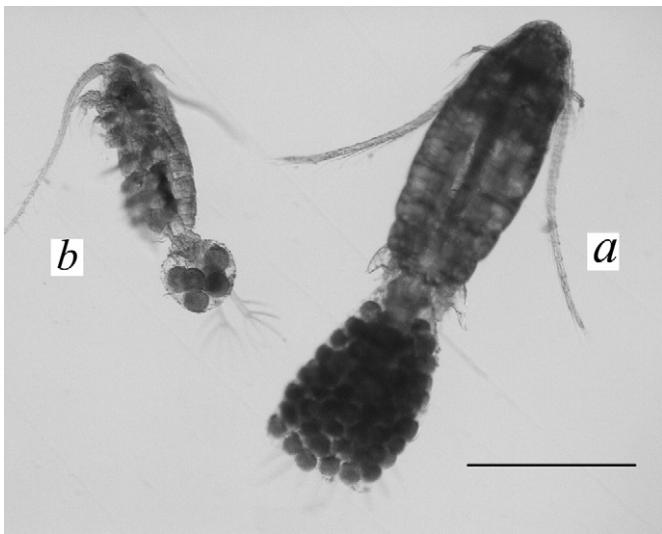
Fig. 2. Temporal variation. a) Environmental variables, b) Female size and abundance of *E. americana* and c) Hatching success and clutch size.

(17402 ind m<sup>-3</sup>) greatly exceeded those previously recorded in estuaries of origin (Jeffries, 1962; Heron, 1964; Sage and Herman, 1972), as well as those recently reported for other places in Argentina such as Golondrina and Ushuaia bays (Fernandez-Severini and Hoffmeyer, 2005; Biancalana et al., 2007). Under similar conditions of temperature and salinity as in the present study, low abundances of *E. americana* have been reported in Duwamish River Estuary (40–150 ind m<sup>-3</sup>) (Avent, 1998) and Ushuaia Bay (<2 ind m<sup>-3</sup>) (Biancalana's unpublished data), in relation to other copepods. Taking into account these precedents, the strong response in abundance observed during pulse 2007 may be explained by an unusual combination of environmental conditions, low competition and the existence of a large egg-bank, deposited in the sediments over the years. These unusual

environmental conditions during the 2007 winter can be related to a polar wave of Antarctic origin which affected the south of South America, likely lowering the temperature of estuarine water. On the

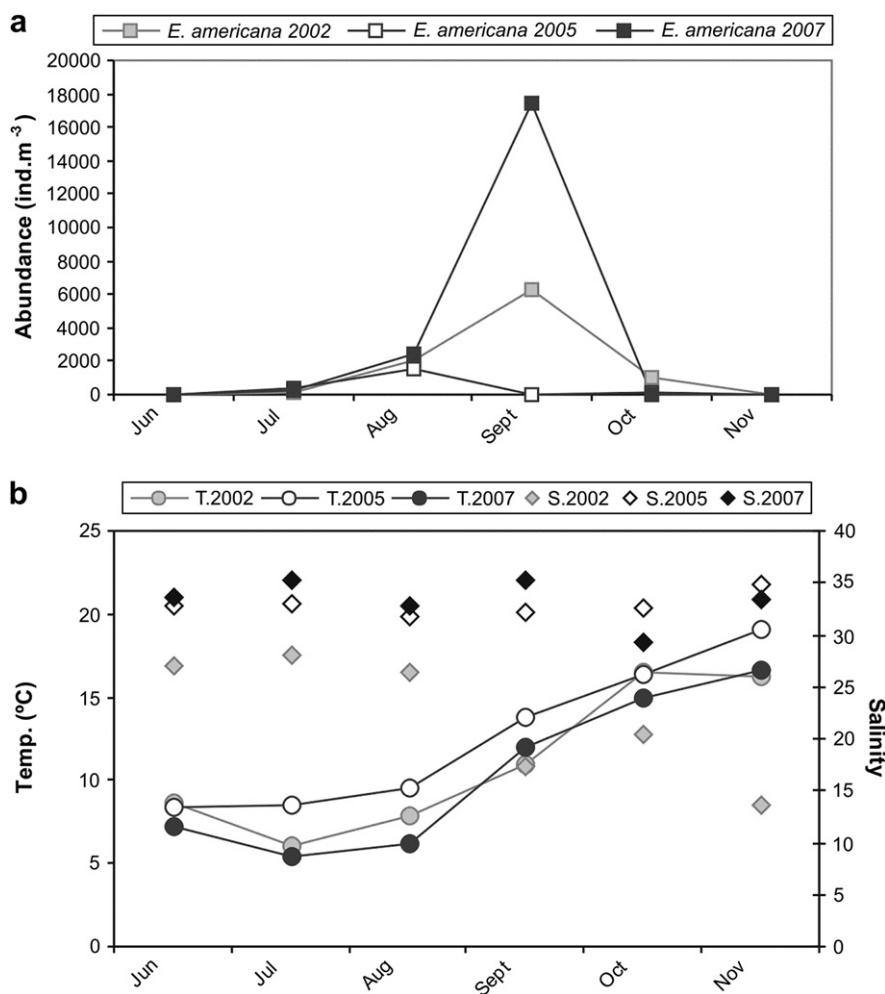
**Table 1**  
Spearman's rank correlation matrix. The correlation coefficients correspond to only significant correlations. \*\**p* < 0.01; \**p* < 0.05 and ns means no significant correlation (*n* = 25 for hatching success and *n* = 226 for the other variables).

