BJOCE

Differences in the distribution and abundance of Teredinidae (Mollusca: Bivalvia) along the coast of Rio de Janeiro state, Brazil

Gustavo Carvalho Maldonado[1], *Luis Felipe Skinner*[1]*

[1] Departamento de Ciências, Laboratório de Ecologia e Dinâmica Bêntica Marinha, Universidade do Estado do Rio de Janeiro.
(Rua Dr. Francisco Portela, 1470, sala 172, São Gonçalo, RJ, Brasil)

*Corresponding author: lskinner@uerj.br

ABSTRACT

Teredinidae are wood-boring mollusks found in marine and estuarine regions. Evaluation of the distribution and abundance of Teredinidae is a very important task, as the impact of the destruction of wood in man-made structures is still underestimated, mainly in tropical regions. It is also know that temperature and salinity are key factors affecting the abundance and activity of Teredinidae due to their effects on the physiological responses of Teredinidae. The aim of this study was to evaluate the distribution and abundance of Teredinidae along the Rio de Janeiro coast according to temperature range and pattern. Artificial pine collectors were used and remained immersed for three months in four regions at 14 sites. We recorded seven species of Teredinidae, identified according to their pallets. Ilha Grande Bay was the region with the highest density and species richness, and the region with the lowest was Guanabara Bay. One gradient of abundance related to temperature was found. The most abundant species were *Lyrodus floridanus* and *Teredo furcifera*. Besides temperature, wood availability among regions was another important factor. For the first time, we recorded the occurrence of *Bankia destructa* on the Rio de Janeiro coast, but this record does not indicate any species introduction or expanding distribution range.

Descriptors: Shipworms, Coastal bays, Upwelling, Estuaries, Wood destruction.

RESUMO

Teredinidae são moluscos marinhos ou estuarinos perfuradores e degradadores de madeira. Avaliar sua distribuição e abundância se mostrou importante, uma vez que a destruição de madeira é ainda subestimada, sobretudo em regiões tropicais. Dados de literatura têm mostrado também que temperatura e salinidade são dois fatores que afetam fisiologicamente as espécies de Teredinidae. Os objetivos deste trabalho foram avaliar a distribuição e abundância de Teredinidae ao longo da costa do Rio de Janeiro, em relação ao padrão de temperatura e sua variação. Coletores artificiais de pinho foram imersos por três meses em 14 localidades em quatro regiões do estado. Sete espécies foram registradas e identificadas pela forma de suas palhetas. Os maiores valores de densidade e riqueza específica foram registrados na Baía da Ilha Grande e os menores, na Baía de Guanabara. Foi observado um gradiente na abundância relacionado à temperatura. As espécies mais abundantes foram *Lyrodus floridanus* e *Teredo furcifera*. Além da temperatura, a diferença na disponibilidade de madeira entre as regiões parece ser também um fator importante. Pela primeira vez registramos a ocorrência de *Bankia destructa* para o Rio de Janeiro, embora este registro não signifique introdução ou expansão de distribuição.

Descritores: Perfurantes de madeira, Baías costeiras, Ressurgência, Estuários, Destruição de madeira.

http://dx.doi.org/10.1590/S1679-87592016127806404

INTRODUCTION

Teredinidae wood-boring bivalves are specialized in cellulose degradation in marine environments. The main factors that affect their distribution and activity are cellulose (wood) availability (TURNER, 1966) and oceanographic conditions, mainly temperature and salinity (BORGES et al., 2014b; PATI et al., 2014). These conditions affect the survival (BARRETO et al., 2000) and also the activity of endosymbiont bacteria (DISTEL et al., 2002; HORAK; MONTOYA, 2014; TRINDADE-SILVA et al., 2009), thus also affecting the rate and amount of wood consumption.

The Brazilian coast can be divided into two biogeographical realms: the tropical Atlantic and the temperate South Atlantic (SPALDING et al., 2007). These realms are divided into provinces and ecoregions. The coast from Cabo Frio down to Paraná constitutes the ecoregion of southeastern Brazil, within the *warm temperate southwestern Atlantic* province. However, this classification includes several local, different oceanographic patterns that are not at all congruent with their classification as a single province, even when divided into several distinct ecoregions.

In the state of Rio de Janeiro, aside from its inclusion in the same ecoregion, there are various differences in oceanographic conditions, mainly related to temperature, freshwater input by rivers or rainfall, nutrient availability and large oceanographic phenomena such as gyres and upwelling (SIGNORINI, 1980; BARCELLOS et al., 1997; CREED et al., 2007; MOLISANI et al., 2004; SOARES-GOMES et al., 2016; VALENTIN, 2000).

Distribution studies of Teredinidae are concentrated mainly in Rio de Janeiro and São Paulo states, albeit using different methods. While in Rio de Janeiro the most common method is the use of artificial collectors (BARRETO et al., 2000; JUNQUEIRA et al., 1989; JUNQUEIRA et al., 1991; SILVA et al., 1988; VAROTTO; BARRETO, 1998), in São Paulo direct sampling in mangrove forests is common, despite some use of artificial collectors (LOPES; NARCHI, 1993; LOPES et al., 2000; MORAES et al., 2015). This leads to some differences in research results as regards the composition and abundance of species, beyond the effects of the differences in oceanographic conditions between regions. Only two studies have undertaken the evaluation of the distribution of Teredinidae over a wide range of habitats and geographical extent (JUNQUEIRA et al., 1989), from Paraty to the Cabo Frio region and BARRETO et al. (1993) from Vitória (Espírito Santo state) to São Sebastião (São Paulo state). Since them, no distribution study has been undertaken, despite several modifications in coastal structure and urban development and many impacts on marine biodiversity (AMARAL; JABLONSKI, 2005).

In recent years, due to several changes in environmental characteristics, the distribution and damage caused by Teredinidae have increased in some European areas, such as the Netherlands, with the introduction of species such as *Teredo navalis* Linnaeus, 1758 and *Lyrodus* sp. (BORGES et al., 2014a). For Brazil, until now, we have not recorded any recent introduction of Teredinidae.

In this study, we evaluate the distribution of Teredinidae along the Rio de Janeiro coast relating it to the pattern of Sea Surface Temperature (SST) as one indicator of differences in oceanographic conditions, since this variable is strongly correlated in Rio de Janeiro with upwelling, circulation, depth and the impact of humans on the ocean. We tested the hypothesis that SST could be a good indicator of differences in the composition and abundance of species. We also up-dated the list of species in the quest for possible species introductions or extinctions.

MATERIAL AND METHODS

Study region (Figure 1)

The Cabo Frio region is characterized by upwelling events, mainly during the spring and summer months. Usually, SST is under 20 °C and salinity is above 35 (SKINNER et al., 2011; VALENTIN, 2000). The annual rainfall is less than 900 mm (INEA, 2015). The bathymetry of the region shows greater depths close to the coast. The 50 and 100 m isobaths are located approximately 3 and 17 km, respectively, from the shore.

