Universidade Federal Fluminense

Instituto de Biologia

Programa de Pós-Graduação em Biologia Marinha

O papel dos cascos de navios no transporte regional de espécies marinhas

Dissertação apresentada ao Programa de Pós-Graduação em Biologia Marinha da Universidade Federal Fluminense, como requisito para obtenção do grau de Mestre em Biologia Marinha

Fabio Mostacato Bastos

Orientador

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Resumo

Estudos recentes demonstram a importância do transporte intra-regional de espécies, principalmente através de cascos de navios domésticos. Navios com água de lastro atuam predominantemente em rotas internacionais, portanto têm recebido grande atenção como vetores de espécies, principalmente, no nível inter-regional. Todavia, navios domésticos representam uma ameaça subestimada no transporte de espécies via casco. Desta forma, as incrustações dos cascos destes navios atuam tanto na homogeneização de espécies nativas e criptogênicas, quanto no aumento do limite de distribuição de espécies exóticas já estabelecidas em determinadas regiões portuárias. O objetivo do presente estudo foi avaliar o papel dos cascos de navios no transporte regional de espécies marinhas. Duas embarcações, o cargueiro Frotargentina e a lancha balizadora Tubarão foram utilizadas em 4 campanhas experimentais. O potencial dos cascos de navios no transporte de espécies marinhas para diferentes regiões portuárias, o efeito das viagens dos navios sobre as densidades populacionais de espécies / grupos sésseis e vágeis, e a distribuição destas populações ao longo dos cascos dos navios foram avaliados com dados de porcentagem de cobertura e densidade relativa. Organismos sésseis tais como as cracas *Balanus amphitrite*, *Balanus* spp., o poliqueto *Hydroides elegans* e, as macroalgas *Enteromorpha* sp. e *Ulva* sp. demonstraram um grande potencial de transporte para outras regiões através de casco do navios. Por outro lado, o briozoário *Bugula neritina* e a ascídia *Styela plicata* tiveram uma redução significativa de suas densidades após as viagens, principalmente de populações predominantemente adultas. Em relação aos organismos vágeis, o isópode *Sphaeroma walkeri* apresentou um grande potencial de transporte, provavelmente pelo seu hábito de abrigar-se dentro de carapaças de cracas mortas. Verificou-se que algumas partes do casco de navio são ocupadas preferencialmente por organismos tais como *Ulva* sp., *B. neritina* e *P. perna*, enquanto que todo o casco foi homogeneamente ocupado por outras espécies, por exemplo, *B. trigonus, Balanus* spp. e o caprelídeo *Caprella penantis*. Espécies exóticas como *Megabalanus coccopoma*, *Perna perna*, *Isognomon bicolor* e *Styela plicata* também foram transportadas nos cascos dos navios estudados.

Abstract

Recent studies demonstrate the importance of the intraregional transport of species, particularly through the hulls of domestic vessels. Vessels with ballast water act predominantly on international routes, and so they have received much attention as species' vectors mainly in the interregional transport mode. However, domestic vessels represent an underestimated threat in the species' transport via hulls. Thus, the fouling on the vessels hulls may act as far in the homogenization of native and cryptogenic species as in the increase of the distribution range of exotic species already established in port regions. The aim of the present study was to evaluate the role of vessel hulls in the regional transport of marine species. Two vessels, the bulk carrier Frotargentina and the sea marker Tubarão were used in 4 experimental campaigns. The potential of vessel hulls in the transport of marine species, the effect of vessel voyages in the population densities of sessile and vagile species / groups, and the distribution of these populations along the hull were evaluated with evaluated with percentage cover and relative density data. Sessile organisms such as *Balanus amphitrite*, *Balanus* spp., the polychaete *Hydroides elegans*, the macroalgae *Enteromorpha* sp. and *Ulva* sp. demonstrated a large potential of being transport to other regions through the hull of vessels. On the other hand, the bryozoan *Bugula neritina* and the ascidian *Styela plicata* had a significative reduction of their densities after voyages, mainly of adult populations. Regarding to the vagile organisms, the isopod *Sphaeroma walkeri* presented a large potential of transport, probably by its habit of sheltering within dead barnacles' caracapaces. It was also verified that some parts of the vessel hull were preferentially occupied by organisms such as *Ulva* sp., *B. neritina* and *P. perna*, while the whole hull was homogeneously occupied by others species as *B. trigonus, Balanus* spp. and the caprelid *Caprella penantis*. Exotic species such as *Megabalanus coccopoma*, *Perna perna, Isognomon bicolor* and *Styela plicata* were also transported on the hulls of the vessels of this study.

Fundamentação Teórica

É bem provável que espécies incrustantes tenham sido transportadas para diversas regiões costeiras no casco de embarcações antigas há cerca de 4.000 anos atrás. Por exemplo, o início da navegação comercial no Mar Mediterrâneo estabeleceu contato entre os portos fenícios da Palestina, Norte da África e Sul da Espanha (Watzman, 2004). Além disso, o Mar Mediterrâneo constituía-se em uma rota barata o bastante para o transporte de grãos, óleo e vinho, principalmente entre portos egípcios e fenícios (Temin, 2003).

Após milhares de anos, a expansão marítima e colonial aumentou a perturbação na biogeografia original das espécies através da navegação interoceânica a partir da Idade Média (Carlton, 1992). Navios vagando por costas e oceanos começaram uma revolução na estrutura dos ecossistemas marinhos: o movimento e introdução, ao redor do mundo, e em escala ecológica (= atual), de organismos que estiveram isolados por milhares de anos em escala evolucionária (Carlton, 1999). Por exemplo, acredita-se que o mexilhão *Perna perna* foi uma espécie introduzida no Brasil durante a época do comércio de escravos. Este bivalve foi considerado uma espécie nativa até que investigações recentes em “sambaquis” (depósitos fósseis em praias) demonstraram sua ausência na pré-história brasileira (Souza et al., 2004).

Finalmente, a revolução industrial abriu um caminho para uma rápida transformação da frota naval mundial: navios a vapor se tornaram maiores e podiam transportar mais carga. Novas rotas comerciais foram abertas, e as rotas tradicionais tiveram fluxo acentuado. Mais adiante, a navegação comercial se tornou a maior atividade econômica mundial. Mais tarde, os navios foram acrescidos de cascos de metal e do uso de lastro líquido. Por causa dessas inovações, o transporte de espécies tem aumentado para diferentes regiões, e invasores marinhos de sucesso ganharam notoriedade através de prejuízos ecológicos e econômicos (Carlton, 1996 a).

Conseqüentemente, muitas espécies puderam encontrar condições adequadas para o seu estabelecimento em novos ambientes, dependendo das suas habilidades para competir por espaço e alimento, através do transporte freqüente em cascos de navios ao longo do desenvolvimento da indústria naval. Este processo de dispersão de espécies para diferentes regiões sem registros históricos causou uma recente confusão sobre o limite de distribuição natural de espécies, surgindo a questão sobre quais espécies são nativas, exóticas ou criptogênicas (Carlton, 1996 b).

Como as espécies podem ser transportadas e eventualmente estabelecer populações? Navios são capazes de atuar em dois modos de transporte. O transporte inter-regional é desempenhado por navios internacionais, os quais podem trazer espécies exóticas de diferentes regiões. O transporte intra-regional (ou regional) é desempenhado por navios domésticos, os quais podem facilitar a dispersão de espécies nativas e exóticas dentro da costa de um país principalmente através de seus cascos (Wasson et al., 2001).

Presumivelmente, a probabilidade de sucesso no transporte, principalmente de espécies vágeis, decresce com o aumento da distância da viagem e, assim, uma maior probabilidade destas espécies se perderem no mar. Para muitas espécies incrustantes, o transporte nos cascos de navios pode ser bem sucedido entre dois pontos relativamente próximos da costa, porém pode não ser em uma travessia transoceânica (Carlton, 1985). Contudo, os navios retornam periodicamente para águas costeiras após viagens oceânicas, especialmente para enseadas e estuários. Este retorno pode prover renovação energética, para a assembléia incrustante, suficiente para a próxima viagem (Carlton, 1999).

Além disso, cascos de navios podem criar novos caminhos para transferência de comunidades biológicas, mesmo através de fortes barreiras biogeográficas (Lewis et al., 2005). Exemplos de espécies superando barreiras biogeográficas, tais como temperatura e regiões oceânicas, são documentados por alguns estudos: o transporte potencial de espécies incrustantes de zonas temperadas em cascos de navios para a Antártica (Lewis et al., 2003); bivalves incrustados no casco de um navio militar viajando de Washington para o Havaí (EUA) (Apte et al., 2000), etc.

A despeito das espécies incrustantes nos navios, houve várias tentativas de prevenir a incrustação de cascos de navios com o uso de tintas antiincrustantes, principalmente no século XX. Entretanto, a tinta antiincrustante mais eficaz, com um tempo de ação de até 5 anos, é também a mais tóxica: o revestimento de autopolimento de copolímeros de organoestanho (TBT). Devido a sua toxicidade, ela não foi só competente contra espécies incrustantes nos cascos, mas também para muitos organismos habitando em ambientes marinhos artificiais e naturais (Watermann, 1999). Assim, as tintas à base de TBT foram reconhecidas como ameaças ao ambiente marinho, e a Organização Marítima Internacional (IMO) sugeriu o seu banimento (Hewitt e Martin, 2001).

Embora o TBT funcionasse bem como antiincrustante, a bioincrustação não foi completamente exterminada nos cascos de navios. Muitos organismos resistem aos biocidas, principalmente, quando as tintas envelhecem, perdendo a toxicidade, ficando os cascos de navios mais susceptíveis à incrustação. Portanto, a tolerância aos biocidas antiincrustantes, como o TBT e o cobre, é um importante determinador da probabilidade do transporte de espécies (Trentin et al., 2001; Floerl e Inglis, 2005).

Em relação aos organismos componentes da fauna e flora incrustante, a maior parte destes organismos é séssil, mas muitos organismos vágeis como gamarídeos, tanaidáceos, isópodes e decápodes vivem associados aos sésseis (Minchim e Gollasch, 2003). Em um estudo realizado na Alemanha, a observação de cascos de navios docados mostrou que as cracas são os componentes sésseis mais abundantes, seguidos dos bivalves (Gollasch, 2002). Em geral, a fauna e a flora incrustante é dominada por organismos sésseis encontrados em comunidades de entremarés e infralitoral, tais como poliquetas tubícolas, cracas, bivalves, tunicados, hidróides, briozoários, esponjas e macroalgas (Carlton, 1987; Godwin, 2003).

Assim, o transporte de espécies, principalmente por navios, é uma grande preocupação atual, por causa dos problemas ambiental, econômico e social. De um modo desequilibrado, a água de lastro de navios tem a maior atenção da comunidade científica, enquanto o transporte de espécies por cascos de navios recebe muito menos atenção (Bax et al., 2003; Godwin, 2003). Além disso, o papel dos cascos de navios no transporte de espécies continua avaliado de forma deficiente. Além disso, a maioria dos estudos sobre incrustações em casco de navios é do começo do século XX, e a minoria é, ironicamente, do final do mesmo século (Carlton, 1992; 1999). Contudo, vários estudos recentes têm sugerido que este transporte continua importante e perigoso (Apte et al., 2000; Wasson et al., 2001; Hewitt e Martin, 2001; Gollasch, 2002; Godwin, 2003; Lewis et al., 2003; Minchim e Gollasch, 2003; Ferreira et al., 2004; Floerl et al., 2005 a; Floerl e Inglis, 2005; Lewis et al., 2005).

O objetivo do presente estudo foi (1) avaliar o papel de cascos de navios no transporte regional de espécies marinhas, (2) o efeito do deslocamento dos navios sobre a densidade das populações de espécies / grupos sésseis e vágeis durante as viagens, e (3) a distribuição destas populações ao longo do casco.

As hipóteses nulas foram: (1) os cascos de navios não atuam como vetores no transporte regional de espécies marinhas, (2) as espécies / grupos sésseis e vágeis nos cascos dos navios não sofrem alterações em suas densidades após viagens, (3) as espécies distribuem-se de forma homogênea ao longo dos cascos de navios. As hipóteses alternativas foram: (1) os cascos de navios atuam como vetores no transporte regional de espécies marinhas, (2) as espécies / grupos sésseis e vágeis nos cascos dos navios sofrem alterações em suas densidades após viagens, (3) as espécies distribuem-se de forma heterogênea ao longo dos cascos de navios.

A metodologia adotada foi baseada em dados de porcentagem de cobertura dos organismos incrustantes para ambos os navios estudados, o cargueiro Frotargentina e a lancha balizadora Tubarão (Marinha Brasileira), além de densidade relativa, somente para a lancha Tubarão. As amostras foram realizadas antes que o navio saísse do porto e após a chegada no porto, isto é, a cada porto em que o navio atracava se tomou uma amostra. Considerou-se "viagem" o intervalo em que o navio navegou de um porto ao outro. O estudo teve 4 campanhas experimentais, as quais consistiram de períodos de viagens. A campanha Frotargentina teve 3 amostras (ou 2 viagens). Já a lancha Tubarão teve 3 campanhas, chamadas A, B e C. A campanha Tubarão A teve 3 amostras, a B teve 4 amostras, e a C teve 2 amostras. A amostragem dos cascos se deu através dos seguintes desenhos experimentais: as amostras foram realizadas da meia nau à proa (a popa não pode ser amostrada) de forma aleatória totalizando 48 réplicas para o navio Frotargentina; em relação ao navio Tubarão, o casco foi dividido em 6 partes (linha d'água e obras vivas divididas em proa, meia nau e popa), e foram obtidas 4 réplicas em cada parte do casco, totalizando 24 réplicas. A análise dos dados foi realizada com ANOVA, balanceada, fixa, e com a transformação dos dados em arco seno, logaritmo de x + 1 na base 10 e raiz quadrada, quando os dados não obedeceram às premissas. O teste *a posteriori* HSD de Tukey foi utilizado quando diferenças significativas ($p < 0,05$) foram detectadas entre as médias.

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1. Introduction

It is probable that fouling species were transported to several coastal regions in the hull of ancient vessels about 4.000 years ago. For instance, the beginning of trading navigation in the Mediterranean Sea established contact between the Phoenician ports of Palestine, North Africa and South Spain (Watzman, 2004). Besides, the Mediterranean Sea became a route for long-distance transportation that was cheap enough to use for grain, oil and wine, particularly between Egyptian and Phoenician ports (Temin, 2003).

After thousands of years, the maritime and colonial expansion increased the disturbance in the original species' biogeography through interoceanic navigation since Middle Age (Carlton, 1992). Vessels roaming coasts and oceans set in motion what was a revolution in the structure of marine ecosystems: the movement and introduction around the world in ecological scale (= present) of organisms that had been isolated for millions of years over evolutionary scale (Carlton, 1999). For instance, it is believed that the mussel *Perna perna* was an introduced species in Brazil during slave-trader time. This bivalve was considered a native species until recent investigations in "sambaquis" (beach fossil deposits) that have demonstrated its absence in Brazilian prehistory (Souza et al., 2004).