	% hatching	Abundance	Prosome length	Clutch size
Abundance	0.475*			
Prosome length	0.874**	ns		
Clutch size	0.848**	ns	0.782**	
Temperature	-0.810**	ns	-0.786**	-0.788**
Salinity	0.675**	0.208**	0.537**	0.543**
Chl-a	ns	-0.437**	0.472**	0.657**



**Fig. 3.** Variability of *E. americana* female size and clutch size. a) Female at the beginning of pulse (August) and b) female at the end of pulse (October). The scale bar represents 700  $\mu\text{m}$ .

other hand, a drought period in the temperate eastern coast of South America, postulated as an effect of an ENSO episode (La Niña) (Barros and Silvestri, 2002; Silvestri, 2005), was also recorded in 2007. This phenomenon produced a low freshwater input into the estuary generating high salinity. Although other factors such as the scarcity of competitors (low abundances of *A. tonsa* and *B. glandula* larvae) and fish larvae predation (Lopez-Cazorla et al., 2006) could be modulating the abundance of *E. americana* population, we believe that the combination of low temperatures and high salinities also had an important role in 2007's pulse. Furthermore, analyzing comparatively the fluctuations of the environmental conditions during the *E. americana* pulses in 2002, 2005 and 2007 years, there were no large differences among peak values of Chl-a ( $17\text{--}20 \mu\text{g L}^{-1}$ ) but the lowest temperatures and highest salinities were observed during the 2007 pulse (Fig. 4b). According to previous studies, an inverse correlation between abundance and temperature as we expected (Hoffmeyer et al., 2009) was not found in this study. However, the high significant negative correlations between temperature and clutch size–hatching success suggest a possible indirect relationship between abundance and temperature. On the other hand, correlation analysis showed a significant direct relationship between abundance and salinity. Our findings on the maximal population abundance in Bahía Blanca Estuary suggest that this species seems to benefit from high salinity conditions (32–37) compared with those from the estuaries of



**Fig. 4.** Comparative analysis among *E. americana* pulses in Bahía Blanca Estuary. a) *Eurytemora americana* annual pulses and b) temperature and salinity conditions. Pulse 2002 data extracted from Hoffmeyer et al. (2009) and pulse 2005 data (M.D. Fernandez Severini, unpubl. data).



origin and also with those registered in this estuary in previous years. However, this hypothesis should be corroborated with further experimental studies on tolerance range for salinity.

Despite being considered the temperature as the main factor influencing in copepod fertility (Castro-Longoria, 2003; Holste and Peck, 2006), it is known in other estuarine copepod species that salinity can also have a direct effect on egg production, development time and survival (Castro-Longoria, 2003; Lee et al., 2003; Calliari et al., 2008). From the relationships observed in the present study between hatching percentage/clutch size and salinity coupled with temperature, it is clear that *E. americana* fecundity was positively influenced by the high salinity. On the other hand, since this species is an herbivore (Hoffmeyer and Prado-Figueroa, 1997), rich available food also plays a fundamental role in relation to its fecundity which is supported by the positive relationship found between Chl-a concentration and clutch size.

