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VARIATIONS OF MESOZOOPLANKTON COMPOSITION IN A EUTROPHICATED SEMI-ENCLOSED SYSTEM (ENCERRADA BAY, TIERRA DEL FUEGO, ARGENTINA)

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Anthropogenic eutrophication of coastal waters caused by sewage discharge and agricultural runoff is currently one of the most serious problems in the world (SMITH et al., 1999; CLOERN, 2001; TETT et al., 2003). The increase in primary productivity, which is accompanied by a deterioration of water and sediment quality, is due to nutrient and organic matter enrichment (NIXON, 1995; COSTANZO et al., 2001). The latter: i) favuors the conditions for phytoplankton bloom development, ii) increases the abundance of certain zooplankton taxa and iii) decreases zooplankton community diversity (SMITH et al., 1999; URIARTE; VILLATE, 2004; THOMPSON et al., 2007).

Bio-indicator species evidencing the environmental quality of the system can be found among zooplankton. For example, species belonging to the genera *Acartia* and *Eurytemora* have been associated with areas of human disturbance (UYE et al., 1992; BIANCHI et al., 2003; CAULLEAUD et al., 2009).

Encerrada Bay (EB) is located off the coast of Ushuaia city, Argentina (54º49S - 68º19W) and receives the discharge of three sewage effluents (Onas, Guaraní and Beban) and Buena Esperanza stream (BES) (Fig. 1). The latter transports thaw water from Martial glacier, which is enriched with wastewater from Ushuaia city. Buena Esperanza stream has a flow range between 0.3 and 3.0 m^3seg^{-1} depending on rain and thaw periods and the flow of the other effluents does not attain 0.01 m^3 seg^{-1} (TORRES et al., 2009). Encerrada Bay covers a total area of ~0.3 km^2 and has a medium depth of 0.8 m. It communicates with Ushuaia Bay (UB) through two 4.5 m long pathway vents (P1 and P2). Water exchange between EB and UB takes place through these vents at a rate of ~1 m^3 seg^{-1} during semidiurnal tidal cycles. Water with low nutrient concentration enters EB during flood tide and water with high nutrient concentration flows out of UB during ebb tide (TORRES et al., 2009).

The aim of the present study was to analyze EB mesozooplankton composition in the light of the physico-chemical parameters of the water column. Particular attention was paid to the presence of opportunistic species which adapt favourably to EB's environmental conditions.

Sampling was carried out in December, 2004 and March and September, 2005. Mesozooplankton samples were collected at ebb tide for 5 minutes using a 200 µm mesh-0.30 m open mouth net containing a mechanical RIGOSHA® flowmeter. Qualitative and quantitative analyses were carried out under a Wild M5 stereomicroscope. Organism count was made by means of aliquots extracted at random from the homogenized samples until 10% of each sample was completed (BOLTOVSKOY, 1981). Temperature, salinity, dissolved oxygen, pH, ammonium (NH_4^+), nitrate+nitrite (NO_3^-), phosphate (PO_4^{-3}), silicate (SiO_3^{-2}), chlorophyll *a* (chl. *a*) and phaeophytin values were taken from Torres et al. (2009). Shannon-Wiener diversity (H'-log $_2$) and Simpson dominance (λ) indexes (PIELOU, 1975) were calculated from mesozooplankton taxa and abundance using Primer 5 software (CLARKE; WARWICK, 1994).

Twenty taxa corresponding to Arthropoda, Bryozoa and Mollusca phyla were found in the mesozooplankton samples. Holoplankton and meroplankton were represented by five taxa (Table 1). Ten taxa corresponded to adventitious plankton, eight of which belonged to Harpacticoida copepods. Taxa number was highest (13 taxa) in September and lowest (7 taxa) in March (Fig. 2). Total abundance ranged from 19.1 ind. m^{-3} (December) to 595.9 ind. m^{-3} (March) (Table 1). Whitin holoplankton, Eurytemora americana and Podon leuckarti evidenced highest abundance in March (413.5 ind. m^{-3} and 97.0 ind. m^{-3}, respectively) and both were present throughout the study period. *Acartia tonsa* was present in December and March, abundance being highest (62.3 ind. m^{-3}) in March. Cirripedia larvae belonging to meroplankton were present throughout the period studied. Abundance attained its highest values in September. On the other hand, adventitious plankton did not exceed 8.8 ind. m^{-3} (Diosaccidae family) (Table 1). The highest Shannon diversity values (H'=2.5) and the lowest Simpson dominance indexes (λ=0.2) were recorded in December (Fig. 2). An inverse pattern was observed in September and intermediate values of both indexes were found in March.