At last, the industrial revolution opened a path to a rapid transformation of the world naval fleet: steamships became bigger and could transport more cargo. New trade routes were opened and the traditional ones had their flow enhanced. Farther on, the commercial navigation became the world's greatest economic activity. Afterwards, vessels were improved with metal hulls and the use of liquid ballast. Because of these innovations, species' transport has been increased to different world's regions and successful marine invaders reached notoriety through economic and ecological damages (Carlton, 1996 a).

Consequently, many species could found suitable conditions to their establishment in new environments, depending on their abilities to compete for space and food, through frequent transport on vessel hulls during the development of the naval industry. This process of species' dispersion to different regions without historical records caused a recent confusion about species' natural distribution range, raising the question about what species are native, exotic, or cryptogenic (Carlton, 1996 b).

How can species be transported and eventually establish populations? Vessels are able to act in two ways of transport. The interregional transport is performed by international vessels, which may bring exotic species to a new region. The intraregional one is performed by domestic vessels, which may facilitate the native and exotic species dispersion within a country coast mainly through their hulls (Wasson et al., 2001).

Presumably, the probability of successful transport, particularly of free-living species, decreases with increasing distance travel, and thus a greater likelihood of being lost at sea. For many fouling species, transport on vessels hull may be successful between two relatively near coastal points, but may be unsuccessful in a transoceanic crossing (Carlton, 1985). Yet, vessels periodically return to coastal waters after oceanic voyages, especially shallow embayment and estuaries. This return to inshore waters may provide an energetic renewal to fouling species for the next voyage (Carlton, 1999).

In addition, vessel hulls may create entirely new transfer pathways for biological communities even across substantial biogeographically barriers (Lewis et al., 2005). Examples of species overcoming biogeographically barriers, such as temperature and oceanic regions, are documented by some papers: potential transport of fouling species of temperate regions on hulls of vessels traveling to Antarctic (Lewis et al., 2003); bivalves harboring the hull of a navy vessel traveling from Washington State to Hawaii (USA) (Apte et al., 2000) etc.

Despite of species fouling vessels hull, there have been many attempts to prevent fouling with the use of paints, particularly, in the XX century. However, the most effective antifouling paint with a lifetime up to five years is also the most toxic: the self-polishing copolymer organotin coating (TBT). Due to its toxicity, it was not only competent against fouling species on hulls, but a threat to many organisms living in marine artificial and natural environments (Watermann, 1999). Since the '70, paints with TBT have been the "hit" to the world naval fleet (Townsin, 2003), and this success was related to the vessels performance improvement, because marine micro and macrofouling may cause drag increase and speed diminution, resulting in 1-2%, 10% to 40% more fuel consumption due to slime, weed and shells, respectively (International Marine Coatings, 2002).

However, the IMO (International Maritime Organization) has recognized TBT toxicity as a threat to the marine environment and has suggested its banishment in 2008. For that reason, many labs are working to develop biocides less toxic and more accurate to prevent fouling organisms on vessel hulls (Hewitt and Martin, 2001).

TBT is an effective antifouling toxic compound, although it does not mean that biofouling was completely exterminated on hulls. Many organisms may resist to tributyltin paints, yet they have difficulty to reach high densities. As the paints on hulls age and its toxicity decrease, vessels become increasingly susceptible to fouling. Therefore, the tolerance to antifouling biocides, as TBT and copper (the most widely used antifouling nowadays), is an important determiner of the likelihood of species' transport (Trentin et al., 2001; Floerl and Inglis, 2005). Thus, vessels hull is a concern to naval industry in general, because the new paints do not have the same efficiency as TBT (Hewitt and Martin, 2001; Lewis et al., 2003; Minchim and Gollasch, 2003), and the actual practice to substitute TBT by copper and organic biocides cannot and is not regarded as a real alternative (Watermann, 1999).

Many parts of vessels hull have flaws in their painting during the dry dock time. These flaws do not offer any resistance to fouling process, working as a proper substratum for colonization and development of biofouling. Sea chests also work as a sheltered place for organisms like oysters, mussels, barnacles, ascidians, polychaetes, gastropods, decapods etc (Godwin, 2003; Dodgshun and Coutts, 2002; Coutts et al., 2003).

A recent study demonstrated that current approaches to prevent the colonization of vessels hull by fouling organisms, as manual hull cleaning and antifouling paints, do not prevent the transport of many species. The first approach is prohibited for large vessels in many countries (e.g. Australia), but no regulations exist for small private boats. In-water hull cleaning raises the risk of cross-contamination of species between ports by depositing foreign taxa removed from the boat hull within the port where the boat is cleaned, and by increasing the chances that species from the local port will be transported elsewhere when the vessel leaves. The latter approach has global consent, particularly ablative and self-polishing paints, but problems like misuse of antifouling paints and prolonged "mooring" time diminish paints ability to prevent fouling. Besides, there is an extra problem: antifouling paints may be highly selective, and effective only for small number of taxa like barnacles and bivalves (Floerl et al., 2005).

Besides, those prevention methods approached above, the mooring at ports near to mouth of rivers has been realized to kill most of fouling organisms through low salinity. Nevertheless, this method may not work effectively for all species living on vessel hulls. As a registered example of the inefficiency of this method for some species, the bivalve *Mytilus* *galloprovincialis* could survive at low salinity condition around 2 – 10 ppt during 9 days before the vessel travel to Hawaii departing from Washington State, USA (i.e. supporting thousands miles in oceanic conditions) (Apte et al., 2000).

Regarding to the organisms compounding the hull fouling fauna and flora, most of these organisms are sessile, but many vagile organisms, such as amphipods, tanaids, isopods and decapods, live in association to sessile ones. Vagile benthos can live sheltered in algae thalli, dead barnacles and hull crevices. When vessels berth, they give chance for vagile organisms of hulls to colonize port structures and vice-versa. Moreover, sessile benthos of hull can find environmental conditions for gametes' release (Minchim and Gollasch, 2003).

In a study accomplished in German dry docks, hull fouling was composed mainly by crustaceans (53, 6%) and secondarily by mollusks (27, 3%). Barnacles were the most usual crustaceans, and mussels were the most usual mollusks. Some vessels, in dry docks, had nearly 30 cm fouling thick. Most of species were sessile, but 19, 1% of species were vagile including amphipods, isopods, decapods etc (Gollasch, 2002). In general, the fouling fauna and flora is dominated by sedentary organisms found in natural marine intertidal and subtidal communities such as tubiculous polychaetes, barnacles, mussels, tunicates, hydroids, bryozoans, sponges and seaweeds (Carlton, 1987; Godwin, 2003). Thereby, when fouling accumulation is thick and stable enough it may harbor free-living taxa, with high propensity to hide deep within a fouling matrix, such as nereidae polychaetes, peracarid crustaceans (amphipods, isopods and tanaids), crabs (e.g. xanthids) and fishes (e.g. gobbies and blennies) (Carlton, 1985).

At last, species transport, particularly by vessels, is a great concern nowadays, because it brings environmental, economic and social problems. In an unbalanced way, ballast water bears the largest attention by the scientific community regarding to the bioinvasion problem, while the transport of fouling organisms on vessels hull has less attention (Bax et al., 2003; Godwin, 2003). In addition, the role of vessels in species' transport on hulls is still poorly understood. Ironically, the minority of studies is from late 20th century and the majority is from early and mid 20th century (Carlton, 1992; 1999). However, several recent studies have suggested that this way of transport is still important and dangerous (Apte et al., 2000; Wasson et al., 2001; Hewitt and Martin, 2001; Gollasch, 2002; Godwin, 2003; Lewis et al., 2003; Minchim and Gollasch, 2003; Ferreira et al., 2004; Floerl et al., 2005 a; Floerl and Inglis, 2005; Lewis et al., 2005).

The aim of this study was (1) to evaluate the role of vessel hulls in the regional transport of marine species, (2) the effect of displacement of vessels upon sessile and vagile populations during voyages, and (3) the distribution of these populations along hull.

The null hypotheses were: (1) vessel hulls are not vectors in the regional transport of marine species, (2) the sessile and vagile's species / groups do not have any alteration in their densities after voyages on the vessel hulls, (3) the species have homogeneous distribution along the vessel hulls. On the other hand, the alternative hypotheses were: (1) vessel hulls are vectors in the regional transport of marine species, (2) the sessile and vagile's species / groups have alteration in their densities after voyages on the vessel hulls, (3) the species have heterogeneous distribution along the vessel hulls.

2 – Material and methods

Four experimental campaigns were performed in the present study. One campaign occurred at Frotargentina vessel and three campaigns (A, B and C) occurred at Tubarão vessel (Tab. 1). Here, "sample" is called the collection of species on hull before a voyage. Two to four samples were achieved in a campaign, that is, 3 samples in Frotargentina campaign, 3 in Tubarão campaign A, 4 in Tubarão campaign B and, 2 in Tubarão campaign C. Therefore, samples were named as times from T1 to T4.

Table 1 – Specifications of vessels studied

	Frotargentina	Tubarão
Vessel type:	Bulk Carrier	Sea-marker
Classification:	Bureau Veritas	Navy vessel
Length/beam/draft:	193, 84 - 27, 65 - 10, 92 m	26 - 6, 4 - 3, 2 m
Gross tonnage:	67 - 100 tt (thousand tons)	~ 38 t
Antifoulant:	Yes	Yes
Last dry dock:	July' 02	August' 04
Cruising speed:	15 knots = 27, 6 km/h	9 knots = 18, 6 km/h

The Frotargentina campaign had the longest duration and distance of all campaigns, 30 days and ~ 4.000 km respectively (Tab. 3). After the first sample at the port of Arraial do Cabo (RJ), the vessel took 5 days to leave this port. It navigated to Guanabara Bay (RJ) where it was moored for 9 days (to repair the engines) and started the 5 days voyage northward to the coast of Rio Grande do Norte State. The vessel moored at the Termisa port at

Areia Branca (RN), and it was sampled in the next day by the second time. The vessel left Areia Branca after a mooring period of 3 days, starting the 5 days voyage southward to the coast of Rio de Janeiro. The third sample was taken 3 days after the vessel moored at Forno's port at Arraial do Cabo.

The Tubarão campaign A had 14 days of duration and 288 km traversed (Tab. 3). The Tubarão vessel left the port of Arraial do Cabo one day after the first sample. It navigated to Macaé (RJ) where it stayed until its arrival to Arraial do Cabo again after 8 days. It was not possible to achieve one sample at Macaé and the vessel had overnights in this voyage period. The second sample was taken in the Forno's port, one day after its arrival. Then, it navigated to Guanabara Bay, where it moored in the CAMR's dock (Brazilian Navy base) at Niterói (RJ), one day after the second sample at Arraial do Cabo. The Tubarão vessel hull was sampled at CAMR's dock 3 days after its arrival.

The Tubarão campaign B lasted 7 days and had 778 km traversed (Tab. 3). The first sample of Tubarão was achieved in the port of Arraial do Cabo (RJ). In the next day, the vessel left this port northward to the coast of Espírito Santo State, where it moored at the port's captaincy of Vitória (ES) after one day of voyage. The second sample was obtained 2 h after its arrival at Vitória. Then, it navigated southward to Macaé (RJ) where the third sample was taken when the vessel moored at Santana's Island after 3 days navigating (in this period the vessel had overnights in two ports). The vessel was sampled by the fourth time when it arrived at Arraial do Cabo in the same day of its departure from Macaé.

At last, the Tubarão campaign C had duration of 25 h and 394 km traversed (Tab. 3). The vessel was sampled by the first time 2 h before its departure of CAMR's dock at Niterói (RJ). Subsequently, it navigated about 24 h southward to the coast of São Paulo where it moored at the port of Santos (SP). The second sample was taken 1 h after its arrival.

There was the attempt to achieve the samples as quick as possible before the vessels' departure from a port and after the vessels' arrive to a port, at least in a period of 1 day. However, it was not accomplished in all campaigns because it depended on the authorization of the vessel captains and the safety conditions to achieve samples by scuba diving.

Aqui entra a tabela 2 sobre as viagens

Samples of fouling organisms were taken by SCUBA diver(s). All samples were taken at starboard vessel hull (Figure 1). The Tubarão vessel had its starboard hull side divided horizontally and vertically. Stern, mid ship and bow of both water line and bilge were the horizontal vessel parts, while water line and bilge were the vertical ones. In this manner, there were six hull parts sampled each one with four replicates: water line (WL) – stern (ST), WL – mid-ship (MS) and WL – bow (BO), bilge (BI) – ST, BI – MS and BI – BO. Water line is the vessel hull part marked by seawater surface. Bilge is the lower vessel hull part.

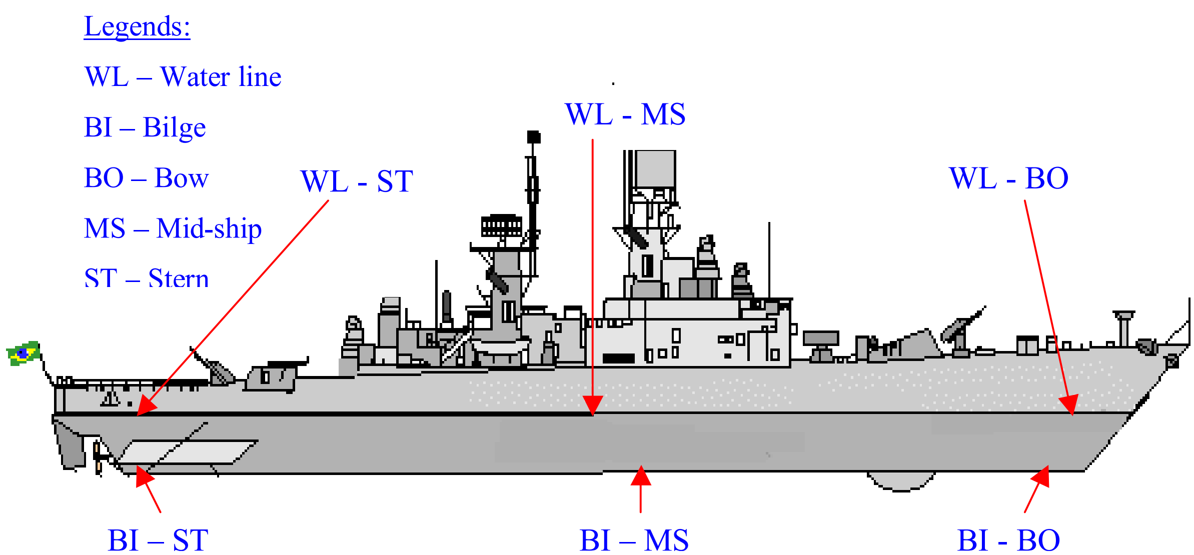


Fig.1 Vessel hull sampled parts.

Four random replicates were taken in each of six parts of Tubarão vessel hull, while forty-eight random replicates were taken on Frotargentina vessel hull. The difference among the sampling design of the two vessels was due to the possibility of sampling only from MS to BO, because bilge pumps on stern hull were activated when Frotargentina was moored. Besides, samples were not categorized in Frotargentina campaign as done with Tubarão campaigns.