Although *E. americana* shows a k-strategy similar to that of *E. affinis* (Hirche, 1992) within its annual pulse, it presented two markedly distinct behaviours depending on temporal environmental variability. From July to early September, when there was high salinities (32–37), low temperatures (<7 °C) and high food availability in the estuary, *E. americana* produced large females, large clutch size (Fig. 3a) and high hatching success. When environmental conditions became unfavourable (salinity lower than 30, temperatures above 11 °C and Chl-a below 8 µg L<sup>-1</sup>) from September to October, small females, small clutch size (Fig. 3b) and very low hatching success were observed. As in the case of *E. affinis* (Ban, 1992; Katajisto, 2006), this second behaviour is associated with diapause egg laying to ensure population recruitment (Marcus, 1996; Hoffmeyer et al., 2009). On the other hand, an inverse relationship between egg size and clutch size has been mentioned for *E. affinis* (Hirche, 1992) and the same relationship has been observed for *E. americana* in this study. Temporal variation of female size and egg production (clutch size) might be well related to the use of metabolic resources (Ikeda et al., 2000) in relation to environmental changes. In this sense, the small size of females observed in this study at the end of pulse could probably be the result of a metabolic balance in favour of diapause egg production (Marcus, 1996; Belmonte, 1998; Castro-Longoria, 2001) and osmotic regulation in front of changes in water temperature–salinity (Kimmel and Bradley, 2001), leaving little reserves to be accumulated in body mass.

In conclusion, the particular combination of low temperatures, high salinities and high available food (i.e. variables which each year modulate its pulse) during 2007 winter–spring gave rise to the highest abundance peak of *E. americana* in the last years in Bahía Blanca Estuary. This invading species in its opportunistic role has managed to exploit a vacant niche in the estuary, developing two different behaviours within the k-strategy depending on change in environmental conditions. Certainly, these two behaviours contributed to its success as invasive species in this estuary.

## Acknowledgments

We are grateful to Instituto Argentino de Oceanografía and Chemistry Lab. staff for their collaboration. Particularly we thank R.O Asteasuain and L. Kaufman. This study was supported by grant PICT1713-2006 (ANPCYT) and a postgraduate fellowship (CONICET).

## References

Avent, S.R., 1998. Distribution of *Eurytemora americana* (Crustacea, Copepoda) in the Duwamish River Estuary, Washington. School of Oceanography, University of Washington, USA (report of Project results).