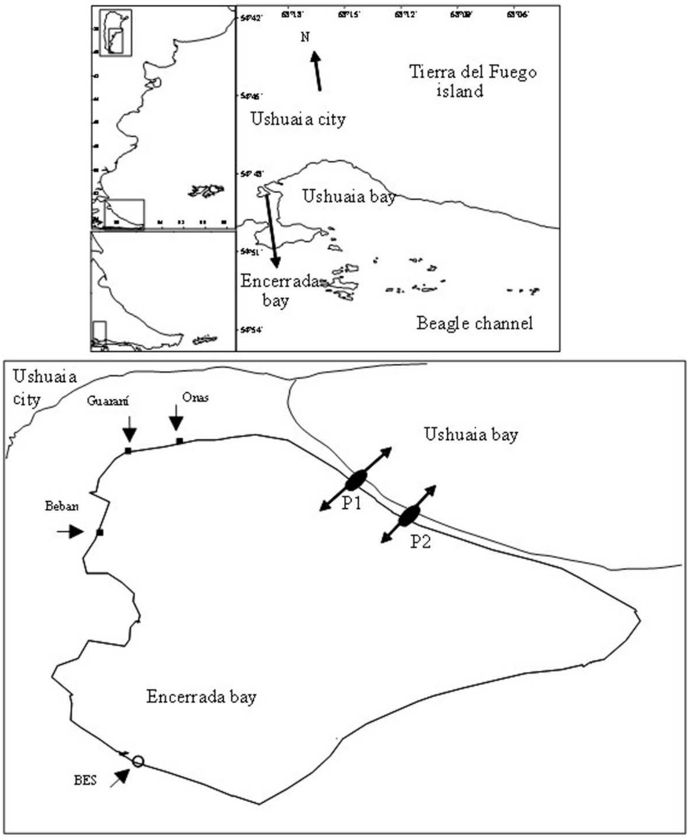

Fig. 1. Map of the study area: location of sampling station and outfalls (Buena Esperanza stream-BES) and runoff (Beban, Guaraní and Onas) and vents (P1 and P2) that communicate EB with UB.

Table 1. Mesozooplankton abundance (ind. m^{-3}) at P1 pathway vent in EB. L.: Larvae

	Taxa	Dicember-04	March-05	September-05
Holoplankton	*Acartia tonsa* (Dana, 1849)	0.30	**62.33**	0.00
	Drepanopus forcipatus (Giesbrecht, 1888)	0.00	0.30	0.00
	Eurytemora americana (Williams, 1906)	**4.86**	**413.50**	**411.37**
	Oithona similis (Claus, 1866)	0.30	0.00	8.21
	Podon Leuckarti (Sars, 1862)	**3.04**	**96.99**	**0.61**
Meroplankton	*Halicarcinus plantus* (Fabricius, 1775)	0.00	0.00	4.26
	Munida gregaria (Fabricius, 1793)	0.00	0.00	0.91
	Bivalvia (L.)	1.52	0.00	0.00
	Bryozoa (L.)	0.30	0.00	0.00
	Cirripedia (L.)	1.22	1.82	6.99
Adventitious Plankton	*Eupelte simile* (Monk, 1941)	0.30	0.00	0.00
	Harpacticidae	0.00	6.08	6.99
	Laophontidae	0.00	6.08	0.61
	Tegastidae	0.00	0.00	0.61
	Tisbidae	0.00	0.00	1.22
	Diosaccidae	0.00	8.82	0.91
	Harpacticus pacificus (Lang, 1965b)	6.69	0.00	0.00
	Tisbe varians (T. Scout, 1914)	0.00	0.00	0.61
	Isopoda	0.61	0.00	0.00
	Ostracoda	0.00	0.00	3.95
Total Abundance		**19.15**	**595.93**	**447.25**

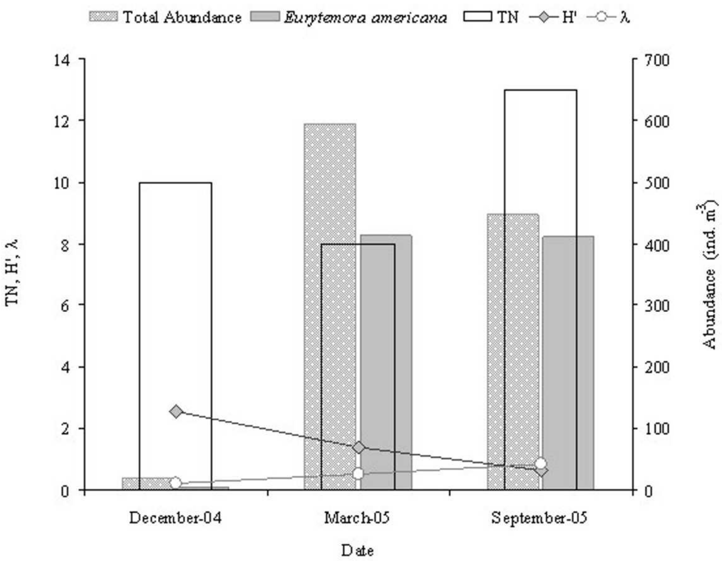

Fig. 2. Taxa number (TN), Shannon Diversity index (H'), Simpson Dominance (λ), Total abundance and *E. americana* abundance (ind. m^{-3}) in EB.