A quadract of 10 x 10 cm with 30 random points on a 100 intersections was used to estimate sessile populations' percentage cover on hull. The number of individuals and species were registered on a "drawing-board wrist" underwater. This methodology was used in Frotargentina and Tubarão (A, B and C) campaigns. Scrapings were done to estimate sessile and vagile populations' relative densities using a spatula and a 10 x 10 cm empty quadract. The sampling started with the counting of organisms and ended with scrapings of fouling inside the quadract. Soon after scraping, the collected material was sealed in a proper plastic bag underwater. Later on, bags were frozen in a temperature of -5 ºC to preserve biological material. The scraping methodology was used only in Tubarão A, B and C campaigns, while the percentage cover one was used in Frotargentina. All organisms were classified in their minor possible taxon.

At lab, the material collected was sorted using a 2 mm mesh circular metal sieve. Firstly, sessile organisms were counted, separated and kept in 250 ml plastic flasks with 4% formaldehyde-freshwater solution. Then, vagile organisms were kept in 30 ml plastic flasks with 4% formaldehyde-freshwater solution. Vagile organisms were counted in number and taxonomic groups through a 250 x magnification stereomicroscope and a Dolphus glass container.

3.1 Data analyses

One-way ANOVA was performed in Frotagentina campaign because it had only the factor time. The model of Frotargentina campaign ANOVA was:

$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$, where

Y_{ij} = variable (% cover);

μ = parametric mean;

α_i = factor time; and

ε_{ij} = random error.

Factorial ANOVA (three-way) was performed in all Tubarão campaigns (A, B and C) with factors time, vertical parts, and horizontal parts. The model of Tubarão campaigns ANOVA was:

$Y_{ijkl} = \mu + \alpha_i + \beta_{ij} \quad \gamma_{ijk} + \varepsilon_{ijkl}$, where

Y_{ijkl} = variable (% cover or relative density);

μ = parametric mean;

α_i = factor time;

β_{ij} = factor vertical parts;

γ_{ijk} = factor horizontal parts; and

ε_{ijkl} = random error.

Post-hoc comparisons HSD Tukey´s Test were performed when main effect was significant in Frotargentina campaign, and when main effects and interactions were significant in Tubarão campaigns. The analysis of variance model was balanced, orthogonal and fixed one (Model I ANOVA). The significance level used was $\alpha = 0.05$. All tests were performed using a StatSoft Statistica 6.0 version (2001). All data were analyzed for homogeneity of variances and normality. Logarithmic, square root and arcsine transformations were applied when data did not conform to assumptions.

3 – Results

3.1 Qualitative analyses of the hulls of Frotargentina and Tubarão vessels

The qualitative analysis demonstrated that most of species was found in the campaigns of Tubarão vessel (Tab. 3). This difference is evident because the only variable estimated in Frotargentina campaign was the percentage cover. On the other hand, the variables percentage cover and relative density were estimated in all Tubarão campaigns. Thus, the combination of variables used to infer estimates about the species on Tubarão campaigns showed to be more powerful to detect species.

The species *Balanus amphitrite*, *Polysiphonia* sp. *and Hydroides elegans* were species found in all samples of Frotargentina campaign, whereas *Enteromorpha* sp., *Spyridia filamentosa* and *Bunodosoma caisarum* were found in one or two samples.

The species *Balanus amphitrite*, *Balanus eburneus*, *Balanus improvisus*, *Megabalanus coccopoma*, *Styela plicata*, *Perna perna*, *Hydroides elegans, Bugula neritina, Caprella penantis* and *Sphaeroma walkeri* were species found in all samples and campaigns of Tubarão vessel. However, *Obelia dichotoma*, *Bunodosoma caisarum*, *Megabalanus vesiculosus*, *Chthamalus proteus*, crabs, polychaetes, gastropods, ofiuroids, anemones, pycnogonids, amphipods, tanaids, nematodes, *Enteromorpha* sp. and *Ulva* sp. were found only in one campaign or in some samples.

Table 3 – Taxa found in the present study (* exotic species)

	Frotargentina	Tubarão
Coelenterata		
Hydrozoa		
- *Obelia dichotoma*		x
Anthozoa		
- *Bunodosoma caisarum*	x	x
Nematoda		
Adenophorea		
- *Phanoderma* sp.		x
- *Oncholaimus* sp.		x
- *Viscosia* sp.		x

Table 3 – Continued

	Frotargentina	Tubarão
- *Eurystomina* sp.		x
Annelida		
Polychaeta		
- *Nereis* sp.		x
- *Perinereis ponteni*		x
- *Amphiglena* cf. *mediterranea*		x
- *Hydroides elegans*	x	x
Mollusca		
Bivalvia		
- *Perna perna**		x
- *Hiatella arctica*		x
- *Atrina seminuda*		x
- *Isognomon bicolor**		x
- *Litophaga* sp.		x
- *Brachidontes* sp.		x
Gastropoda		
- *Stramonita haemastoma*		x
- Unidentified species		x
Echinodermata		
Ophiuroidea		
- unidentified species		x
Arthropoda		
Pycnogonida		
- Unidentified species		x
Crustacea		
Cirripedia		
- *Balanus amphitrite*	x	x
- *Balanus improvisus*		x
- *Balanus eburneus*		x
- *Balanus trigonus*		x

Table 3 – Continued

	Frotargentina	Tubarão
- *Megabalanus coccopoma**	x	x
- *Megabalanus vesiculosus*		x
- *Chthamalus proteus*		x
Brachyura		
- *Cataleptodius floridanus*		x
- *Pachygrapsus transversus*		x
- *Pilumnus spinosissimus*		x
Anomura		
- *Pachycheles monilifer*		x
- *Petrolysthes* sp.		x
Amphipoda		
- *Stenothoe valida*		x
- *Photis longicaudata*		x
- *Podocerus brasiliensis*		x
- *Elasmopus pectenicrus*		x
- *Jassa* sp.		x
- *Corophium* sp.		x
Caprellidae		
- *Caprella penantis*		x
Isopoda		
- *Sphaeroma walkeri*		x
Tanaidacea		
- *Hexapleomera robusta*		x
- *Zeuxo coralensis*		x
- Leptocheliidae (unidentified species)		x
Ectoprocta		
Gymnolaemata		
- *Bugula neritina*		x
- *Watersipora* aff. *subovoidea*		x

Table 3 – Continued

	Frotargentina	Tubarão
Chordata		
Urochordata		
- *Styela plicata**		x
Algae		
Chlorophyceae		
- *Ulva* sp.		x
- *Enteromorpha* sp.	x	x
Rhodophyceae		
- *Polysiphonia* sp.	x	
- *Spyridia filamentosa*	x	

Taxa found only on Tubarão vessel: 43 species

Taxa found only on Frotargentina vessel: 2 species

Taxa found on both vessels: 5 species

Total taxa found on vessels: 50 species

Total exotic taxa: 4 species

3.2 Quantitative analyses of the dominant species on the hulls of Frotargentina and Tubarão vessels

3.2.1 Frotargentina campaign results

Three organisms were dominants on Frotargentina hull: *Balanus amphitrite* (Fig. 2 a), *Polysiphonia* sp. (Fig. 2 b) and *Enteromopha* sp. (Fig. 2 c). None of them had their presence significantly altered by times ($p > 0.05$), except for *Enteromorpha* sp. This Chlorophycea was not detected in sample 1 (T1), but it possibly settled on Frotargentina hull while it stayed moored in Guanabara Bay during 9 days before sampling 2 (T2) (Tab. 2). In this case, there was a significative difference particularly between time 1 versus times 2 and time 3 ($p < 0.05$). The occurrence of *Enteromorpha* sp. had a tendency of decrease along time 2 and 3 although not significative ($p > 0.05$).

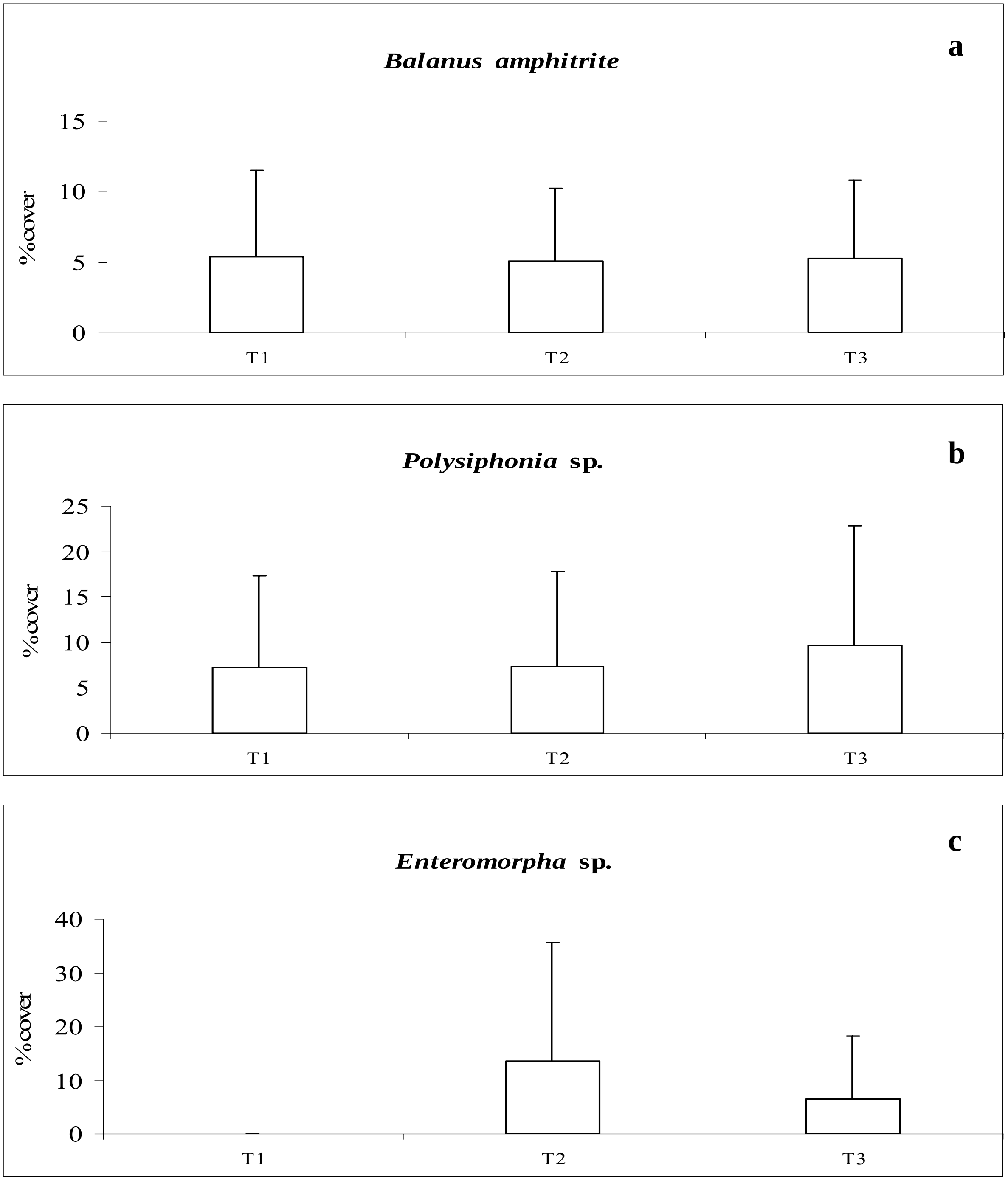


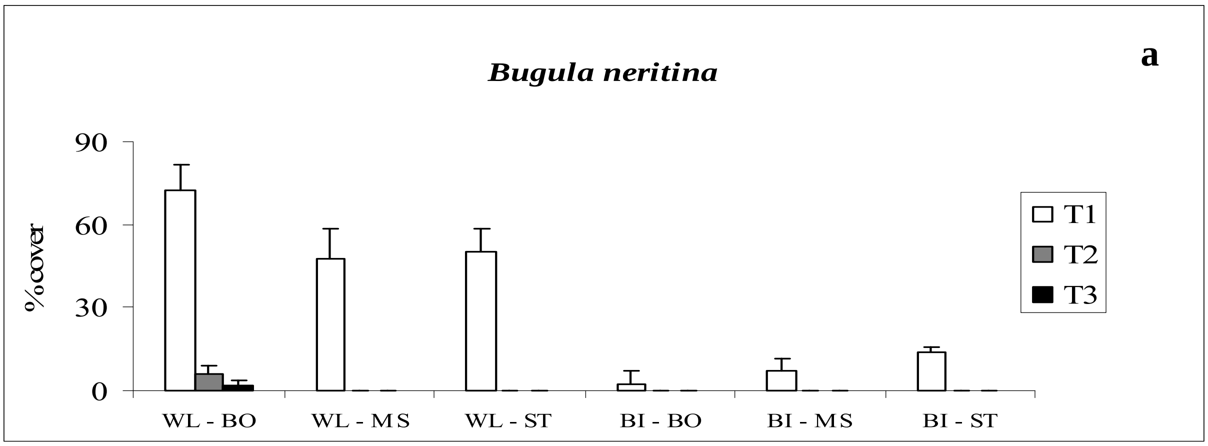
Fig. 2: The percentage cover and standard deviation of *Balanus amphitrite* (a), *Polysiphonia* sp. (b) and *Enteromorpha* sp. (c), sampled at Frotargentina hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Areia Branca / RN) and time 3 (T3 - Arraial do Cabo / RJ).

3.2.2 Tubarão campaigns results

3.2.2.1 Tubarão A

The bryozoan *Bugula neritina* occurred mainly on water line ($p < 0.05$) and on bow ($p < 0.05$) (Fig. 3 a). Besides, this species had its presence decreased by times ($p < 0.05$).

Similar results were obtained with *Styela plicata* (Fig. 3 b). Its occurrence was limited to water line ($p < 0.05$). There was no *S. plicata*'s presence on bilge parts. This ascidian had its presence decreased by times as well ($p < 0.05$).