In the central region of the Rio de Janeiro coast, the hydrology of Guanabara Bay presents a seasonal variation, with a rainy summer and a dry winter. The tidal regime is also important for circulation and water exchange between the bay and the adjacent ocean. Thirty-five rivers flow into the bay, providing not only freshwater but also high levels of organic waste and industrial effluents. Guanabara Bay is one of the most eutrophic and polluted environments in the world (SOARES-GOMES et al., 2016; VALENTIN et al., 1999). The 50 and 100 m isobaths lie, respectively, 17 and 41 km from the shore. The maximum depth of

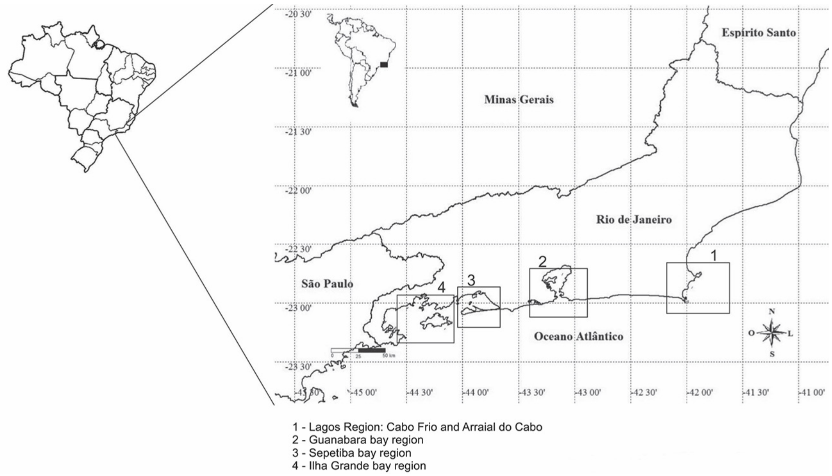

Figure 1. Map of the Rio de Janeiro state and the four studied regions indicating the indicating sampling sites: 1 - Lagos region (Cabo Frio and Arraial do Cabo); 2 - Guanabara bay; 3 - Sepetiba bay; 4 - Ilha Grande bay.

Guanabara Bay is approximately 25 m, close to the central channel (dredged).

Sepetiba Bay is a semi-enclosed shallow bay, with depths of less than 20 m (6 m on average), except in its navigation channels. Tidal currents are strong (50 to 75 $cm.s^{-1}$), precipitation is approximately 1,400 mm/year, with a rainy season from September through March and a dry season from April to August, corresponding to summer and winter, respectively. Pollutant levels, mainly of heavy metals, are high, but eutrophic conditions are found close to the main river discharges or densely populated regions (BARCELLOS et al., 1997; MOLISANI et al., 2004; SIGNORINI, 1980).

Ilha Grande bay consists of several coves and smaller bays, with numerous islands, mostly covered by lush vegetation, typical of the Atlantic Forest. On the mainland, immediately behind the coastal region, lies the Serra do Mar, also exuberantly covered by Atlantic Forest. This proximity increases the rainfall to values up to 2700 mm/year, with a rainy season in spring-summer and a dry season in autumn-winter. The Bay has warm (from 20 to 28 °C), calm waters (INEA, 2015). The water in this region is mainly oligotrophic, except close to large towns, where sewage treatment is insufficient, leading to an increase in organic contamination and the eutrophication of coastal waters (CREED et al., 2007; MAYER-PINTO; JUNQUEIRA, 2003; SKINNER et al., 2016).

Immersion of collectors

For the collection of wood-boring animals, we used artificial collectors made of commercial pine sheets (*Pinus elliotti*). According to SILVA et al. (1988) and JUNQUEIRA et al. (1991), this kind of collector facilitates the sampling, counting and identification of Teredinidae, and is inexpensive. Each collector was constructed from ten sheets of wood measuring 10.0 x 10.0 x 0.08cm, pressed by plastic tiles into sandwich form. The final volume of the available substrata was 80 cm^3.

Four collectors were immersed at each site at a depth of 1 m, remaining immersed for three months throughout the experiment, without being exposed to the air. This method was chosen because the Teredinidae settlement is more intensive in shallow waters (TURNER et al., 1985), and three months is the ideal time taken for individuals to grow to a size that permits their identification. Also, after three months, the available substrate is reduced, and high density and the competition for space and food increases Teredinidae mortality (JUNQUEIRA et al., 1991). The use of this method also permits us to compare our results with those obtained in previous experiments undertaken in Rio de Janeiro with the same method.

Simultaneously with the collector immersion, we immersed temperature sensors (iButton®) programmed to record the temperature of the water every hour to characterize the study sites thermally and to identify the direct and indirect influence of upwelling.

Immersion sites were determined in four regions of Rio de Janeiro state: Lagos Region, at Cabo Frio (22°52'37.29"S 42°01'09.22"W) and Arraial do Cabo (22°58'22.06"S 42°00'49.54"W), Guanabara Bay, at Praia Vermelha (22°57'23.43"S 43°09'47.33"W) and Urca (22°56'35.66"S 43°09'37.40"W), Sepetiba bay

(22°58’51.14”S 44°02’03.10”W), Ilha Grande Bay at Bracuy river estuary (22°56’58.51”S 44°23’51.06”W), Angra dos Reis (23°00’26.99”S 44°18’43.10”W), Piraquara de Fora, (23°01’00.67”S 44°27’38.22”W), Abraão (23°08’12.33”S 44°10’03.76”W) and Ponta Leste (23°03’09.80”S 44° 14’37.54”W). On the oceanic side of Ilha Grande, samples were collected at Ilha da Amarração (23°11’08.27”S 44°11’28.02”W) and in the estuarine region of Barra Grande River (23°11’8.37”S 44°11’28.06”W). A distance of approximately 280 km along the Rio de Janeiro coast was surveyed. All of these sites were chosen to include the various distinguishable oceanographic conditions existing in the state of Rio de Janeiro, in addition to other sites previously investigated by other authors (Figure 1).

Two samples were collected between May and August, 2012 at Ilha Grande bay at Abraão and Ilha da Amarração sites. The remaining samples were collected from September through December 2012, except at Cabo Frio, where the collectors remained immersed from November 2012 to February 2013. The reason for maintaining samples in some places at different times was to evaluate whether temporal variability at these sites has more influence on species distribution and abundance than the geographical/ regional scale.

Following their retrieval, the collectors were immersed in buckets of 95% analytical grade ethanol. In the laboratory, the buckets were opened and the collector sheets were opened one by one, like pages in a book, to remove, identify and count Teredinidae individuals. The identification of species was based on the shape and periostracum characteristics of pallets under a stereomicroscope, as described by the identification keys and illustrations in TURNER (1966, 1971), which are considered the most useful method of Teredinidae identification. In the case of *Lyrodus floridanus*, which is morphologically indistinguishable from *Lyrodus pedicellatus*, identification was based on the presence of late straight-hinge larvae (CALLOWAY, TURNER, 1983). During the second half of the 1980s, Dr. R.D. Turner confirmed that *Lyrodus* species found in samples from Rio de Janeiro corresponded to *L. floridanus* and not *L. pedicellatus* (SILVA et al., 1988). Photos of the pallets are provided in the results section.

