CURRENT DISTRIBUTION OF THE EXOTIC COPEPOD *PSEUDODIAPTOMUS TRIHAMATUS* WRIGHT, 1937 ALONG THE NORTHEASTERN COAST OF BRAZIL

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The introduction of exotic species is a major cause of depletion and extinction of native populations, a threat only surpassed by habitat destruction (Williamson, 1999). Exotic organisms may inflict negative impact upon native species by several ways, including transmission of pathogens and parasites, genetic degradation, habitat utilization, direct predation or competition for food, and other food web interactions (Williamson, 1996). Aquaculture activities account for a large number of accidental introductions worldwide because of non-intentional releases of small-sized organisms associated with target imported species (Carlton, 1996; Weigle *et al.*, 2005). Copepods, like other planktonic organisms, are usually transported as active or dormant stages with breed stocks of fish, shrimps and clams (Reid & Reed, 1994; Saunders, 1993; Saunders *et al.*, 1983).

The planktonic copepod *Pseudodiaptomus trihamatus* Wright, 1937, native from Indo-Pacific coastal waters, was accidentally introduced in Northeast Brazil in 1977 (Medeiros *et al.*, 1991). This species was first encountered in shrimp ponds along the margins of the Potengi River estuary, in the city of Natal. Its presence was attributed to an accidental introduction from a breeder stock of the shrimp *Penaeus monodon* Fabricius, 1798, imported from Philippines by EMPARN (a State research division dedicated to farming, cattle raising and aquaculture studies) in the same year, because *Pseudodiaptomus trihamatus* had been recorded in that country (Walter, 1984). No further investigation on this exotic copepod species has been carried out in the Brazilian coast.

In this study we inspected the occurrence of *Pseudodiaptomus trihamatus* in the Brazilian Northeast coast, from Tamandaré in Pernambuco State to Carutapera in Maranhão STATE, to evaluate whether

or not the species has expanded its distribution range since the early records. Three native species of the same genus were also recorded and their presence compared to *P. trihamatus*. Additional notes on the salinity ranges of the *Pseudodiaptomus* species and incidence of associated ectoparasites are also reported here. Annual water temperature in estuaries and coastal waters of the study area is quite constant throughout the year, reaching values from 26 to 30°C (mean about 27°C).

Samples were collected at estuaries and inshore waters in the Northeast region by ~50-m long horizontal hauls of a conical plankton net (30-cm diameter, 1.5-m length and 120-µm mesh size), from 2001 to 2005 (Fig. 1). Samples from the Tamandaré region were obtained by using a net trap placed on the sea floor, and applying artificial light as an attraction device. The collected organisms were preserved in 4% formalin neutralized with sodium borate. Zooplankton samples were inspected under a stereomicroscope and all adult *Pseudodiaptomus* were sorted for further identification. Identification of *P. trihamatus* was based on the shape of 5th legs (L5) for males and on the external shape of the genital segment for females, according to Walter (1984; 1989). Identification of other *Pseudodiaptomus* species was based on Björnberg (1981) and Bradford-Grieve *et al.* (1999). Distinction of *Pseudodiaptomus trihamatus* from congeneric species previously known for Brazilian waters is easy to perform, as it does not require dissection of specimens during routine zooplankton sorting, except for observation of L5 features in males (Fig. 2). The female genital somite bears two posterolateral spines on the dorsal surface in addition to a ventral pair of long spines, the tip of right spine reaching the margin of the anal somite (Walter, 1984). In addition, females of *Pseudodiaptomus* spp. so far recorded in Brazil do not carry a centrally positioned, single egg sac as in *P. trihamatus*.

Fig. 1. Localities along the Northeastern coast of Brazil where zooplankton samples were taken for the assessment of *Pseudodiaptomus trihamatus* distribution during 2001-2005.