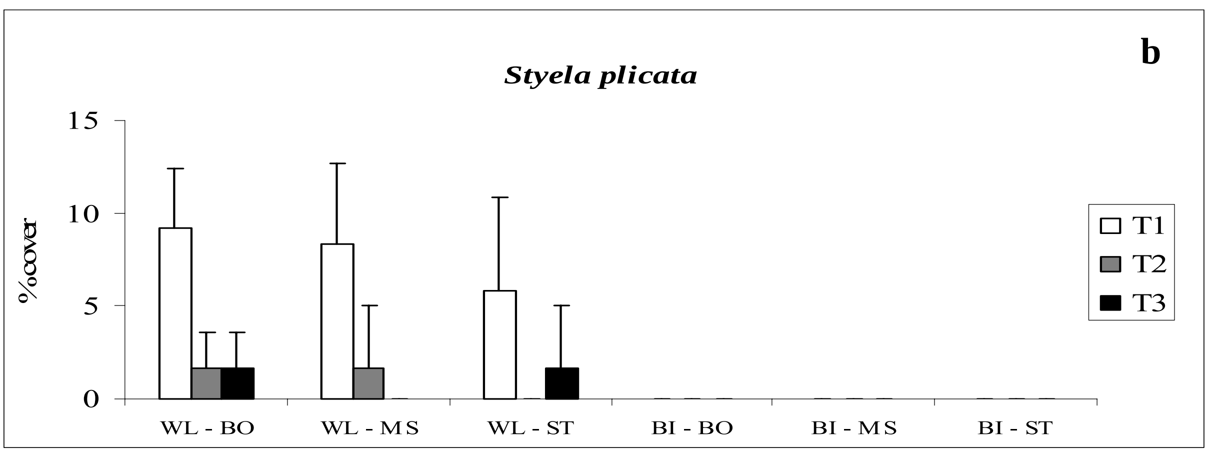


Fig. 3: The percentage cover and standard deviation of *Bugula neritina* (a) and *Styela plicata* (b) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Areia Branca / RN) and time 3 (T3 - Arraial do Cabo / RJ).

The barnacle *Balanus amphitrite* had homogeneous occurrence on vertical and on horizontal parts of hull ($p > 0.05$), with no significative change of its density by times ($p > 0.05$) (Fig. 4 a). However, a tendency of decrease was observed on bilge over time.

Two species were grouped as *Balanus* spp.: *Balanus improvisus* and *Balanus eburneus*. It happened due to the similarity between their carapaces, making difficult their count as one species at field and lab. However, alike results were observed with *Balanus* spp. when compared to *Balanus amphitrite* (Fig. 4 b). They also had homogeneous distribution along hull ($p > 0.05$), and their density was not altered by times, notwithstanding with a tendency of decrease as well ($p > 0.05$).

In accordance with the results above, *Balanus trigonus* had a homogeneous incidence on vertical and on horizontal parts of hull ($p > 0.05$) (Fig. 4 c). This species had its presence unaltered by times too ($p > 0.05$).

The distribution of *Megabalanus coccopoma* was homogeneous alongside hull ($p > 0.05$), even if a larger occurrence had been observed on water line (Fig. 5 a). However, this species' density decreased by times ($p < 0.05$).

Conversely, *Perna perna* showed a superior incidence on water line ($p < 0.05$), even though it had a homogeneous distribution on horizontal parts ($p > 0.05$) (Fig. 5 b). Its occurrence had no alteration by times ($p > 0.05$).

The ascidian *Styela plicata* had most of its population placed on water line ($p < 0.05$) and on stern ($p = 0.05$) (Fig. 5 c). Furthermore, it had its density decreased by times ($p < 0.05$).

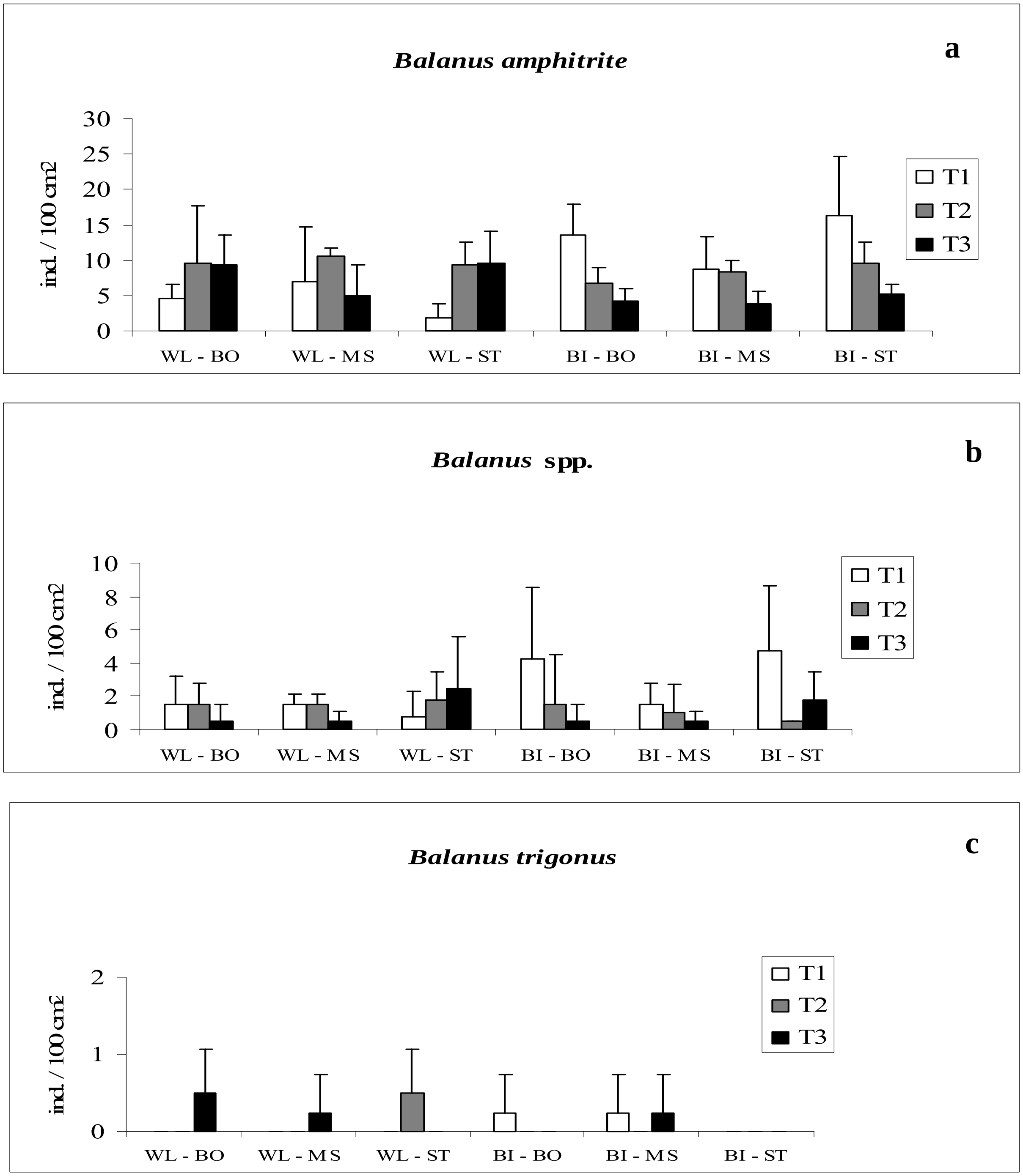


Fig. 4: The relative density and standard deviation of *Balanus amphitrite* (a), *Balanus* spp. (b – *Balanus improvisus* and *Balanus eburneus*) and *Balanus trigonus* (c) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Areia Branca / RN) and time 3 (T3 - Arraial do Cabo / RJ).

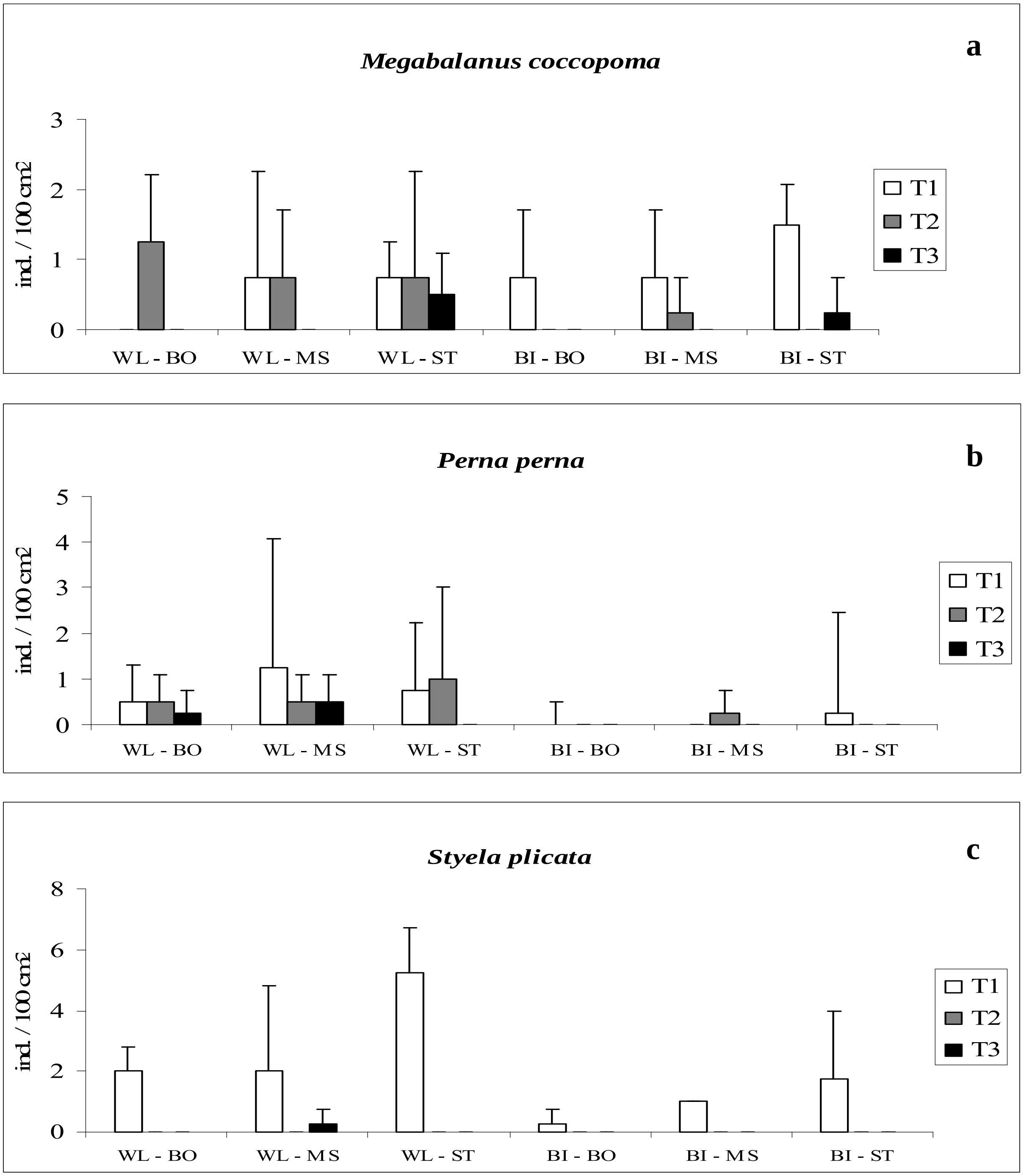
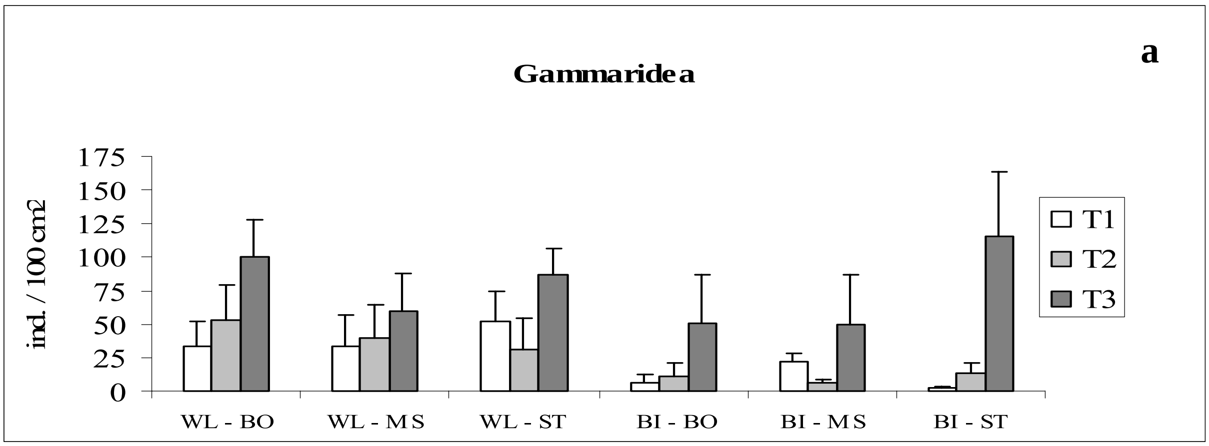


Fig. 5: The relative density and standard deviation of *Megabalanus coccopoma* (a), *Perna perna* (b) and *Styela plicata* (c) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Areia Branca / RN) and time 3 (T3 - Arraial do Cabo / RJ).

The Gammaridea had a larger presence on water line ($p < 0.05$), it had a homogeneous distribution along horizontal parts though ($p > 0.05$) (Fig. 6 a). Surprisingly, the gammaridea increased its density over times ($p < 0.05$).

In addition, the Caprellidae *Caprella penantis* had a larger presence on water line ($p < 0.05$), even if its distribution on horizontal parts was homogeneous ($p > 0.05$) (Fig. 6 b). It had a different alteration of its density by times: it decreased from T1 to T2, and increased from T2 to T3 ($p < 0.05$).



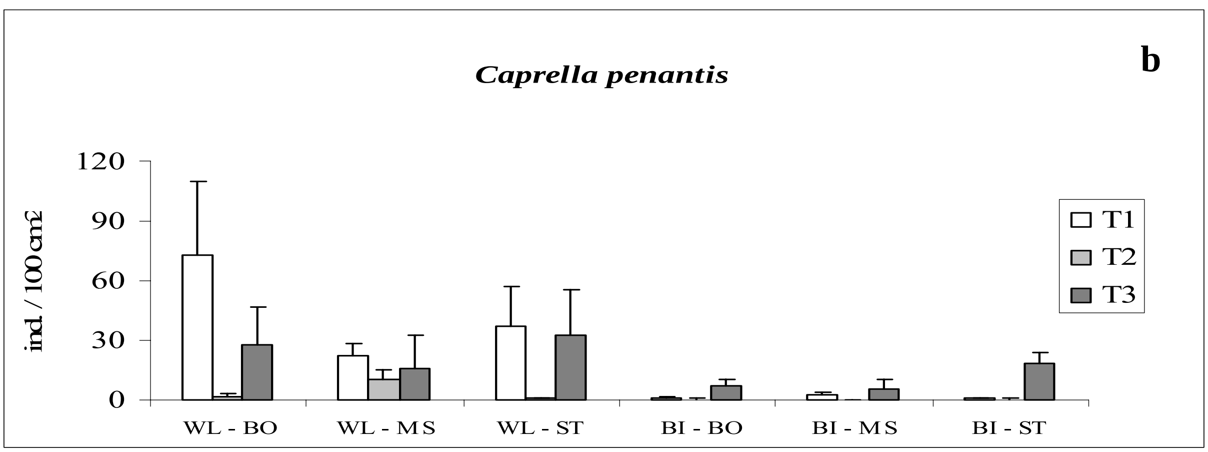


Fig. 6: The relative density and standard deviation of Gammaridea (a) and *Caprella penantis* (b) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Areia Branca / RN) and time 3 (T3 - Arraial do Cabo / RJ).