The individuals of Teredinidae and other wood-boring groups were transferred to the Zoological Collection of the Departamento de Ciências of the Universidade do Estado do Rio de Janeiro (DCIEN/UERJ), where they were stored in a solution containing ethanol 96% and glycerine (MORAES et al., 2015).

Data Analysis

The total number of living and dead individuals of each species and the number of non-identified species due to their small size (recruits) were obtained from each collector.

Data on species abundance and richness were used to compare sites along the coast using the software PRIMER 6.0. Data were analysed by multivariate methods using the Bray-Curtis similarity index and a non-metric ordination plot (MDS) (CLARKE; GORLEY, 2006).

RESULTS

Sea Surface Temperatures (SST)

A total of 1653 temperature records obtained from iButton® sensors in each immersion site on the Rio de Janeiro coast were used. From these, a wide range of SST (Table 1), ranging from 13.5 °C in the Cabo Frio region (Forno Harbor) and Praia Vermelha up to 33.5 °C at Ilha Grande Bay (Piraquara) were recorded. The SST increased in minimum, maximum and average values from the Cabo Frio region (East) to Ilha Grande Bay (West). Mean water temperatures were higher than 20 °C at all sites but at Ilha Grande Bay they exceeded 25 °C.

Temperatures below 20 °C were only recorded at three sites: Forno Harbor, Praia Vermelha and Ilha da Amarração, indicating the effect of upwelling. At all the other sites, the temperatures were always above 20 °C. From Cabo Frio to Mangaratiba, temperatures between 20.0 and 24.5 °C were frequently measured. However, the sites in Ilha Grande bay were those which had the highest frequencies of temperatures above 30.0 °C, from 55 to 90.6% of the data. In some cases, such as that of Piraquara, the frequency of temperatures between 35.0 and 39.5 °C represented 27.2% of the measurements taken (Table 2).

Teredinidae and other wood-boring organisms

After three months, we recorded seven species of Teredinidae: *Teredo furcifera* MARTENS, 1894, *Teredo bartschi* CLAPP, 1923, *Lyrodus floridanus* (BARTSCH, 1922), *Bankia gouldi* (BARTSCH, 1908), *Bankia fimbriatula* MOLL and ROCH, 1931, *Bankia destructa* CLENCH and TURNER, 1946 and *Nototeredo knoxi* (BARTSCH, 1917). Two other species of wood-boring

Table 1. Mimimum, maximum, average and standard deviation of sea surface temperatures ºC recorded by Ibutton® sensors at the sites studied.

SITES	Canal de Itajuru	Porto do Forno	Ilha de Cabo Frio	Praia Vermelha	Mangaratiba	Ponta Leste	Angra dos Reis	Piraquara	Abraão	Ilha da Amarração
Min.	17.0	13.5	15.5	13.5	15.5	19.0	21.5	22.5	17.5	14.0
Max.	31.5	28.5	30.5	28.0	31.0	32.0	31.5	33.5	32.0	32.0
Average	23.8	21.7	23.3	20.2	23.1	25.4	26.7	28.8	25.0	24.5
Standard deviation	7.3	7.5	7.5	7.3	7.8	6.5	5.0	5.5	7.3	9.0

Table 2. Percentage of temperature values measured at each site using iButton® sensors programmed to sample at each hour of the day.

Temperatures ºC	Canal de Itajuru	Porto do Forno	Ilha de Cabo Frio	Praia Vermelha	Mangaratiba	Ponta Leste	Angra dos Reis	Piraquara	Abraão	Ilha da Amarração
13.5 - 19.5	0.0	2.5	0.0	2.7	0.0	0.0	0.0	0.0	0.0	1.5
20.0 - 24.5	11.3	35.2	13.0	48.8	16.5	2.1	0.0	0.0	9.1	17.0
25.5 - 29.5	58.6	42.4	64.5	46.9	58.0	37.1	31.1	9.4	35.8	26.5
30.5 - 34.5	29.6	19.9	22.1	1.6	25.5	59.8	65.5	63.4	53.0	53.1
35.5 - 39.5	0.5	0.0	0.4	0.0	0.1	1.0	3.5	27.2	2.1	2.0

organisms were also recorded: Pholadidae *Martesia striata* (LINNAEUS, 1758) and the Crustacea - Limnoriidae *Limnoria tripunctata* (MENZIES, 1951). For Teredinidae, photos of the pallets of the main species are provided in Figure 2 for illustrative purposes.

Species composition, richness and abundance varied according to the region studied (Table 3). The most conspicuous species was *Lyrodus floridanus*, recorded at 13 of the 14 experimental sites. The second most frequent species was *Teredo furcifera*, recorded at 7 of the 14 sites.

The region with the highest richness was Ilha Grande Bay, while Forno Harbor and Urca only recorded one and two species, respectively. The same pattern was recorded for the total number of individuals, with the highest values at many sites in Ilha Grande Bay, and the lowest, at Cabo Frio, in Guanabara Bay and in the Mangaratiba region. The Urca site presented the lowest abundance and richness of Teredinidae throughout the experiment - only three individuals - in contrast to the Barra Grande River, with 230 individuals recorded and four species identified (Table 3).

Except for the Barra Grande site in which *T. furcifera* was the dominant species, in all other sites, the comparative abundance of *L. floridanus* was not reduced, even in the case where the dominant species was another, such as *B. gouldi* at the Abraão site or *T. furcifera* at Bracuy.

Three sites recorded the highest number of species: Bracuy, Piraquara de Fora and Angra dos Reis, with five species each. The abundance was quite similar at all of

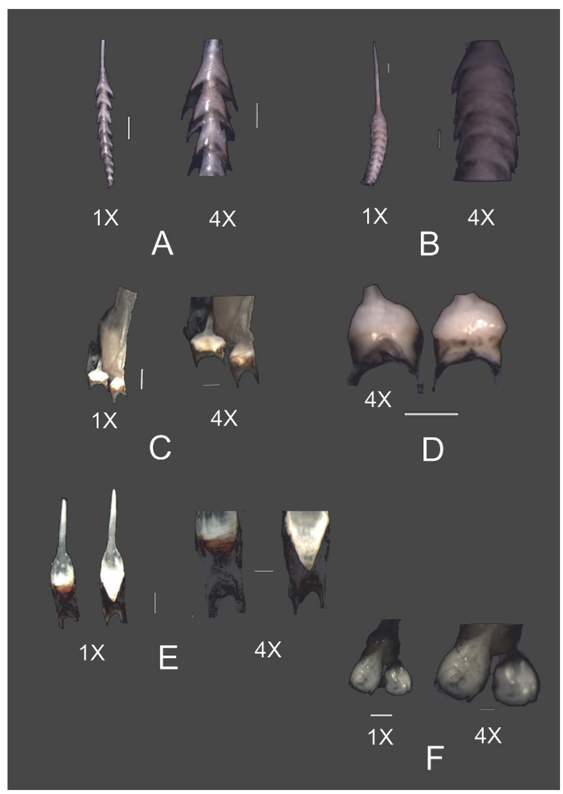

Figure 2. Pallets of main Teredinid species found during the study. A) *Bankia fimbriatulla* 1X and 4X; B) *Bankia gouldi* 1X and 4X; C) *Teredo furcifera* 1X and 4X; *Teredo bartschi* 4; D) *Lyrodus floridanus frontal* and back view, 1X and 4X; *Nototeredo knoxi*, frontal and back view, 1X and 4X. Scale bars: 1X: 1.0mm; 4X: 0.5 mm