- Ban, S., 1992. Seasonal distribution, abundance and viability of diapause eggs of *Eurytemora affinis* (Copepoda: Calanoida) in the sediment of Lake Ohnuma, Hokkaido. Bulletin of Plankton Society of Japan 39, 41–48.
- Barros, V.R., Silvestri, G.E., 2002. The relation between sea surface temperature at the subtropical south-central Pacific and precipitation in southeastern South America. Journal of Climate 15, 251–267.
- Belmonte, G., 1998. The egg morphology of *Acartiidae* species: a preliminary survey of the ootaxonomy of calanoids. Journal of Marine Systems 15, 35–39.
- Berasategui, A.A., Hoffmeyer, M.S., Menendez, M.C., Biancalana, F., 2009. Análisis exploratorio sobre la estrategia reproductiva del copépodo invasor *Eurytemora americana*. In: Cazzaniga, N.J., Arelovich, H.M. (Eds.), Ambientes y recursos naturales del sudoeste bonaerense: producción, contaminación y conservación. Actas de las 5tas. Jornadas Interdisciplinarias del Sudoeste Bonaerense. Universidad Nacional Del Sur Press, Bahía Blanca, pp. 409–419.
- Biancalana, F., Barria de Cao, M.S., Hoffmeyer, S.M., 2007. Micro and mesozooplankton composition during winter in Ushuaia and Golondrina Bays (Beagle Channel, Argentina). Brazilian Journal of Oceanography 55 (2), 83–95.
- Calliari, D., Andersen Borg, M.C., Thor, P., Gorokhova, E., Tiselius, P., 2008. Instantaneous salinity reductions affect the survival and feeding rates of the co-occurring copepods *Acartia tonsa* Dana and *A. clausi* Giesbrecht differently. Journal of Experimental Marine Biology and Ecology 362, 18–25.
- Castro-Longoria, E., 2001. Comparative observations on the external morphology of subitaneous and diapause eggs of *Acartia* species from Southampton water. Crustaceana 74 (3), 225–236.
- Castro-Longoria, E., 2003. Egg production and hatching success of four *Acartia* species under different temperature and salinity regimes. Journal of Crustacean Biology 23 (2), 289–299.
- Chen, F., Marcus, N.H., 1997. Subitaneous, diapause, and delayed-hatching eggs of planktonic copepods from the northern Gulf of Mexico: morphology and hatching success. Marine Biology 127, 587–597.
- Diodato, S.L., Berasategui, A.A., Hoffmeyer, M.S., 2006. Morphological types and seasonal variation in eggs of zooplankton species from bottom sediments in Bahía Blanca Estuary, Argentina. Brazilian Journal of Oceanography 54 (3), 161–167.
- Fernandez-Severini, D.M., Hoffmeyer, S.M., 2005. Mesozooplankton assemblages in two bays in the Beagle Channel (Argentina) during January 2001. Scientia Marina 69, 27–37.
- Freije, R.H., Marcovecchio, J.E., 2004. Oceanografía Química. In: Piccolo, M.C., Hoffmeyer, M.S. (Eds.), El Ecosistema del Estuario de Bahía Blanca. Instituto Argentino de Oceanografía, Bahía Blanca, Argentina, pp. 69–78 (Editorial de la Universidad Nacional del Sur).
- Grice, G.D., 1970. The developmental stages of *Eurytemora americana* Williams, 1906, and *Eurytemora herdmani* Thompson and Scott, 1897 (Copepoda, Calanoida). Crustaceana 20, 145–158.
- Heron, G.A., 1964. Seven species of *Eurytemora* (Copepoda) from Northwestern North America. Crustaceana 7 (3), 199–211.
- Hirche, H.J., 1974. Die Copepoden *Eurytemora affinis* Poppe and *Acartia tonsa* Dana und ihre Besiedelung durch Myoschiston centropagidarum Precht (Peritricha) in der Schlei. Kieler Meeresforschungen 30, 43–64.
- Hirche, H.J., 1992. Egg production of *Eurytemora affinis* effect of K-strategy. Estuarine, Coastal and Shelf Science 35, 395–407.
- Hoffmeyer, M.S., 1994. Seasonal succession of Copepoda in the Bahía Blanca estuary. In: Ferrari, F.D., Bradley, B.P. (Eds.), Ecology and Morphology of Copepods, pp. 303–308.
- Hoffmeyer, M.S., 2004. Decadal change in zooplankton seasonal succession in the Bahía Blanca estuary, Argentina, following introduction of two zooplankton species. Journal of Plankton Research 26 (2), 181–189.
- Hoffmeyer, M.S., Berasategui, A.A., Beigt, D., Piccolo, M.C., 2009. Environmental regulation of the estuarine copepods *Acartia tonsa* and *Eurytemora americana* during coexistence period. Journal of the Marine Biological Association of the United Kingdom 89 (2), 355–361.
- Hoffmeyer, M.S., Fernandez-Severini, M.D., Menendez, M.C., Berasategui, A.A., Biancalana, F., 2008. Composition and dynamics of mesozooplankton assemblages in the Bahía Blanca Estuary. In: Neves, R., Baretta, J., Mateus, M. (Eds.), Perspectives on Integrated Coastal Zone Management in South America. IST Press, Lisboa, pp. 303–316.
- Hoffmeyer, M.S., Frost, B.W., Castro, M.B., 2000. *Eurytemora americana* Williams, 1906, not *Eurytemora affinis* (Poppe, 1880), inhabits the Bahía Blanca Estuary, Argentina. Scientia Marina 64 (1), 111–113.
- Hoffmeyer, M.S., Prado-Figueroa, M., 1997. Integumental structures in the oral field of *Eurytemora americana* and *Acartia tonsa* (Copepoda, Calanoida) in relation to their trophic habits. Crustaceana 70, 257–271.
- Hoffmeyer, M.S., Torres, E.R., 2001. Morphometric variables and individual volume of *Eurytemora americana* and *Acartia tonsa* females (Copepoda, Calanoida) from the Bahía Blanca estuary, Argentina. Hydrobiologia 459, 73–82.
- Holste, L., Peck, A.M., 2006. The effects of temperature and salinity on egg production and hatching success of Baltic *Acartia tonsa* (Copepoda: Calanoida): a laboratory investigation. Marine Biology 148, 1061–1070.
- Ikeda, T., Torres, J.J., Hernandez-Leon, S., Geiger, S.P., 2000. Metabolism. In: Harris, R.P., Wiebe, P.H., Lenz, J., Skjoldal, H.R., Huntley, M. (Eds.), Zooplankton Methodology Manual. Academic Press, Great Britain, pp. 454–532.
- Jeffries, H.P., 1962. Salinity space distribution of the estuarine copepod genus *Eurytemora*. Internationale Revue der gesamten Hydrobiologie und Hydrographie 47, 291–300.