Most of Tanaidacea was placed on water line ($p < 0.05$), while it had a homogeneous distribution along horizontal parts ($p > 0.05$) (Fig. 7 a). The tanaidacea had its density increased by times ($p < 0.05$).

The Isopoda *Sphaeroma walkeri* had a larger presence placed on bilge ($p < 0.05$) and on bow ($p < 0.05$) (Fig. 7 b). Nevertheless, *S. walkeri* had its density unaltered by times ($p > 0.05$).

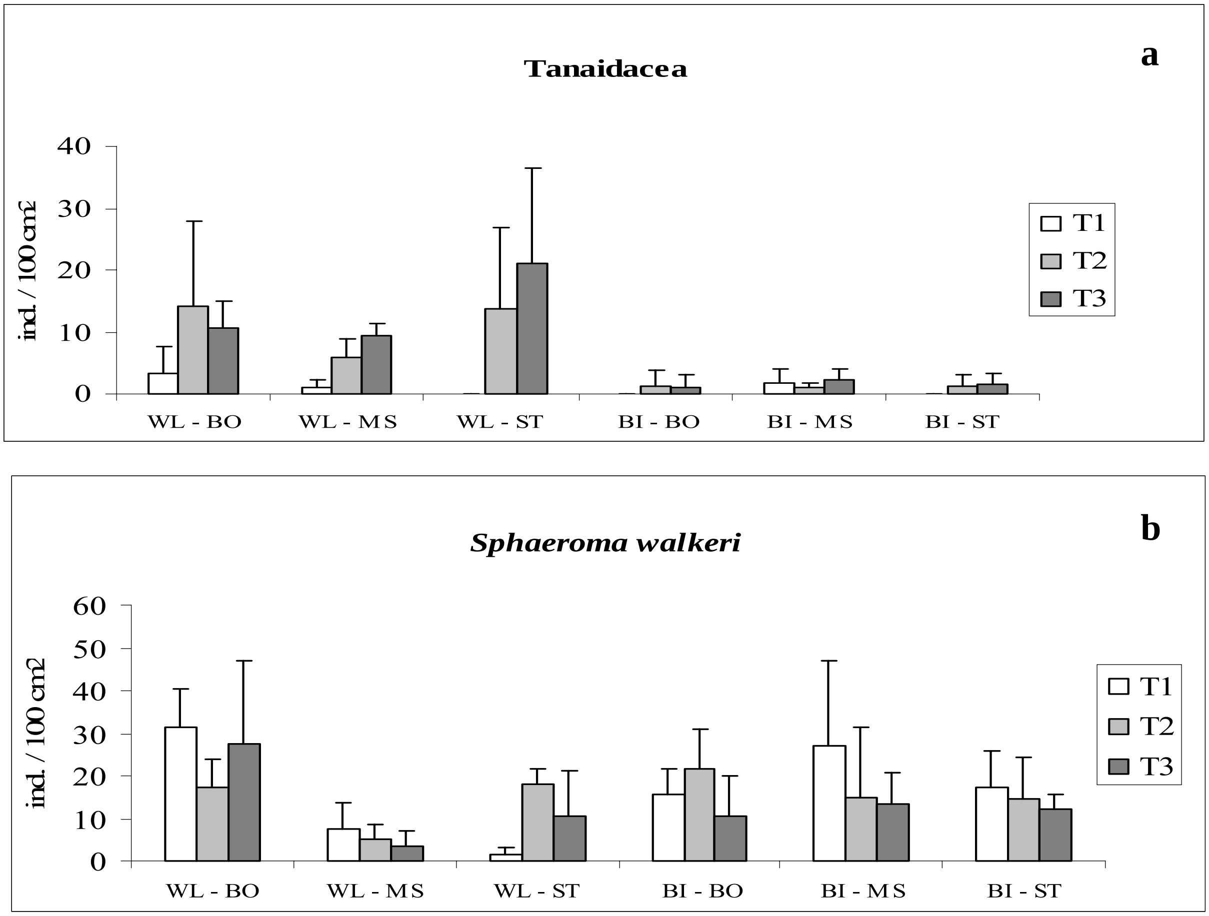


Fig. 7: The relative density and standard deviation of Tanaidacea (a) and the Isopoda *Sphaeroma walkeri* (b) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Areia Branca / RN) and time 3 (T3 - Arraial do Cabo / RJ).

3.2.2.2 Tubarão campaign B

The hydroid *Obelia dichotoma* had a larger incidence of its population on bilge ($p < 0.05$) than water line (Fig. 8). In addition, most of *O. dichotoma* presence was located on mid-ship and stern ($p < 0.05$). It had its cover decreased by times ($p < 0.05$).

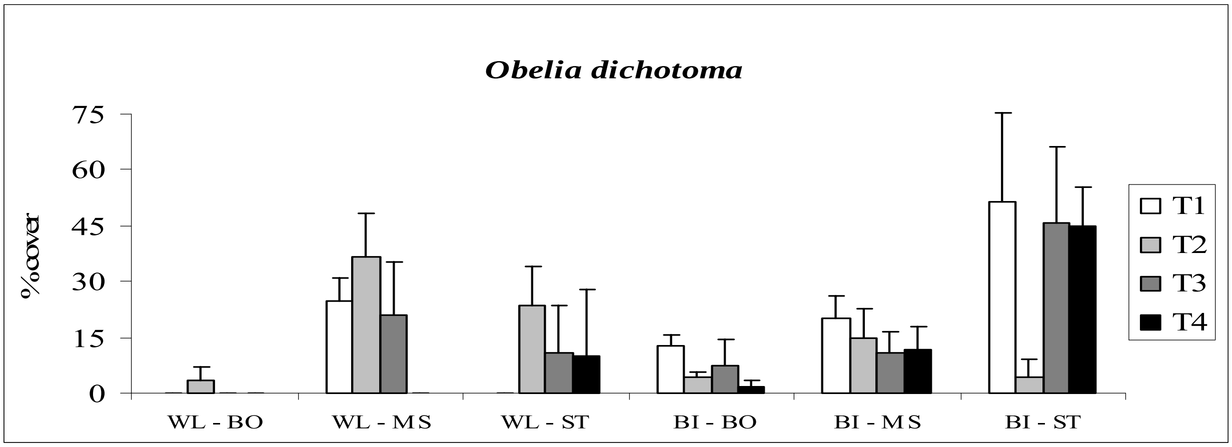


Fig. 8: The percentage cover and standard deviation of *Obelia dichotoma* on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Vitória / ES), time 3 (T3 – Macaé / RJ) and time 4 (T4 – Arraial do Cabo / RJ) of campaign B.

The barnacle *Balanus amphitrite* had most of its population placed on bilge ($p < 0.05$) and on bow ($p = 0.\ 05$) (Fig. 9 a). However, this barnacle had no change in its density by times ($p > 0.05$).

The distribution of *Balanus* spp. was homogeneous as vertical as horizontal hull parts ($p > 0.05$) (Fig. 9 b). Additionally, there were no modification of their density by times ($p > 0.05$), even though some parts of the hull as WL – BO and WL – MS showed a decrease of density.

On the other hand, *Balanus trigonus* also occurred mainly on bilge ($p < 0.05$), while it was quite distributed on horizontal parts ($p > 0.05$) (Fig. 9 c). Differently, this barnacle had its density decreased by times ($p < 0.05$).

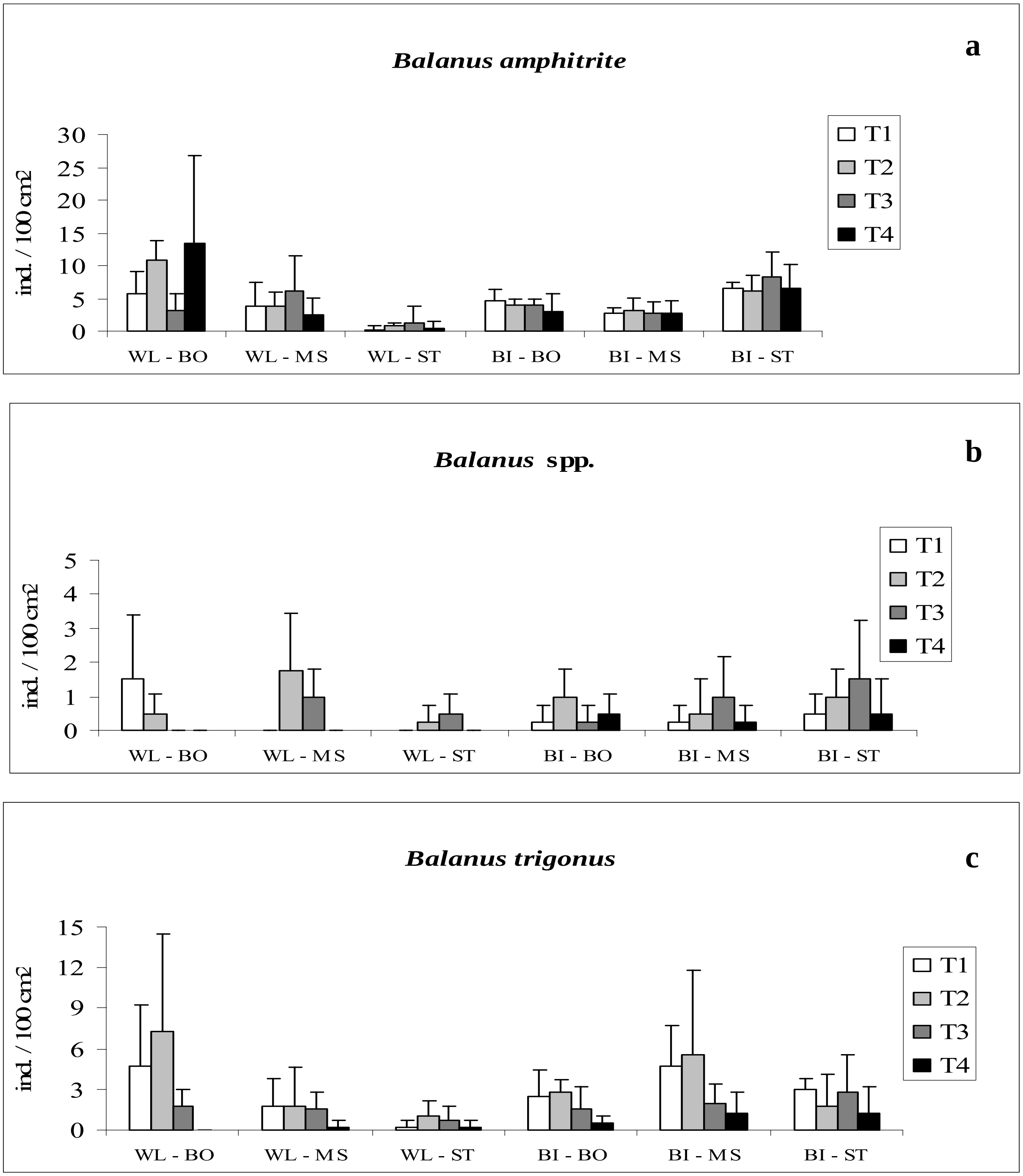


Fig. 9: The relative density and standard deviation of *Balanus amphitrite* (a), *Balanus* spp. (b – *Balanus improvisus* and *Balanus eburneus*) and *Balanus trigonus* (c) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Vitória / ES), time 3 (T3 – Macaé / RJ) and time 4 (T4 – Arraial do Cabo / RJ) of campaign B.

The *Megabalanus coccopoma*'s results showed homogeneous incidence on vertical parts ($p > 0.05$), although it had a larger presence on stern ($p < 0.05$) (Fig. 10 a). It had no modification of its population's density over times ($p > 0.05$).

The bivalve *Perna perna*, in its turn, had a larger presence on water line ($p < 0.05$) and on stern as well ($p < 0.05$) (Fig. 10 b). This bivalve had its density decreased from time 1 to time 3 particularly on the stern of water line ($p < 0.05$) as shown by HSD Tukey's test.

In addition, *Styela plicata* had a larger incidence on water line ($p < 0.05$) and on stern ($p < 0.05$) (Fig. 10 c). Conversely, this ascidian's results showed no change of its density in times ($p > 0.05$).

The Gammaridea occurred predominantly on bilge ($p < 0.05$) and on stern ($p < 0.05$) (Fig. 11 a). It had its density altered, but this time a decreased density by times ($p < 0.05$).

The caprellid *Caprella penantis* had a homogeneous distribution along vertical parts ($p > 0.05$) while it had a larger occurrence sited on stern ($p < 0.05$) (Fig. 11 b). In addition, this caprellid had its density altered by times ($p < 0.05$), but this time a decrease from T1 to T4.

The Tanaidacea's results showed a prevalent density placed on water line ($p > 0.05$) and on stern ($p < 0.05$) (Fig. 11 c). It had its occurrence decreased by times ($p < 0.05$).

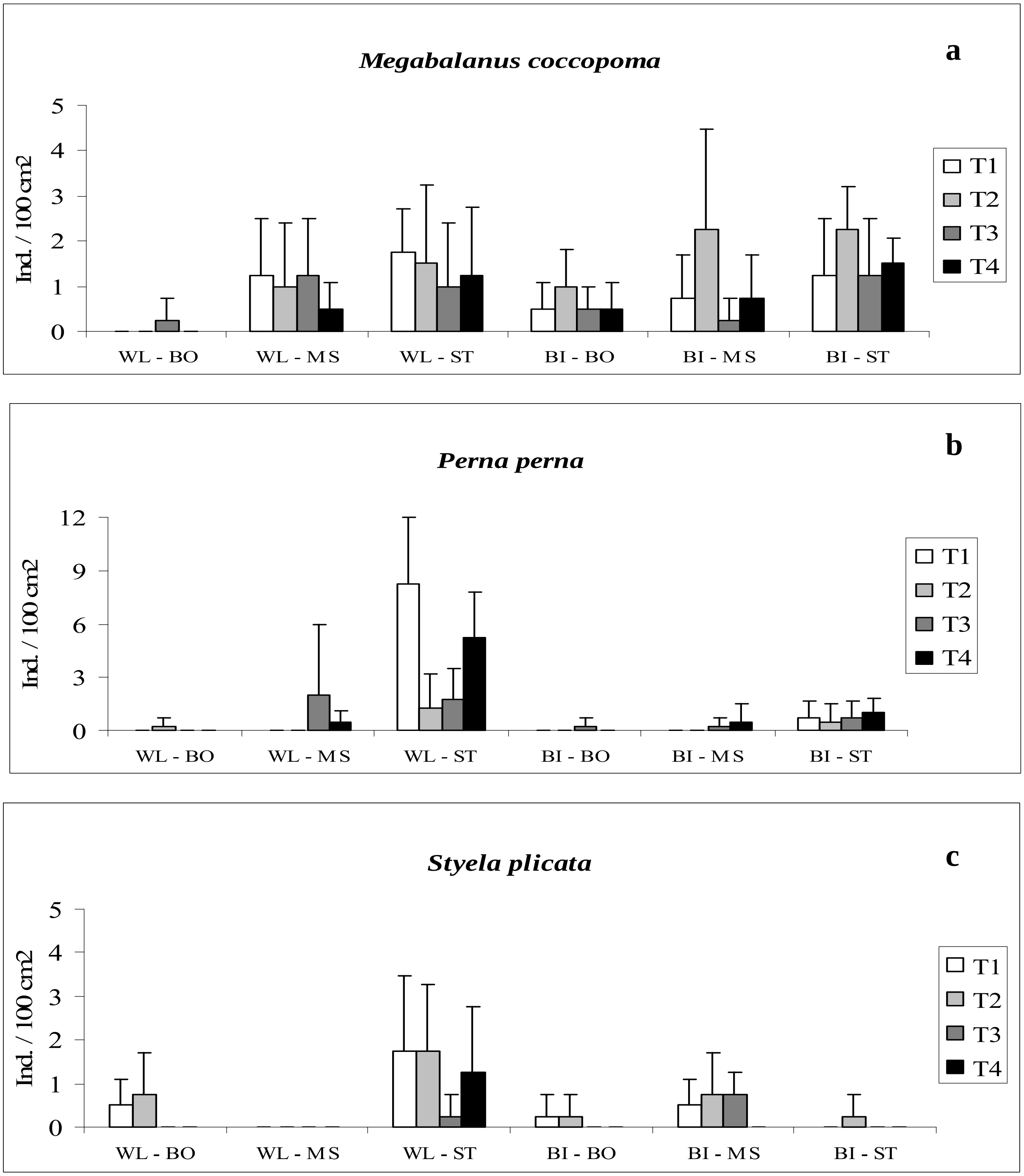


Fig. 10: The relative density and standard deviation of *Megabalanus coccopoma* (a), *Perna perna* (b) and *Styela plicata* (c) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Vitória / ES), time 3 (T3 – Macaé / RJ) and time 4 (T4 – Arraial do Cabo / RJ) of campaign B.