Table 3. Total number of individuals of Teredinidae for species, number of species and total number of all individuals in all collectors at sites studied

SITES	*Teredo furcifera*	*Teredo barstchi*	*Lyrodus floridanus*	*Bankia gouldi*	*Bankia fimbriatula*	*Bankia destructa*	*Nototeredo knoxi*	Number of species	Total Number of all individuals
Canal de Itajuru	5		3	2				3	10
Porto do Forno			14					1	14
Praia Vermelha			4	4				2	8
Urca			1		2			2	3
Mangaratiba	1		7	10			1	4	19
Rio Bracuy	48	1	30		6		1	5	86
Angra dos Reis	14		37	15	19		1	5	86
Piraquara de Fora	9		136	21	8		1	5	175
Abraão II			70	93				2	163
Ponta Leste	1		90	13			1	4	105
Abraão I			70	23	1			3	94
Ilha da Amarração I			23	6		1		3	30
CEADS - Dois Rios (rio Barra Grande)	212	13		4	1			4	230
Ilha da Amarração II			9	4				2	13
Total for each site	290	14	494	195	37	1	5		

these sites, but Piraquara, the warmest site in our study recorded twice as many individuals as the other two sites.

One species, *Bankia destructa* was only recorded at one site, Ilha da Amarração, during the first run of the experiment.

Multiparametric analysis using the Bray-Curtis index and the graphic plot of MDS (Figure 3) revealed two groups: the first one grouped the sites on the inner side of Ilha Grande Bay (Bracuy, Piraquara, Angra dos Reis, Ponta Leste and Abraão). The second group joined the sites from the Cabo Frio region, Mangaratiba and the sites located on the oceanic side of Ilha Grande (Ilha da Amarração). Two sites were plotted away from these groups: Urca and Barra Grande river, due to the reduced number of individuals or the dominance of *T. furcifera*. The sites where samples were collected in different seasons, Ilha da Amarração and Abraão, were plotted close to each other, indicating that differences between regions are greater than those between seasons.

DISCUSSION

The SST range recorded at all locations agrees with the pattern of the transitional biogeographical boundaries between tropical and warm temperate regions as described by SPALDING et al. (2007) and indicated by many other investigators of Mollusca (ABSALÃO, 1989; FLOETER; SOARES-GOMES, 1999). This region is characterized by the influence of summer upwelling events, mainly in the Cabo Frio region, but its influence could even reach as far as Ilha Bela, in São Paulo state, as its southernmost location (CASTELAO; BARTH, 2006; CERDA; CASTRO, 2014). The highest SST was recorded close to the opening of the cooling system discharge of Alvaro Alberto nuclear power plant, located at Piraquara. That discharge changes SST and affects fouling (MAYER-PINTO et al., 2012) and fish (TEIXEIRA et al., 2012) communities. Only one experiment has ever been conducted on Teredinidae there - that by CURBELO-FERNANDEZ, but the data are to be found in an unpublished MS. Dissertation. The high values of SST found in Ilha Grande and Sepetiba bays are due to their confined and shallow waters and are a constant phenomenon, especially during the summer months (CREED et al., 2007). At the most oceanic site (Ilha da Amarração), the influence of upwelling is stronger than at the more coastal sites.

The pattern of SST presents its lowest values at Cabo Frio and in the proximity of Rio de Janeiro, the highest values occurring at Sepetiba and in Ilha Grande Bay. Although all the sites could be included within the same geographical boundary as delineated by SPALDING et al. (2007), differences in SST are evident. These results are different from those registered by JUNQUEIRA;

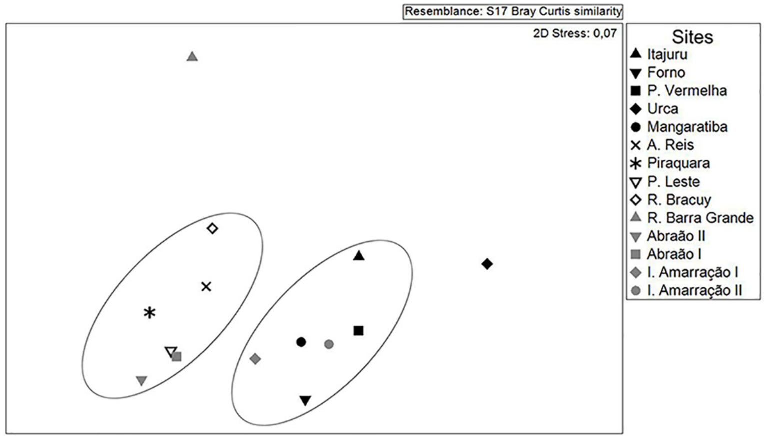

Figure 3. nMDS plot based on Bray-Curtis matrix of Teredinidae species abundance among all investigated sites along the Rio de Janeiro coast. The most similar sites (>70% resemblance) are circled.

SILVA et al. (1989) and BARRETO et al. (1993) who found warmer waters in northern sites than in southern sites. This difference could be attributed to the method of monitoring SST, since we used a high frequency of data acquisition. This gave more detailed evidence of the differences in SST between the study sites.

Teredinids

Of the 68 known species of Teredinidae, 16 have been recorded on the Brazilian coast, 14 of which on the Rio de Janeiro coast. In our results, all these species recorded on the Brazilian coast, were registered with no invasion detected (JUNQUEIRA et al., 1989; LOPES; NARCHI, 1993; MÜLLER; LANA, 1986). However, *Bankia destructa* has never been attributed in a published paper to the Rio de Janeiro coast (SILVA et al., 1988; JUNQUEIRA et al., 1989; BARRETO et al., 1993); though many monographs and dissertations have registered its presence there (personal observation). In São Paulo state, many authors have recorded its presence. Therefore, this record may be considered its first official record in the state of Rio de Janeiro, thus increasing the number of known species for the state to 15.

Comparing species richness to that given by other previous studies on the Rio de Janeiro coast (Table 4), JUNQUEIRA et al. (1989) found a higher richness at almost all similar sites, except Mangaratiba (same number) and Urca (lower). BARRETO et al. (1993) found a greater richness only for Forno Harbor, equal to that of Angra dos Reis (five species) and lower than that of Mangaratiba and Urca. Other studies conducted on Teredinidae in Rio de Janeiro at Angra dos Reis and surroundings (SILVA et al., 1988; VAROTTO; BARRETO, 1998) revealed similar species richness and composition, indicating that in the last 20 years, no changes in these biological indicators have occurred. We found records of two species in JUNQUEIRA et al. (1989), with no records in the recent literature: *Teredo navalis* and *Lyrodus massa*. These could be past or current misidentifications or could indicate changes in environmental characteristics. *T. navalis* has recently been investigated using DNA barcoding, comparing populations of Europe and the east coast of the USA, confirming the similarity of the two populations but the available information does not enable us to give further answers on this widespread species (WEIGELT et al., 2016). We need to verify whether samples of *T. navalis* are available in any scientific collection in Brazil and examine the specimens in more detail to confirm its presence or absence in Brazilian waters.