- Katajisto, T., 2006. Benthic Resting Eggs in the Life Cycles of Calanoid Copepods in the Northern Baltic Sea. W and A. de Nottberck Foundation Scientific Reports No. 29. Helsinki, 46 pp.
- Kimmel, D.G., Bradley, B.P., 2001. Specific protein responses in the calanoid copepod *Eurytemora affinis* Poppe, 1880 to salinity and temperature variation. *Journal of Experimental Marine Biology and Ecology* 266, 135–149.
- Kos, M.S., 1977. Species of the genus *Eurytemora* (Copepoda, Calanoida) in northern part of the Pacific Ocean: systematics, distribution, variability. *Issled Fauny Morei* 20 (28), 20–53.
- Lee, C.E., Remfert, J.L., Gelembiuk, G.W., 2003. Evolution of physiological tolerance and performance during freshwater invasions. *Integrative and Comparative Biology* 43, 439–449.
- Lopez-Cazorla, A., Tejera, L., Pettigrosso, R., Camina, R., 2006. Preferencia y selectividad en la dieta de *Ramnogaster arcuata* (Osteichthyes, Clupeidae). In: VI Jornadas del Ciencias del Mar. Centro Nacional Patagónico (CONICET) y Universidad Nacional de la Patagonia San Juan Bosco, Puerto Madryn Argentina, 241 pp.
- Lorenzen, C.L., 1967. Determination of chlorophyll-a and phaeopigments. Spectrophotometric equations. *Limnology and Oceanography* 12, 343–346.
- Marcus, N.H., 1996. Ecological and evolutionary significance of resting eggs in marine copepods. *Hydrobiologia* 320, 141–152.
- Marcus, N.H., Lutz, R., Burnett, W., Cable, P., 1994. Age, viability and vertical distribution of zooplankton resting eggs from an anoxic basis: evidence of egg bank. *Limnology and Oceanography* 39, 154–158.
- Perillo, G.M.E., Piccolo, M.C., 1999. Geomorphological and physical characteristics of the Bahía Blanca Estuary, Argentina. In: Perillo, G.M.E., Piccolo, M.C., Pino-Quivira, M. (Eds.), *Estuaries of South America: Their Geomorphology and Dynamics*. Springer-Verlag, Berlin, pp. 195–216.
- Piccolo, M.C., Perillo, G.M.E., Arango, J.M., 1990. Hidrografía del estuario del Rio Sauce Chico (Bahía Blanca). *Geoacta*, 13–23.
- Popovich, C.A., Marcovecchio, J.E., 2008. Spatial and temporal variability of phytoplankton and environmental factors in a temperate estuary of South America (Atlantic coast, Argentina). *Continental Shelf Research* 28, 236–244.
- Runge, J.A., Roff, J.C., 2000. The measurement of growth and reproductive rates. In: Harris, R.P., Wiebe, P.H., Lenz, J., Skjoldal, H.R., Huntley, M. (Eds.), *Zooplankton Methodology Manual*. Academic Press, Great Britain, pp. 407–419.
- Sage, L.E., Herman, S.S., 1972. Zooplankton of the Sandy Hook Bay area, N.J. *Chesapeake Science* 13 (1), 29–39.
- Silvestri, G.E., 2005. Comparison between winter precipitations in southeastern South America during each ENSO phase. *Geophysical Research Letters* 32, 1–4 (L05709).