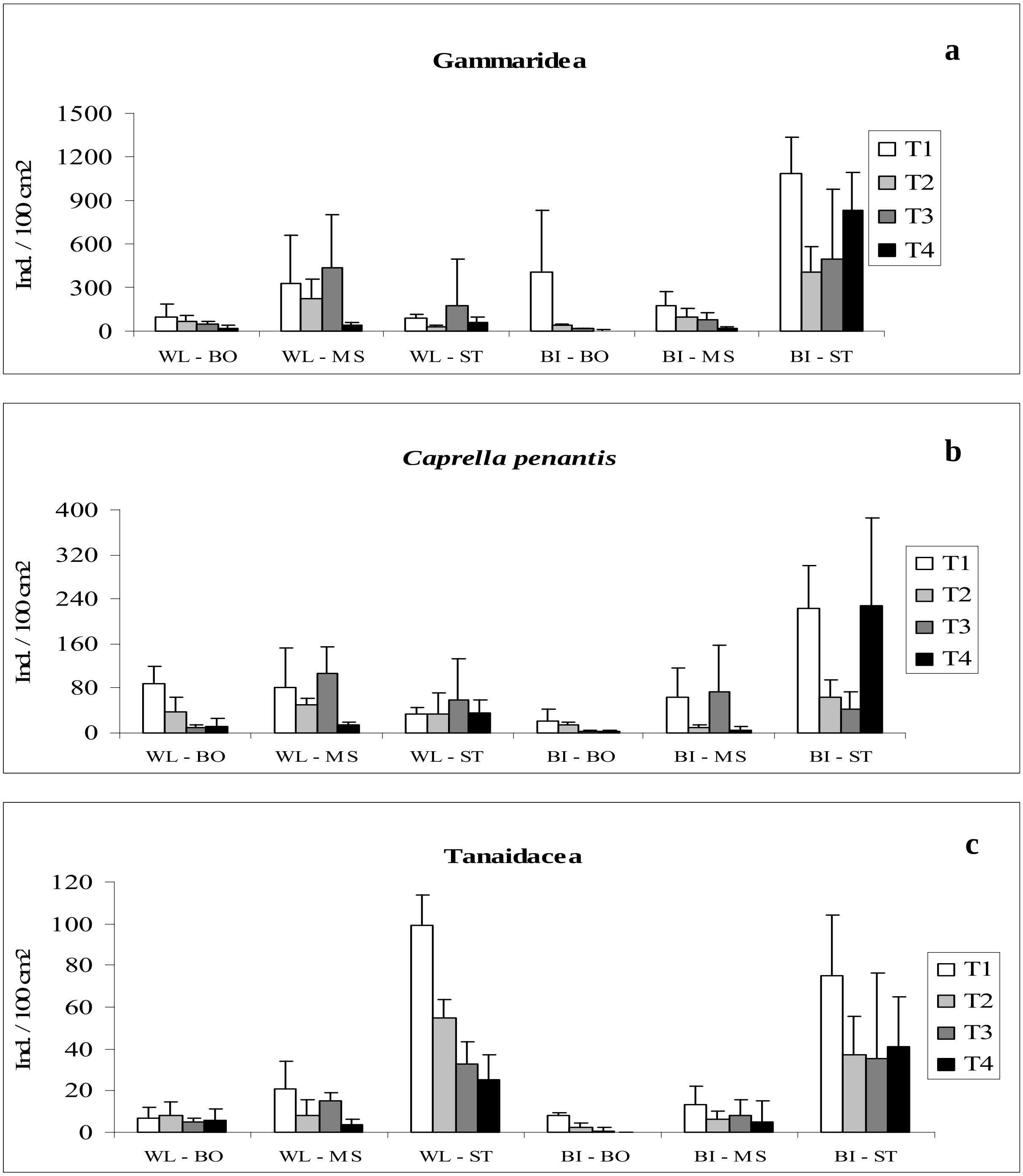
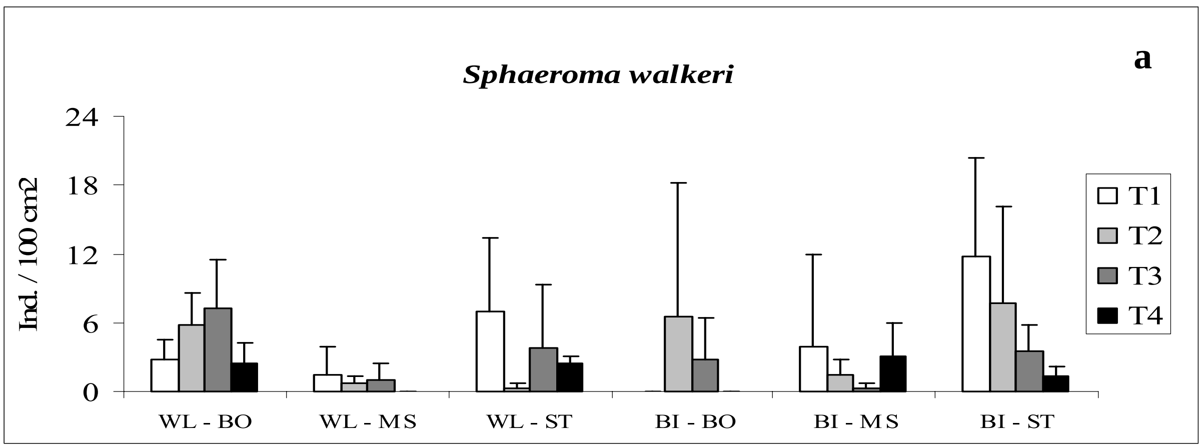


Fig. 11: The relative density and standard deviation of Gammaridea (a), Caprellidea (b) and Tanaidacea (c) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Vitória / ES), time 3 (T3 – Macaé / RJ) and time 4 (T4 – Arraial do Cabo / RJ) of campaign B.

The isopod *Sphaeroma walkeri* was homogeneously distributed on vertical hull parts ($p > 0.05$), while it had a larger presence both on bow and on stern when compared to mid-ship ($p < 0.05$) (Fig. 12 a). This isopod had no modification of its density by times ($p > 0.05$) even though a tendency of decrease is verified in its density.

Nematoda was not taking into consideration in campaign A. However, it was tested in campaign B and C. In fact, it was a surprise to find them at the samples, so we decided to count them from campaign B.

Most of Nematoda's population was placed on bilge ($p < 0.05$) and on mid-ship and stern when compared to bow ($p < 0.05$) (Fig 12 b). Besides, it had its density decreased by times ($p < 0.05$).



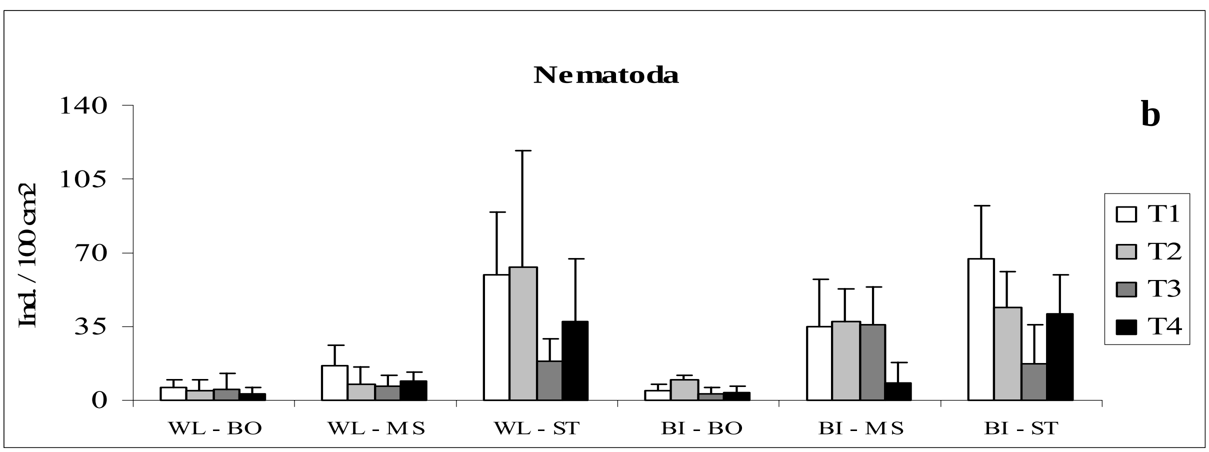


Fig. 12: The relative density and standard deviation of the Isopoda *Sphaeroma walkeri* (a) and Nematoda (b) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Arraial do Cabo / RJ), time 2 (T2 – Vitória / ES), time 3 (T3 – Macaé / RJ) and time 4 (T4 – Arraial do Cabo / RJ) of campaign B.

3.2.2.3 Tubarão campaign C

The hydroid *Obelia dichotoma* had most of its occurrence on bilge ($p < 0.05$) and on stern ($p < 0.05$) (Fig. 13 a). However, it had its cover unaltered over times ($p > 0.05$).

The Chlorophyceae *Ulva* sp. had its occurrence restricted to water line ($p < 0.05$) and on two horizontal parts: mid-ship and stern ($p < 0.05$) (Fig. 13 b). This alga had no modification of its presence by times ($p > 0.05$), although with a tendency of decrease.

The occurrence of *Enteromorpha* sp**.** was restricted to water line ($p < 0.05$) and bow ($p < 0.05$), exclusively (Fig. 13 c). This alga had its cover unaltered by times ($p > 0.05$), with a tendency of decrease as well.

The tubeworm *Hydroides elegans* was homogenous in the vertical parts of hull, while placed preferentially on stern ($p > 0.05$) (Fig. 14). Surprisingly, this tubeworm had its cover increased by times ($p < 0.05$).

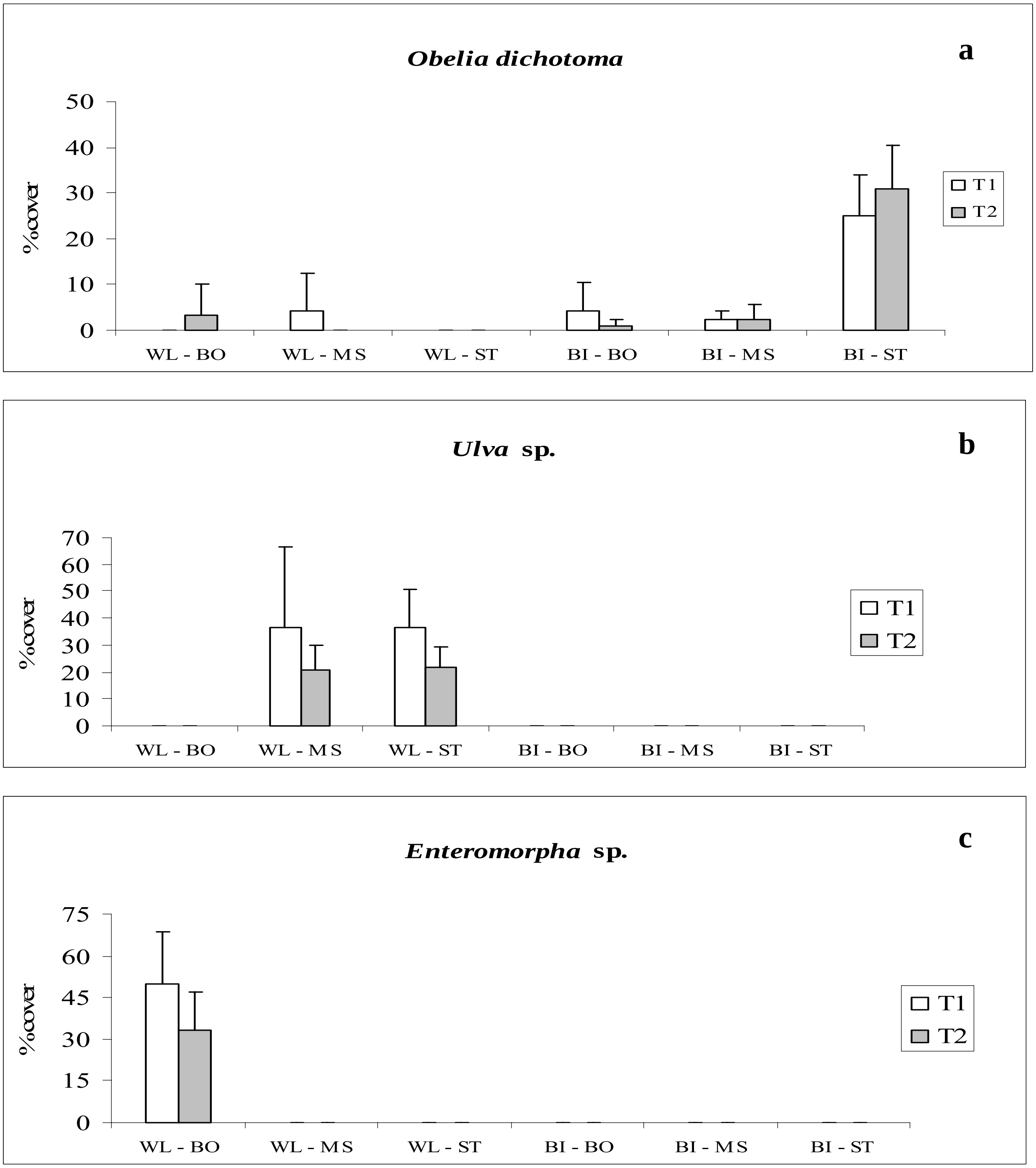


Fig. 13: The percentage cover and standard deviation of *Obelia dichotoma* (a), *Ulva* sp. (b) *Enteromorpha* sp. (c) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Niterói / RJ) and time 2 (T2 – Santos / SP) of campaign C.