In other studies dealing with the geographical distribution of Teredinidae (BARRETO et al., 1993; JUNQUEIRA et al., 1989), Ilha Grande bay is the region with the highest density of individuals and this density decreases progressively towards the more northerly sites of Rio de Janeiro. Species richness follows the same pattern, with an increase in the number of species towards Ilha Grande Bay. Despite the number of eight species found in the Itajuru channel by JUNQUEIRA et al. (1989), no other data reported in published papers or unpublished monographs support this high richness.

Concerning specific composition and dominance, *Lyrodus floridanus* and *Teredo furcifera* have previously been recorded as dominant species throughout the state of Rio de Janeiro (JUNQUEIRA et al., 1989; OMENA et al.,

Table 4. Teredinidae species richness reported by some studies in Rio de Janeiro.

	Present work	Martins Silva et al., 1988	Junqueira et al., 1989	Skinner et al., 1991	Barreto et al., 1993	Varotto & Barreto, 1998
Canal de Itajuru	3		8			
Porto do Forno	1				3	
Praia Vermelha	2					
Urca	2		1		0	
Mangaratiba	4		4	5*	3	
Bracuy river	5					
Angra dos Reis	5		8*		5*	5*
Piraquara de Fora	5		7			
Abraão II	2					
Ponta Leste	4	6**	8**			
Abraão I	3					
Ilha da Amarração I	3					
Barra Grande river	4					
Ilha da Amarração II	2					

* Collectors immersed in different locations but in the same region.

** Portogalo site, close to Ponta Leste.

1990; BARRETO et al., 1993; SKINNER et al., 1994), with some exceptions. Both species have been recognized as dominant in Ilha Grande Bay (JUNQUEIRA et al., 1989; OMENA et al., 1990), with the dominance of *L. floridanus*. However, in VAROTTO; BARRETO (1998) and in two estuarine regions in the present study (Barra Grande and Bracuy rivers), the dominant species is *Teredo furcifera* and BARRETO et al. (1993) found *Bankia gouldi* to be the dominant species. The latter study was conducted at the same site as that of VAROTTO and BARRETO (1998), but our study sites did not include this exact location. This suggests that the high environmental heterogeneity of Ilha Grande Bay (CREED et al., 2007) implies differences in the dominant species according to location. Estuaries such as Sepetiba Bay, Bracuy and Barra Grande rivers could be dominated either by *Teredo furcifera* or *Bankia fimbriatulla*, according to salinity levels, while more oceanic waters are characterized by *Bankia gouldi*, a typical marine species, considered steno-haline (MÜLLER; LANA, 1986). This has already been set out for Rio de Janeiro by JUNQUEIRA et al. (1989) and by SKINNER et al. (1994).

In Guanabara bay, the occurrence of Teredinidae is controlled by biofouling coverage (SILVA et al., 1980; 1989; JUNQUEIRA et al., 1989), which prevents the colonization of wood or could compete for space, preventing Teredinidae water changes and respiration. Previous works conducted in Guanabara Bay at the Urca site have highlighted this competition as well as the influence of organic matter pollution on biofouling coverage (SILVA et al., 1980; 1989; JUNQUEIRA et al., 1989; JUNQUEIRA et al., 1991; BARRETO et al., 1993; OMENA; SOUZA, 1999). In our experience, this result was reinforced mainly by the occurrence of the higher density at the Praia Vermelha site compared with that at Urca. These sites have similar fouling cover but with some differences in the main foulers (Ascidians x Briozoans/Barnacles/Serpulid polychaetes) and differences in the effects of pollution.

In the Cabo Frio region, two sites have historically been investigated: those of the Itajuru Channel and Arraial do Cabo. Both sites, despite their location in the same biogeographical region, have particular environmental characteristics. The Itajuru Channel connects the ocean to a hypersaline lagoon (Lagoa de Araruama), in which salinity could reach 60 units. Arraial do Cabo is influenced by the ocean (SKINNER et al., 2012) and seasonal upwelling (VALENTIN, 2000). Thus, specific composition could be variable over time, but no study has been performed there with time (season) as a factor.

One of the most important and crucial resources for Teredinidae is the wood substrate. The availability of this material has been associated with both species richness and abundance. Along the Rio de Janeiro coast, we found one clear gradient in the abundance of wood. In the region of Ilha Grande Bay, as far as Guanabara Bay, the Dense Ombrophylous Forest (Atlantic Rainforest) is located close to the shore. From Guanabara Bay to the northern sites, the vegetation changes from rain forest to the drier forests more subject to marine influence called “restingas”. Accompanying this change in vegetation structure, the availability of wood input to the ocean decreases and Teredinidae diversity follows this reduction.

Two other important environmental characteristics for Teredinidae distribution and abundance are temperature and salinity. Despite their importance, their precise measurement varies locally and its influence on Teredinidae behaviour, physiology, richness and abundance is still insufficiently described (BORGES et al., 2014b). Salinity has not been measured in our present study. However, the extremely high variation in this variable, mainly in estuaries during tidal changes or during dry or rainy events, does not permit adequate monitoring without access to real-time data, as we used for temperatures. Our collectors remained immersed in stratified estuaries (Brachuy and Barra Grande), close to the bottom where the marine influence is greater (DAME; ALLEN, 1996).

Experiments conducted by BARRETO et al. (2000) show that salinities over 21 do not significantly increase the mortality rate. However, salinities ranging from 14 to 7 could reach up to 100%. They also demonstrated that the most sensitive species were *Teredo furcifera* and *Lyrodus floridanus,* respectively, while *Bankia fimbriatula* was the most tolerant. This species was indicated by MÜLLER; LANA (1986) as occurring in mangrove or marine environments.

During the undertaking of our study, one extremely dry season was recorded during 2012 and 2013. For example, in the year 2010, the annual rainfall at Sepetiba was 1,448.8 mm with a monthly mean of 120.7 mm. In 2012, the annual rainfall was 863.4 mm and the monthly mean 72.0 mm and in 2013, 1,075.0 mm with a mean of 89.6 mm (D’ORSI et al., 2010; D’ORSI et al., 2012; D’ORSI et al., 2013). This could explain the increase in the dominance of *B. goudi* in Sepetiba bay due to an increase in salinity, favoring this species. Despite the absence of salinity data, our temperature records could relate the abundance of this group to the sites/regions studied, higher densities being found in warmer waters, even when salinity is disregarded (e.g., inside estuaries).

The life history of Teredinidae (TURNER, 1985; MANN; GALLAGER, 1985a, b; BORGES et al., 2014a) could also have important influence on the abundance of collectors. Besides larviparous species such as of those *Lyrodus floridanus* and *Teredo furcifera* that could colonize the available substrates almost at the moment of larval release, oviparous species such as *Bankia* spp. have great persistence on plankton, providing long dispersal and lower density on wood substrates.