The present investigation confirmed that *Pseudodiaptomus trihamatus* is widely distributed throughout estuarine and coastal waters off Northeast Brazil (Fig. 1), from Canguaretama in Rio Grande do Norte State (6°19'60"S, 35°04'08"W) to Barroquinha in Ceará State (3°02'12"S, 41°24'32"W). We speculate that the documentation of *Pseudodiaptomus trihamatus* at southern sampling sites 6 and 7 (Fig. 1) might be assigned to a secondary introduction by populations brought along with a stock of *Penaeus monodon* acquired in 1985 by CAMANOR (a shrimp farm located in Canguaretama, site 7, Fig. 1). The shrimp stock came from a cultivation enterprise situated in Valença, Bahia STATE (at about 13°S), which imported the exotic shrimp from Taiwan in 1984 (Ana Carolina de B. Guerrelhas, Aquatec Ltda., Canguaretama, RN, Brazil – personal communication), a country where *P. trihamatus* is known to thrive as a native component of the zooplankton community (Lo *et al.*, 2004). However, after more than 20 years of such a suspected introduction in Bahia State, *Pseudodiaptomus trihamatus* has not been reported in any area south of Rio Grande do Norte (Medeiros *et*

al., 1991), including the southernmost sites covered by the present investigation (Fig. 1). This particular situation might be attributed either to non-release of the exotic copepod from captivity in Bahia (i.e., efficient management of the imported shrimp stock at that time), or to failure in the establishment of self-reproducing copepod populations in the local environment from released propagules. However, it must be stressed that results of coastal and estuarine zooplankton surveys in Bahia State have not been published during the last 20 years, thus hampering our ability to follow a potential invasive process in that region. It would be highly desirable in future studies to expand the sampling coverage towards southern areas, at least from Rio Grande do Norte to Bahia.

If our southernmost records of *Pseudodiaptomus trihamatus* are in fact related to a secondary introduction at the Canguaretama site in 1985, then the present expansion of the species towards the northwest could be alternatively ascribed to this southern population, because the Potengi River population has not been tracked by time-series sampling in estuarine waters upon initial detection in

shrimp ponds. Molecular biology studies could help to answer whether the present *P. trihamatus* distribution in Northeast Brazil is due to a single “founder” population or to mixed “seed” populations introduced at different sites and periods. Many notorious invaders (e.g., the zebra mussel in North America) succeed because they have been introduced repeatedly to ideal habitats and have passed through both the ‘local dispersal’ and ‘environment survival and reproduction’ filters [*sensu* Colautti & MacIsaac (2004)].

Other *Pseudodiaptomus* species occurred simultaneously with *P. trihamatus* during our survey (Table 1), the most frequent of which was *P. acutus* (F. Dahl, 1894) (found at 15 sites), followed by *P. marshi* Wright, 1936 (11 sites) and *P. richardi* (F. Dahl, 1894) (1 site). Males and females were recorded in all localities. Lower salinity ranges for the genus were relatively similar (18 to 23 psu) in all sampling sites, but maximum salinity values differed widely

(Table 1). This result suggests that at least three *Pseudodiaptomus* species (*P. marshi*, *P. acutus* and mainly *P. trihamatus*) are able to survive and even reproduce (based on presence of ovigerous females) in hypersaline waters (up to 70 psu, in the case of *P. trihamatus*). *Pseudodiaptomus richardi* occurred only in the Potengi River estuary during our study, in a narrowed salinity interval not necessarily representative of its natural distribution in Brazilian estuaries (Almeida-Prado Por & Lansac-Tôha, 1984; Lopes, 1994). Tolerance of *P. trihamatus* to a wide range of salinities seems to confer an additional benefit for successful dispersion of the species in the Northeast coast of Brazil, where artificial salts ponds have been established for both salt and *Artemia* production (Camara, 1996). Exotic species that are able to survive and disperse are usually highly tolerant to environmental challenges, a competitive advantage over native species (Arthington, 1991).