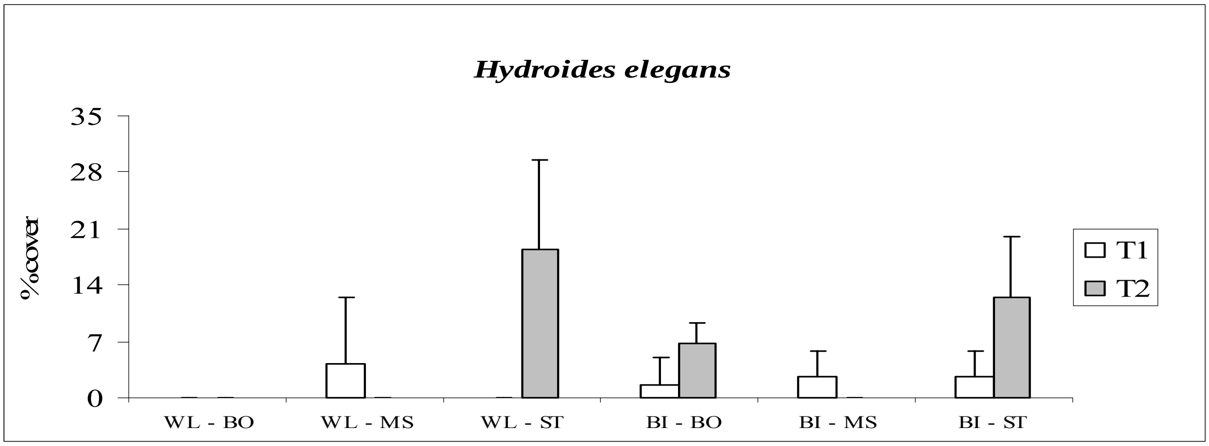


Fig. 14: The percentage cover and standard deviation of *Hydroides elegans* on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Niterói / RJ) and time 2 (T2 – Santos / SP) of campaign C.

The barnacle *Balanus amphitrite* occurred mainly on bilge ($p < 0.05$), although with a homogeneous density on horizontal parts ($p > 0.05$) (Fig. 15 a). This barnacle had no alteration of its density by times (p= 0. 05).

The occurrence of *Balanus* spp.'s on vertical ($p > 0.05$) and horizontal ($p > 0.05$) parts was homogeneous along the hull, even though most of these barnacles had a tendency to be placed on bilge (Fig. 15 b). The presence of *Balanus* spp. had no alteration along times ($p > 0.05$).

The distribution of *Balanus trigonus* was quite balanced as vertical ($p > 0.05$) as horizontal hull parts ($p > 0.05$) (Fig. 15 c). This barnacle had its density unaltered by times as well ($p > 0.05$).

On the other hand, *Megabalanus coccopoma* had a larger presence on water line than bilge ($p < 0.05$), while it had a homogeneous distribution along horizontal parts ($p > 0.05$) (Fig. 16 a). This barnacle had no change of its density by times ($p > 0.05$).

The bivalve *Perna perna* had most of its population sited on water line ($p < 0.05$) and on stern ($p < 0.001$) (Fig. 16 b). However, this bivalve had its density unaltered in times ($p > 0.05$).

With a similar result, *Styela plicata* had a homogeneous presence along vertical parts ($p > 0.05$), it had a larger occurrence on stern though ($p < 0.05$) (Fig. 16 c). This ascidian had no alteration of its density over times ($p > 0.05$).

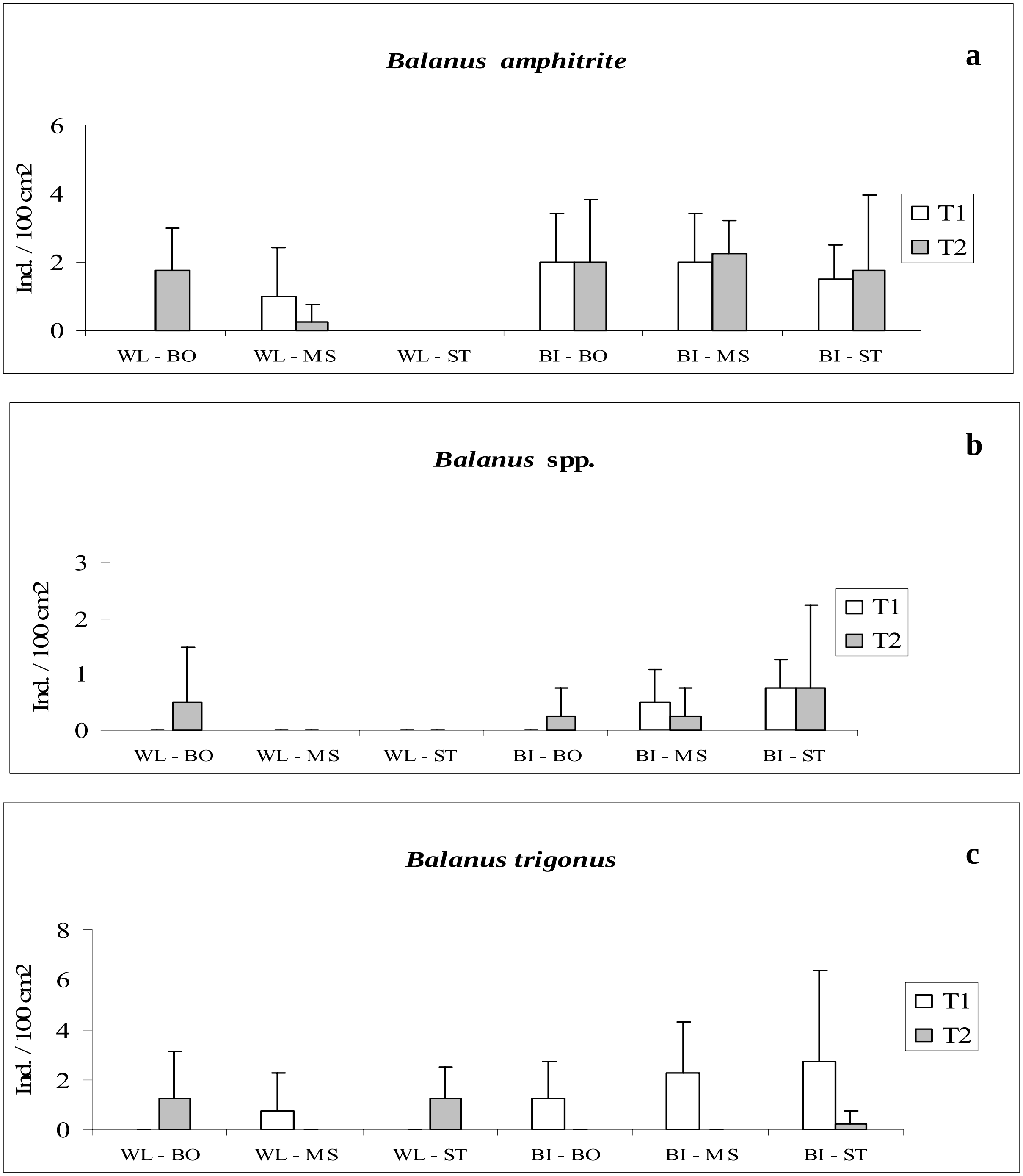


Fig. 15: The relative density and standard deviation of *Balanus amphitrite* (a), *Balanus* spp. (b – *Balanus improvisus* and *Balanus eburneus*) and *Balanus trigonus* (c) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Niterói / RJ) and time 2 (T2 – Santos / SP) of campaign C.

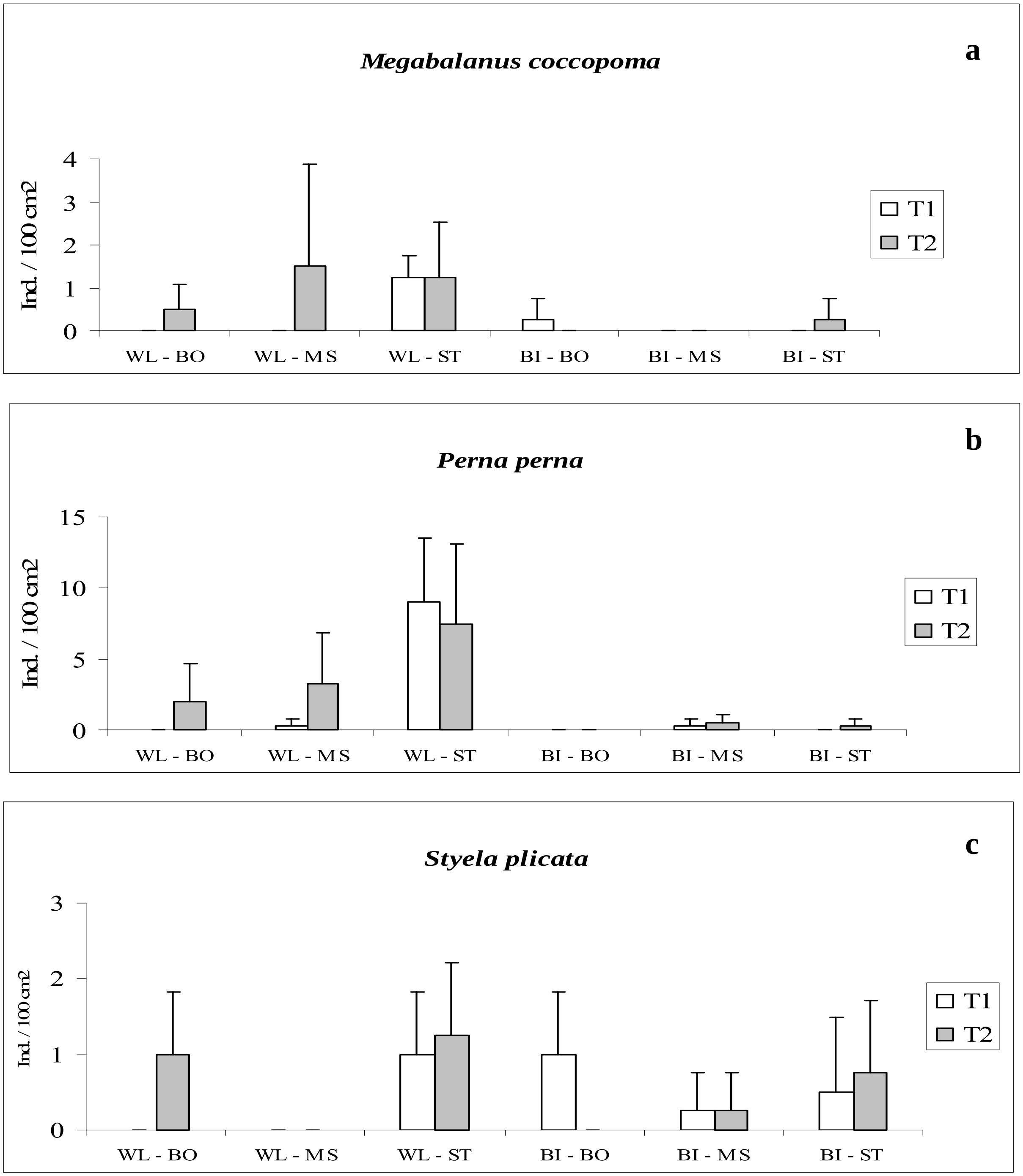


Fig. 16: The relative density and standard deviation of *Megabalanus coccopoma* (a), *Perna perna* (b) and *Styela plicata* (c) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Niterói / RJ) and time 2 (T2 – Santos / SP) of campaign C.

The Gammaridea had a larger incidence sited on bilge ($p < 0.05$), while it had a homogeneous distribution along horizontal parts ($p > 0.05$) (Fig. 17 a). It had no significative modification of its density by times ($p > 0.05$) even though a decrease of density is verified on bilge.

The *Caprella penantis* had homogeneous distribution as vertical ($p > 0.05$) as horizontal parts ($p > 0.05$) (Fig. 17 b). However, it had its density decreased over times ($p < 0.05$).

Conversely, the Tanaidacea occurred prevalently on bilge ($p < 0.05$) and on bow ($p < 0.05$) (Fig. 17 c). Nevertheless, it had its density unaltered by times in campaign C ($p > 0.05$).

The isopod *Sphaeroma walkeri* had a larger presence on bilge ($p < 0.05$), even though it had a homogeneous distribution on horizontal parts ($p > 0.05$) (Fig. 18 a). This isopod had no significative alteration of its density by times ($p > 0.05$) although a decrease of density is verified in some hull parts.

The Nematoda had a homogeneous presence both on vertical ($p > 0.05$) and on horizontal parts ($p > 0.05$) (Fig. 18 b). However, it had its density decreased by times ($p < 0.05$).