Experiments on Teredinidae on the Rio de Janeiro coast were begun in the 1980s by SILVA et al. (1980). Many undergraduate and graduate studies were performed but few of them were published and many remain unpublished, making temporal or geographical comparisons difficult.

Our results provide no data indicating changes in composition or in the abundance of species in the state of Rio de Janeiro. Thus also no new species or introduced species were recorded. According to several authors (CULHA, 2010; ILJIN, 2010; PAALVAST; VAN DER VELDE, 2011; BORGES; COSTA, 2014a; BORGES et al., 2014a; BORGES et al., 2014c), many Teredinidae species are expanding their distribution ranges due to global warming or by human transportation in ballast waters or associated with wooden structures. However, due to the very sparse information about Teredinidae, not only in the state of Rio de Janeiro but also along the Brazilian coast as a whole, we have no information on this issue. Further, we have no information regarding species composition before the XIV century voyages of discovery or the possible introduction of Brazilian teredinid fauna by wooden sailing vessels, as occurred worldwide (NAIR; SARASWATHY, 1971; RAYES et al., 2015).

There are important aspects of our current knowledge of this group on the Brazilian coast. The first one is the almost complete absence of wooden boats undertaking long oceanic journeys, especially between different biogeographical regions, which would have made the transport of species and the potential introduction of species possible. Wooden boats are still used by fisherman, but voyages are normally limited to a small area within the same region. The second aspect is the destruction of the coastline, mainly of mangrove and adjacent forests, which would reduce the availability of wood and the abundance of natural populations of Teredinidae and consequently, affect the larval pool with a reflection on the adult population. The third factor, still underestimated, is the impact of climate change on the distribution and abundance of Teredinidae. If the water temperature increases, the abundance and rate of the destruction of wood could increase at a rapid pace. Our results regarding Teredinidae abundance in the region under the influence of the cooling system of the nuclear power plant at Piraquara had the second highest value, indicating that temperatures over 28 °C could increase the overall abundance of individuals. All these aspects call for attention in ecological studies, especially in studies seeking to assess aspects of environmental conditions with regard to the physiology of Teredinidae and their symbiont.

ACKNOWLEDGMENTS

The authors would like to thank FAPERJ (Proc. E-26/110.838/2013 e E-26/111.454/2011) for their financial support and also the UERJ for the scholarships granted to GCM and LFS. We would also like to express our gratitude to the institutions that authorized our study: Porto do Forno (Arraial do Cabo), Capitania dos Portos de Cabo Frio, Estação Ecológica de Tamoios, Parque Estadual da Ilha Grande/INEA, CEADS-UERJ and Roca Engenharia. Research authorization was granted under INEA Nº 057/2011 and SISBio Nº 36194-1.

REFERENCES

ABSALÃO, R. S. Distribution patterns and zoogeography of the mollusks from the Brazilian continental shelf: Part III. Oceanographic Expedition Espirito Santo I. Mem. Inst. Oswaldo Cruz, Rio de Janeiro, v. 84, n. Supl. 4, p. 1-6, 1989.

AMARAL, A. C. Z.; JABLONSKI, S. Conservation of Marine and Coastal Biodiversity in Brazil. Conserv. Biol., v. 19, n. 3, p. 625-631, 2005.

BARCELLOS, C.; DE LACERDA, L. D.; CERADINI, S. Sediment origin and budget in Sepetiba Bay (Brazil) - an approach based on multielemental analysis. Environ. Geol., v. 32, n. 3, p. 203-209, 1997.

BARRETO, C. C.; JUNQUEIRA, A. O. R.; SILVA, S. H. G. The effect of low salinity on teredinids. Braz. Arch. Biol. Technol., v. 43, p. 399-407, 2000.

BARRETO, C. C.; SILVA, S. H. G.; LAVRADO, H. P. Distribution of teredinids along the Southeast coast of Brazil. Oebalia J. Mar. Biol. Ocean., v. 19, p. 155-162, 1993.

BORGES, L. M.; COSTA, F. New records of marine wood borers (Bivalvia: Teredinidae and Isopoda: Limnoriidae) from São Miguel, Azores, with a discussion of some aspects of their biogeography. Açoreana, v. 10, n. supl., p. 109-116, 2014a.

BORGES, L. M. S.; SIVRIKAYA, H.; CRAGG, S. M. First records of the warm water shipworm *Teredo bartschi* Clapp, 1923 (Bivalvia, Teredinidae) in Mersin, southern Turkey and in Olhão, Portugal. Bioinvasion Rec., v. 3, n. 1, p. 25-28, 2014b.

BORGES, L. M. S.; MERCKELBACH, L. M.; SAMPAIO, I.; CRAGG, S. M. Diversity, environmental requirements, and biogeography of bivalve wood-borers (Teredinidae) in European coastal waters. Front. Zool., v. 11, n. 1, p. 13, 2014c.

CALLOWAY, C. B.; TURNER, R. D.; 1983. Documentation and implications of rapid successive gametogenic cycles and broods in the shipworm *Lyrodus floridanus* (Bartsch) (Bivalvia, Teredinidae). Journal of Shellfish Research 3: 65-69

CASTELAO, R. M.; BARTH, J. A. Upwelling around Cabo Frio, Brazil: The importance of wind stress curl. Geophys. Res. Lett., v. 33, n. 3, p. 1-4, 2006.

CERDA, C.; CASTRO, B. M. Hydrographic climatology of South Brazil Bight shelf waters between Sao Sebastiao (24ºS) and Cabo Sao Tome (22ºS). Cont. Shelf Res., v. 89, p. 5-14, 2014.

CLARKE, K. R.; GORLEY, R. N. PRIMER v6: User Manual/Tutorial. Plymouth: PRIMER-E, 2006.

CREED, J. C.; PIRES, D. O.; FIGUEIREDO, M. O. Biodiversidade marinha da Baía da Ilha Grande. Brasília: MMA, 2007. 416 p.

CULHA, M. The presence of *Teredo navalis* Linnaeus, 1758 (Mollusca, Bivalvia, Teredinidae) in the Southern Black Sea, Turkey. J. Anim. Vet. Adv., v. 9, n. 10, p. 1515-1518, 2010.

D'ORSI, R. N.; PAES, N. M.; MAGALHÃES, M. A.; COELHO, R. S. Relatório anual de chuvas 2010. Diretoria de estudos e projetos. Gerência de programas especiais. Sistema alerta Rio. Prefeitura do Rio de Janeiro. 2010. Available at: <http://alertario.rio.rj.gov.br/upload/rel2010.zip>. Acessed: 10 fev 2016.

D'ORSI, R. N.; PAES, N. M.; MAGALHÃES, M. A.; COELHO, R. S.; COSTA, L. C. Relatório anual de chuvas 2012. Diretoria de estudos e projetos. Gerência de programas especiais. Sistema alerta Rio. Prefeitura do Rio de Janeiro. 2012. Available at: <http://alertario.rio.rj.gov.br/upload/rel2012.zip>. Acessed: 10 fev 2016.