Fig. 2. *Pseudodiaptomus trihamatus*, males and females (A-D), and *P. marshi* (D, left specimen). A and B = 5th legs (L5) of a *P. trihamatus* male. C = adult male; arrows show protozoan ectoparasites (Ciliophora, Peritrichida). D = ovigerous females; arrows show crustacean parasites (Isopoda, Epicaridea). Magnification 400 x in A and B, 100 x in C, 40 x in D.

Table 1. Sampling sites and periods, salinity data (for either estuarine or coastal waters) and presence of parasites on adult *Pseudodiaptomus* spp. recorded on the Northeastern Brazilian coast. Presence of copepods is indicated by + and absence by –

Sampling site	Site number on Figure 1	Years	Sampled species				Salinity	Parasites on <i>P.</i> <i>trihamatus</i>
			<i>P. trihamatus</i>	<i>P. marshi</i>	<i>P. acutus</i>	<i>P.</i> <i>richardi</i>		
Natal	5	2001	+	+	+	+	23 – 34	Protozoa
Macau	2	2002	+	+	+	-	39	-
Diogo Lopes	3	2002	+	+	+	-	42	-
Galinhos (salt pond)	4	2002	+	-	-	-	70	-
G. Avelino	6	2002 & 2003	+	+	-	-	18 – 36	Isopoda
Canguaretama	7	2002 & 2003	+	+	+	-	25 – 35	Protozoa
Galinhos (downstream)	4	2002 to 2004	+	+	+	-	36	Isopoda
Tibau	1	2003	+	+	+	-	36	-
Baia Formosa	8	2003	-	-	+	-	35	-
Sagi	9	2003	-	-	+	-	35	-
B. da Traição	10	2003	-	-	+	-	34	-
Tamandaré	11	2003	-	-	+	-	-	-
Aracati	12	2004	+	+	+	-	33	Protozoa and Isopoda
Fortaleza ²	13	2004	+	+	+	-	34	-
Galinhos (upstream ¹)	4	2005	+	-	-	-	42	-
Barroquinha ³	14	2005	+	-	-	-	48	Protozoa
Luís Correia	15	2005	-	+	+	-	30	-
São José do Ribamar	16	2005	-	+	+	-	34	-
Carutapera	17	2005	-	+	+	-	33	-

¹ About 7 km upstream from the coast

² Only 2 specimens of *P. trihamatus* found

³ Sample taken from a marine shrimp pond

Our sampling effort has not been designed to identify potential ecological impacts of *Pseudodiaptomus trihamatus* upon other planktonic species. Therefore, we suggest this exotic copepod should be classified as an established species (*sensu* Williamson & Fitter, 1996), and not as a typical invader [because the latter category implies that some sort of impact is being infringed by the introduced species] until quantitative abundance data and other relevant ecological information is gathered.

Sampling sites where ectoparasites occurred on *Pseudodiaptomus* spp. are indicated in Table 1. Parasitism by epicarid isopods was rare, both in terms

of sampling sites and number of infected individuals. On the other hand, peritrichid ciliates were detected on several copepods (Fig. 2), and interestingly only in estuarine waters. Previous observations (G. F. Medeiros, unpublished data) showed that *P. trihamatus* collected in shrimp ponds from EMPARN in 1979 were highly infested by the same protozoans, which might suggest a preferential symbiosis between the two species and even a potential “tertiary” introduction of an exotic peritrichid.

In addition to our observations in Piauí and Maranhão States, where the exotic copepod has not been recorded, recent zooplankton studies performed

in the vicinities of the Amazon River mouth also failed to detect the species (Magalhães, 2003; Krumme & Liang, 2004). Nevertheless, the expansion of the distributional range of *Pseudodiaptomus trihamatus* on the North and Northeast coasts of Brazil seems to be an undergoing process, with a potential dispersion trend towards the direction of the Amazon River mouth because of the prevailing northwestward currents. Such scenario demands a long-term monitoring program of exotic planktonic organisms in the region, if we want to understand and develop management practices to control their potential impacts on native aquatic species.

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