The physical, chemical and biological characteristics of the water mass passing through the vents were analyzed in detail by Torres et al. (2009). According to those authors, NH_4^+ concentration in the water mass coming from EB was high in December (60.9 µM) and March (59.5 µM) and it decreased in September (7.4 µM) while NO_3^- concentration evidenced an inverse pattern (5.1; 7.6 and 18.9 µM, respectively). Furthermore, SiO_3^{-2} (29.4 µM) concentration was found to be highest and salinity values lowest in March coinciding with the rainy period. An inverse pattern was observed in September when there was no freshwater contribution from thaw water. It was also found that phosphate concentration did not exceed 3 µM. Chlorophyll *a* concentration increased in September (5.8 mg m^{-3}) coincidentally with the period of low temperature, low NH_4^+ concentration and high salinity values and NO_3^- concentration. These nutrients did not evidence limited concentration and favoured the growth of macroalgae such as *Ulva rigida*, *Enteromorpha intestinales*, *Cladophora falklandica*, *Porphyra woolhouseae* and *Pilayella littoralis*. EB sediment presented anoxic conditions (redox potential ~-300 mV) and high organic matter content (7.8 - 18.9 %) (TORRES et al., 2009).

Zooplankton communities undergo changes firstly due to a decrease in total abundance and taxa number, and after to an increase in the abundance of some opportunistic species (decrease in the diversity index). This is a common phenomenon in EB as well as in areas affected by human disturbance and/or eutrophication (SIOKOU-FRANGOU; PAPATHANASSIOU, 1991; PARK; MARSHALL, 2000). Taxa number and Shannon Diversity were lower in EB than at a station close to the connection between EB and UB during the same period. This could be indicative of the presence of an anthropogenic perturbation gradient which increases towards the connection between EB and UB. On the other hand, total mesozooplankton abundance was high mainly in March and September as a result of the presence of *E. americana*. In addition, the highest availability of nutrients in EB water together with favourable light and temperature conditions were found to facilitate the activity of primary producers, thus giving support to high mesozooplankton abundance values. *E. americana* is a herbivorous species (HOFFMEYER; PRADO-FIGEROA, 1997) which was introduced into the southern hemisphere and has been cited in Bahía Blanca estuary (HOFFMEYER, 1994) as well as in UB and Golondrina bay (FERNÁNDEZ-SEVERINI; HOFFMEYER, 2004; BIANCALANA, 2009). This species is well adapted to low temperatures and intermediate salinities (SAGE; HERMAN, 1972; AVENT, 1998), both of which are conditions that prevailed during March and September, when *E. americana* evidenced highest abundance.

In March, *A. tonsa* and *P. leuckarti* were found to be important contributors to holoplankton abundance and they both contributed to increasing grazing pressure. The latter was evidenced by chl. *a* decrease and phaeophytin increment. Previous studies demonstrated that an increase in temperature, photoperiod and radiation and a decrease in salinity augmented the abundance of both taxa (ROSENBERG; PALMA, 2003; HOFFMEYER et al., 2008). Although *E. americana*, *A. tonsa* and *P. leuckarti* have been associated with anthropogenic disturbance, the factibility of the co-existence of these three species could be due to differences in their feeding behavior, *A. tonsa* and *P. leuckarti* being, in fact, omnivorous (JAGGER et al., 1999; KLEPPEL et al., 1988; HOFFMEYER; PRADO-FIGEROA, 1997; BIANCHI et al., 2003; HOFFMEYER, 2004). The decrease observed in their abundances in September could be associated with a change in salinity and temperature conditions. Meroplankton abundance was low and only Cirripedia larvae, which were probably associated with phytoplankton biomass, were found during the study period. Adventitious plankton, which could be associated with the presence of significant macroalgae biomass, was observed in March and September. Thus, the low grazing pressure was correlated with intermediate levels of chl. *a*, though not with high nutrient concentrations.

In view of the above, the gradual variability in mesozoplankton composition, diversity and abundance from EB to UB seems to respond not only to the availability of resources such as phytoplankton biomass but also to the changes in salinity and temperature in EB. This, in turn, seems to favour the presence of certain opportunistic taxa such as *E. americana*, *P. leuckarti* and *A. tonsa* that are potential bio-indicators and which seem to find in EB and in areas close to UB, conditions appropriate for their development (Biancalana, 2009). These species may therefore become useful water quality bio-indicators.

The findings of this present study lead us to conclude that further research on samples from EB, as well as from the connecting area between EB and UB, should be conducted - taking into account particularly the changes occurring in the mesozooplankton community, with special emphasis on copepod species and their relationship to water quality.

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