D'ORSI, R. N.; PAES, N. M.; MAGALHÃES, M. A.; COELHO, R. S; SILVA JUNIOR, L. R.; CARNEIRO, T. S.; COSTA, L. C. Relatório anual de chuvas 2013. Diretoria de estudos e projetos. Gerência de programas especiais. Sistema alerta Rio. Prefeitura do Rio de Janeiro. 2013. Available at: <http://alertario.rio.rj.gov.br/upload/rel2013.pdf>. Acessed: 10 fev 2016.

DAME, R. F.; ALLEN, D. M. Between estuaries and the sea. **J.** Exp. Mar. Bio. Ecol., v. 200, n. 1-2, p. 169-185, 1996.

DISTEL, D. L.; MORRILL, W.; MACLAREN-TOUSSAINT, N.; FRANKS, D.; WATERBURY, J. *Teredinibacter turnerae* gen. nov., sp. nov., a dinitrogen-fixing, cellulolytic, endosymbiotic gamma-proteobacterium isolated from the gills of wood-boring molluscs (Bivalvia: Teredinidae). Int. J. Syst. Evol. Microbiol., v. 52, n. Pt 6, p. 2261-2269, 2002.

FLOETER, S. R.; SOARES-GOMES, A. Biogeographic and Species Richness Patterns of Gastropoda on the Southwestern Atlantic. Rev. Bras. Biol., v. 59, n. 4, p. 567-575, 1999.

HORAK, R. E. A.; MONTOYA, J. P. Growth, nitrogen fixation, respiration, and a nitrogen budget for cultures of a cosmopolitan diazotrophic endosymbiont (*Teredinibacter turnerae*) of shipworms. J. Mar. Biol. Assoc. UK., v. 94, n. 1, p. 177-185, 2014.

ILJIN, I. N. Known and possible invasions of marine mollusks of the families Teredinidae and Pholadidae (Bivalvia) in the waters of Russia and adjacent countries. Russ. J. Biol. Invasions, v. 1, n. 2, p. 74-80, 2010.

INSTITUTO ESTADUAL DO AMBIENTE (INEA). Diagnóstico do setor costeiro da Baía da Ilha Grande: subsídios à elaboração do zoneamento ecológico-econômico costeiro. Rio de Janeiro: Instituto Estadual do Ambiente, 2015.

JUNQUEIRA, A. O. R.; OMENA, E. P.; SILVA, S. H. G. A comparative study of the methods used to evaluate the activity of Teredinidae molluscs. J. Exp. Mar. Bio. Ecol., v. 150, n. 1, p. 107-115, 1991.

JUNQUEIRA, A. O. R.; SILVA, S. H. G.; SILVA, M. J. M. Avaliação da infestação de Teredinidae (Mollusca - Bivalvia) ao longo da costa do estado do Rio de Janeiro, Brasil. Mem. Inst. Oswaldo Cruz, v. 84, n. Supl 4, p. 275-280, 1989.

LOPES, S. G. B. C.; DOMANESCHI, O.; DE MORAES, D. T.; MORITA, M.; MESERANI, G. D. L. C. Functional anatomy of the digestive system of *Neoteredo reynei* (Bartsch, 1920) and *Psiloteredo healdi* (Bartsch, 1931) (Bivalvia: Teredinidae). Geol. Soc. London, Spec. Publ., v. 177, n. 1, p. 257-271, 2000.

LOPES, S. G. B. C.; NARCHI, W. Levantamento e distribuição das espécies de Teredinidae (Mollusca-Bivalvia) no manguezal da Praia Dura, Ubatuba, São Paulo, Brasil. Bol. Inst. Oceanogr. São Paulo, v. 41, n. 1/2, p. 29-38, 1993.

MANN, R.; GALLAGER, S. M. Growth, morphometry and biochemical composition of the wood boring molluscs *Teredo navalis* L., *Bankia gouldi* (Bartsch), and *Nototeredo knoxi* (Bartsch) (Bivalvia: Teredinidae). J. Exp. Mar. Biol. Ecol., v. 85, n. 3, p. 229-251, 1985a.

MANN, R.; GALLAGER, S. M. Physiological and biochmicalenergetics of larvae of *Teredo navalis* L. and *Bankia gouldi* (Bartsch) (Bivalvia: Teredinidae). J. Exp. Mar. Biol. Ecol., v. 85, n. 3, p. 211-228, 1985b.

MAYER-PINTO, M.; IGNACIO, B. L.; SZÉCHY, M. T. M.; VIANA, M. S.; CURBELO-FERNANDEZ, M. P.; LAVRADO, H. P.; JUNQUEIRA, A. O. R.; VILANOVA, E.; SILVA, S. H. G. How much is too little to detect impacts? A case study of a nuclear power plant. PloS ONE, v. 7, n. 10, p. e47871, 2012.

MAYER-PINTO, M.; JUNQUEIRA, A. O. R. Effects of organic pollution on the initial development of fouling communities in a tropical bay, Brazil. Mar. Pollut. Bull., v. 46, n. 11, p. 1495-1503, 2003.

MOLISANI, M. M.; MARINS, R. V.; MACHADO, W.; PARAQUETTI, H. H. M.; BIDONE, E. D.; LACERDA, L. D. Environmental changes in Sepetiba Bay, SE Brazil. Reg. Environ. Change, v. 4, n. 1. p. 17-27, 2004.

MORAES, D. T.; COELHO JR, C.; CRUZ, R. C. G.; LOPES, S. G. B. C. Ocorrência e recrutamento larval de Teredinidae (Mollusca, Bivalvia) na região do Sistema Costeiro Cananéia-Iguape, São Paulo, Brasil. Iheringia, Sér. Zool., v. 105, n. 1, p. 28-34, 2015.

MÜLLER, A. C. P.; LANA, P. C. Teredinidae (Mollusca: Bivalvia) do litoral do Paraná, Brasil. Neritica, v. 1, n. 3, p. 27-48, 1986.

NAIR, N. B.; SARASWATHY, M. The biology of wood-boring Teredinid molluscs. Adv. Mar. Biol., v. 9, p. 335-509, 1971.

OMENA, E. P.; JUNQUEIRA, A. O. R.; SILVA, S. H. G. Resistência de Teredinidae Rafinesque, 1815 (Mollusca: Bivalvia) a diferentes períodos de exposição ao ar livre. Rev. Bras. Biol., v. 50, n. 3, 701-707, 1990.

OMENA, E. P.; SOUZA, M. M. Efeito da predação no desenvolvimento inicial da comunidade incrustante na região da Urca, Baía de Guanabara, RJ. In: SILVA, S. H. G.; LAVRADO, H. P. (Eds.). Ecologia dos ambientes costeiros do Estado do Rio de Janeiro. Rio de Janeiro: Série Oecologia Brasiliensis, 1999. p. 213-227.

PAALVAST, P.; VAN DER VELDE, G. New threats of an old enemy: the distribution of the shipworm *Teredo navalis* L. (Bivalvia: Teredinidae) related to climate change in the Port of Rotterdam area, the Netherlands. Mar. Pollut. Bull., v. 62, n. 8, p. 1822-1829, 2011.

PATI, S. K.; RAO, M. V.; BALAJI, M.; SWAIN, D. Deterioration of wood by marine borers in a tropical harbour: influence of environmental parameters and biotic factors. Int. J. Mar. Sci., v. 4, n. 13, p. 119-133, 2014.

RAYES, C. A.; BEATTIE, J.; DUGGAN, I. C. Boring Through History: An Environmental History of the Extent, Impact and Management of Marine Woodborers in a Global and Local Context, 500 BCE to 1930s CE. Environ. Hist., v. 21, n. 4, p. 477-512, 2015.

SIGNORINI, S. R. A study of the circulation in bay of Ilha Grande and Bay of Sepetiba: part I, a survey of the circulation based on experimental field data. Bol. Inst. Oceanogr. São Paulo, v. 29, n. 1, p. 41-55, 1980.

SILVA, S. H. G.; JUNQUEIRA, A. O. R.; MARTINS-SILVA, M. J.; ZALMON, I. R.; LAVRADO, H. P. Fouling and wood-boring communities distribution on the coast of Rio de Janeiro, Brazil. In: NEVES, C.; MAGOON, O. (Eds.). Coastlines of Brazil. New York: American Society of Civil Engineers, 1989. p. 95-109.

SILVA, S. H. G.; NUNES, A. J. B.; ALVES, M. C. S.; LAGE, V. A. Contribuição ao estudo das comunidades incrustantes que ocorrem na Baía da Guanabara, Rio de Janeiro, Brasil. Resultados preliminares. Rev. Bras. Biol., v. 40, n. 2, p. 367-382, 1980.

SILVA, M. J. M.; SILVA, S. H. G.; JUNQUEIRA, A. O. R. Distribuição vertical de Teredinidae (*Molusca, Bivalvia*) em Portogallo, Angra dos Reis, Rio de Janeiro, Brasil. Rev. Bras. Zool., v. 5, n. 1, p. 155-165, 1988.

SKINNER, L. F.; BARBOZA, D. F.; ROCHA, R. M. Rapid Assessment Survey of introduced ascidians in a region with many marinas in the southwest Atlantic Ocean, Brazil. Manag. Biol. Invasion., v. 7, n. 1, p. 13-20, 2016.

SKINNER, L. F.; MACHARET, H. K. L.; COUTINHO, R. Influence of upwelling and tropical environments on the breeding development of the intertidal barnacle *Tetraclita stalactifera* (Lamarck, 1818). Braz. J. Oceanogr., v. 59, n. 4, p. 349-356, 2011.

SKINNER, L. F.; SILVA, S. H. G.; LAVRADO, H. P.; MARTINS-SILVA, M. J. Estudo das comunidades incrustantes eperfurantes ao longo do Canal do Bacalhau, Guaratiba, RJ. Anais do III Simpósio de Ecossistemas da Costa Brasileira: subsídios a um gerenciamento ambiental. Volume I - Manguezais e Marismas. São Paulo: Academia de Ciências do Estado de São Paulo, 1994. p. 228-235, 1994.

SKINNER, L. F.; TENÓRIO, A. A.; PENHA, F. L.; SOARES, D. C. First record of *Spirobranchus giganteus* (Pallas, 1766) (Polychaeta, Serpulidae) on Southeastern Brazillian coast: new biofouler and free to live without corals? Panam. J. Aquat. Sci., v. 7, n. 3, p. 117-124, 2012.

SOARES-GOMES, A.; GAMA, B. A. P.; BAPTISTA NETO, J. A.; FREIRE, D. G.; CORDEIRO, R. C.; MACHADO, W.; BERNARDES, M. C.; COUTINHO, R.; THOMPSON, F. L.; PEREIRA, R. C. An environmental overview of Guanabara Bay, Rio de Janeiro. Reg. Stud. Mar. Sci., 2016. https://www.researchgate.net/publication/292921881_An_environmental_overview_of_Guanabara_Bay_Rio_de_Janeiro_Regional_Studies_in_Marine_Science

SPALDING, M. D.; FOX, H. E.; ALLEN, G. R.; DAVIDSON, N.; FERDAÑA, Z. A; FINLAYSON, M.; HALPERN, B. S.; JORGE, M. A.; LOMBANA, A. L.; LOURIE, S. A.; MARTIN, K. D.; MCMANUS, E.; MOLNAR, J.; RECCHIA, C. A.; ROBERTSON, J. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. BioScience, v. 57, n. 7, p. 573-583, 2007.

TEIXEIRA, T. P.; NEVES, L. M.; ARAÚJO, F. G. Thermal impact of a nuclear power plant in a coastal area in Southeastern Brazil: effects of heating and physical structure on benthic cover and fish communities. Hydrobiologia, v. 684, n. 1, p. 161-175, 2012

TRINDADE-SILVA, A. E.; MACHADO-FERREIRA, E.; SENRA, M. V. X.; VIZZONI, V. F.; YPARRAGUIRRE, L. A.; LEONCINI, O.; SOARES, C. A. G. Physiological traits of the symbiotic bacterium Teredinibacter turnerae isolated from the mangrove shipworm Neoteredo reynei. Genet. Mol. Biol., v. 32, n. 3, p. 572-581, 2009.

TURNER, R. D. A Survey and Illustrated Catalogue of the Teredinidae. Boston: Harvard University Press, 1966.

TURNER, R. D. Methods of identification of marine borers and fungi. *In*: Jones E. B. G.; ELTRINGHAM, S. K. (eds). Marine Borers, Fungi and Fouling Organisms of Wood. Paris: Organisation for Economic Co-operation and Development, 1971. p. 18-63.

TURNER, R. D.; LUTZ, R. A.; JABLONKI, D. Modes of molluscan larval development at deep-sea hydrothermal vents. Bull. Biol. Soc. Wash., v. 6, p. 167-184, 1985.

VALENTIN, J. L. The Cabo Frio upwelling system. Ecol. Stud., v. 144, p. 97-105, 2000.

VALENTIN, J. L.; TENEMBAUM, D. R.; BONECKER, A. C. T.; VILLAC, M. C. O sistema planctônico da Baía de Guanabara: síntese do conhecimento. In: SILVA, S. H. G.; LAVRADO, H. P. (Eds.). Ecologia dos ambientes costeiros do estado do Rio de Janeiro. Rio de Janeiro: Série Oecologia Brasiliensis. 1999. p. 35-59.

VAROTTO, R. S.; BARRETO, C. C. Colonization of artificial substrata by teredinid larvae released from a previously infested focus at Ilha Grande Bay, RJ. Braz. Arch. Biol. Technol., v. 41, n. 4, p. 391-400, 1998.

WEIGELT, R.; LIPPERT, H.; BORGES, L. M. S.; APPELQVIST, C.; KARSTEN, U.; BASTROP, R. First time DNA barcoding of the common shipworm Teredo navalis Linnaeus 1758 (Mollusca: Bivalvia: Teredinidae): Molecular-taxonomic investigation and identification of a widespread wood-borer. J. Exp. Mar. Bio. Ecol., v. 475, p. 154-162, 2016.