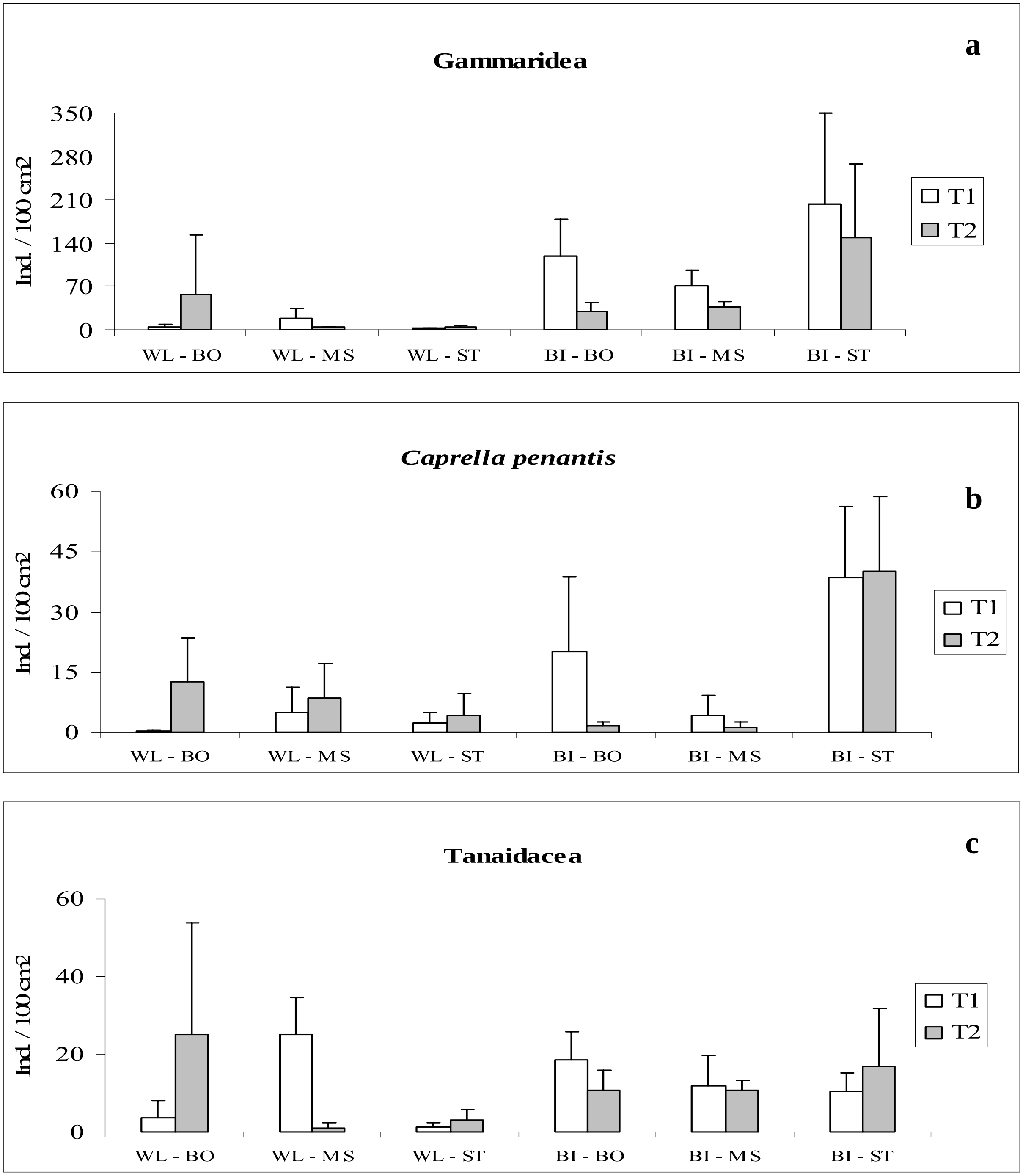


Fig. 17: The relative density and standard deviation of Gammaridea (a), Caprellidae (b) and Tanaidacea (c) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Niterói / RJ) and time 2 (T2 – Santos / SP) of campaign C.

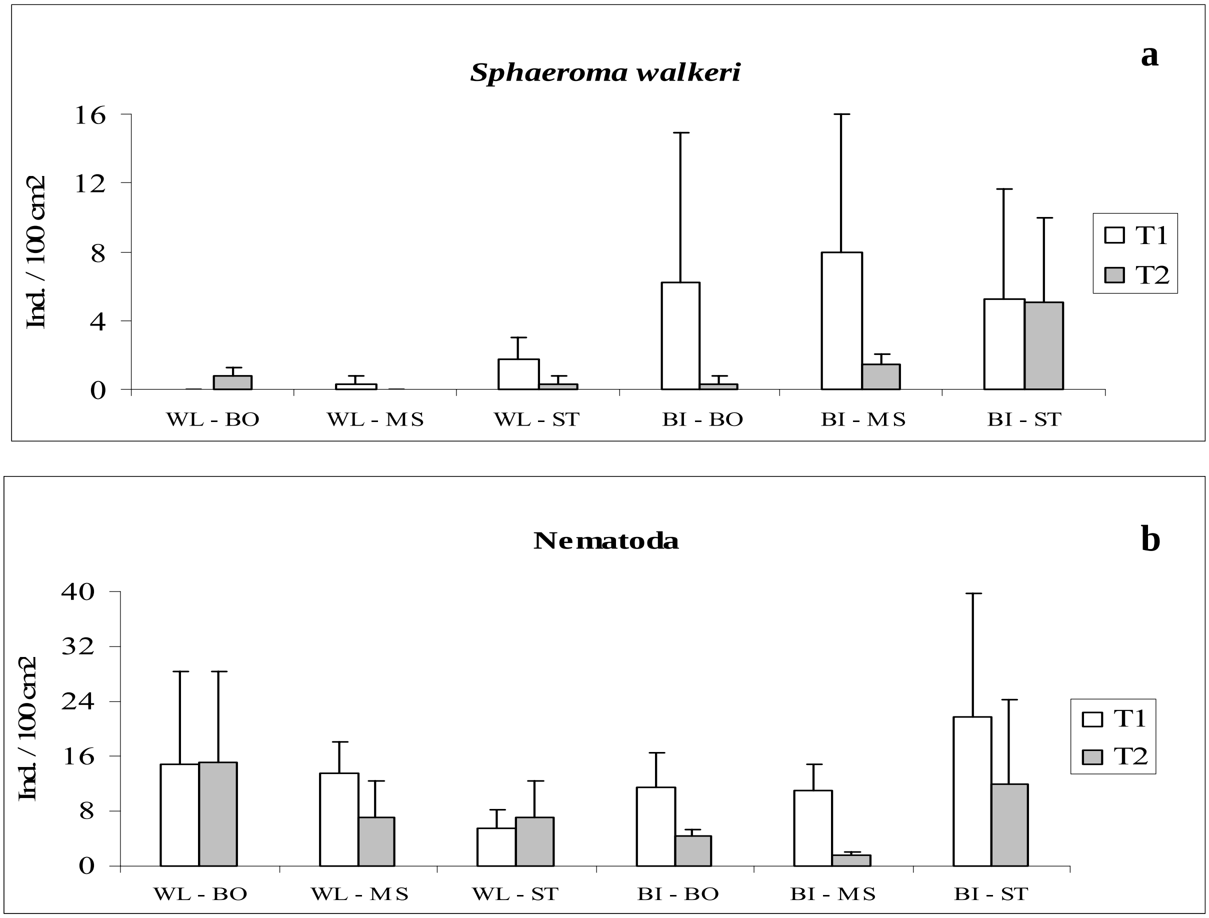


Fig. 18: The relative density and standard deviation of the Isopoda *Sphaeroma walkeri* (a) and Nematoda (b) on water line of bow (WL – BO), water line of mid-ship (WL – MS), water line of stern (WL – ST), bilge of bow (BI – BO), bilge of mid-ship (BI – MS) and bilge of stern (BI – ST), sampled at Tubarão hull along time 1 (T1 – Niterói / RJ) and time 2 (T2 – Santos / SP) of campaign C.

4– Discussion

The results achieved in these four campaigns showed that vessel hulls act as species' vectors to different regions. Several studies showed similar results (Carlton and Hodder, 1995; Rainer, 1995; Apte et al., 2000; Gollasch, 2002; Godwin, 2003; Minchim and Gollasch, 2003; Lewis et al., 2003, 2005; Wotton et al., 2004; Floerl et al., 2005 a; Floerl and Inglis, 2005).

It was observed a wide range of fouling organisms on their hulls such as seaweeds, hydroids, barnacles, polychaetes, bryozoans, crabs, bivalves, periwinkles, anemones, ofiuroids, sea squirts and, panthopods, amphipods, caprellids, tanaids, isopods and nematodes, particularly in Tubarão vessel (Tab. 3). Most of species found in this study are either native or cryptogenic, while four species are considered exotic in the coast of Brazil: *Megalanus coccopoma* (Young, 1998), *Perna perna* (Souza et al., 2004), *Isognomon bicolor* and *Styela plicata* (Fernandes et al., 2004). This fact reinforces that domestic vessels may facilitate the dispersion of exotic species already established within the Brazilian coast via hull fouling.

Thus, the intraregional transport, that is, the domestic navigation, bears great opportunity to the spreading of species beyond their distribution ranges, even with the existence of biogeography barriers. Wasson et al. (2001) stated that domestic navigation is usually more intense in comparison to international one. Carlton and Hodder (1995) and Wotton et al. (2004) declared that most of domestic vessels or crafts are pleasure boats, barges, fisheries boat under low-speed and relatively lengthy port residence, that act extending the distribution of species along continental margins across local barriers such as capes, pontoons, and coastal or ocean currents. Additionally, a study in Western Australia coast suggested that hull fouling of recreational vessels are more likely to spread exotics species already introduced to other non invaded regions, especially World Heritage Properties such as Shark Bay (Wyatt et al., 2005) and the isolated Antarctic continent (Lewis et al., 2005).

Besides, some domestic vessels may traverse distances that could characterize the interregional transport. Thus, regarding the huge Brazilian coast (~ 8.500 km), domestic vessels may transport species on their hulls for thousands of km. For instance, the vessel of Frotargentina campaign traversed ~ 4.000 km of coast, while in Tubarão campaign B the vessel traversed ~ 778 km (Tab. 2).

Other feature verified in this study is that the fact of one species being sessile or vagile does not influence totally the alteration or maintenance of its density on vessel hull after voyages. Sessile and vagile benthic species might have their densities increased, decreased or unaltered by times. Furthermore, they may present or not a prevalently distribution on certain hull part(s). Probably, factors such as mechanisms of fixation or mobility, age of organisms, velocity of vessel, duration of the voyage, and the strong variation of abiotic factors such as salinity and temperature are the most important ones to determine the propensity of certain species to be transported on hull to a number of different port regions. In addition, Floerl et al. (2005 a) assured that hull fouling transport pathway can, itself, impose selective pressures that have a strong influence on the suite of species that subsequently survive transportation.

Frotargentina campaign had 100 % of species' density maintained by times. In Tubarão campaign A there was 63, 6 % of species' density maintained by times; in Tubarão campaign B there was 41,7 %; and Tubarão campaign C had 92, 9 % of species' density maintained by times. The differences in the percentages might be related to duration of campaigns, distances traversed in voyages (see Tab. 2) and species' resistance to turbulence. In addition, the consistent pattern of species being transported to different regions found in this study, even with some restrictions, makes sense with a similar experiment and results demonstrated by Carlton and Hodder in 1995. They verified 95, 92 and 90 % of survivorship (or resistance) of species being successfully transported on hull, in their legs (or campaigns) 1, 2 and 3, respectively.

The barnacles were the most dominant and resistant to vessels voyages. In fact, they are largely known as "vessel-dirtiness" in the whole seas, as pointed out by Ruppert and Barnes in 1996. The barnacle *Balanus amphitrite* had the largest density in comparison to other sessile fauna in all campaigns. Besides, *B. amphitrite* and *Balanus* spp. (*Balanus improvisus* and *Balanus eburneus*) had densities unaltered along times in all campaigns. However, *Balanus trigonus* and *Megabalanus coccopoma* were not constants by times as the other barnacles. For some reason, *M. coccopoma*'s density decreased by times in Tubarão campaign A, and a similar result was observed with *B. trigonus* in Tubarão campaign B. Although Ruppert and Barnes (1996) have mentioned the continuous growing of barnacles' carapace during their life history and its resistance to turbulence, individuals of *M. coccopoma* and *B. trigonus* were likely released from Tubarão hull due to the weakening of their carapaces for some time after their decease.

The bivalve *Perna perna* had a similar pattern to the one observed with barnacles. Although it had its density maintained by times of campaign A and C, there was a significant reduction of its density observed from T1 to T3 on the water line of stern in campaign B. However, mussels showed propensity for the transport to different regions as observed by Apte et al. 2000, where the blue mussel *Mytilus galloprovincialis* was effectively transported on a military vessel hull from Washington to Hawaii (USA).

The size of individuals might increase the pressure drag by the stream, as pointed out by Levinton (1995), and it seems to be an important fact in the transport of species as *Styela plicata* and *Bugula neritina*. The *S. plicata*, the only ascidian found in this study, had most of its population with larger individuals (3 – 7 cm) in Tubarão campaign A than campaign B and C (0, 5 – 2 cm), showing a significant reduction of density in campaign A, but not in campaigns B and C. This pattern was also observed with *Bugula neritina*, because its density decreased significantly by the times of campaign A when most of its population had 4 to 8 cm height, but not in campaigns B and C where most of colonies had 0, 5 to 2 cm height.

On the other hand, *Obelia dichotoma*, the only hydroid found, had its density decreased in campaign B, but unaltered by times in Tubarão campaign C, probably due to the campaign duration. Tubarão campaign B lasted 7 days while campaign C lasted 25 h. This result agrees with Carlton and Hodder (1995), where they observed that hydroids might suffer extensive loss of hydranths in long voyages.

The tubeworm *Hydroides elegans*, conversely, had its density with a significative increase from time 1 to time 2 of Tubarão campaign C (Fig. 14). This "increase" was likely related to the fact that *H. elegans* was more evident in time 2, because *Ulva* sp. might have obscured the presence of *H. elegans* in time 1. Furthermore, both of them were placed at the same hull part (stern), and *Ulva* sp. had its density decreased between times 1 and 2 of campaign C, although not significantly (Fig. 13 b). Carlton and Hodder (1995) found a similar situation between the amphipod *Corophium* sp. and the bryozoan *Conopeum tenuissimun*. In their first sample of Leg II, the mud tubes of *Corophium* sp. probably obscured the presence of *C. tenuissimum*, while this bryozoan became more evident in their second sample because the water-drag removed most of the amphipod's mud tubes.

The macroalgae found in the hulls of vessels showed to be resistant to vessels voyages, including the long round voyage of Frotargentina (~ 4.000 km). None of algae had any limitation to be transported, neither their density suffered significative decrease, even if some tendency of decrease was realized for *Ulva* sp. and *Enteromorpha* sp.. This showed that the algae attachment mechanism, the holdfasts, were efficient to hold on to hull, but their fronds morphotype might play an important hole in their resistance to water-drag. Another important aspect observed was that some species as *Enteromorpha* sp. might settle on hull in a short period of vessel mooring. It probably happened when Frotargentina vessel was moored at Guanabara Bay nine days before its departure to Areia Branca in Rio Grande do Norte State, as it was not found in Frotargentina hull in the first sample (Fig. 2 c). This fact illustrates that opportunist organisms such as *Enteromorpha* sp. might use, effortlessly, vessels hulls as substratum and, consequently, vector to a number of port regions. For instance, the Chlorophyceae *Codium fragile* spp. *tomentosoides* and *Undaria pinnatifida* are pointed out as macroalgae successfully transported on vessels hulls through intraregional and interregional transport, being considered pests in many invaded regions (Schaffelke and Deane, 2005; Wotton et al., 2004).

On the other hand, mobile species such as amphipods and tanaids did not show a clear pattern as some sessile species, because their densities increased in campaign A, decreased in campaign B, and maintained constant campaign C. Two reasonable explanations about the increase of their densities in campaign A are the colonization by amphipods and tanaids from port pilings where Tubarão vessel stayed moored and/or a reproductive event in campaign A. However, it is difficult to explain the reason that made their densities decrease in campaign B, and maintain themselves in campaign C.

The Caprellidae *Caprella penantis*, in its turn, had its density increased in campaign A, but its results showed to be consistent in campaigns B and C, where its density decreased by times. Probably, the results of campaign A have the same explanation given to amphipods and tanaids. However, the results of campaigns B and C are likely related to the mean velocity of Tubarão vessel, which was 18, 6 km/h (Tab. 1). Carlton and Hodder (2005) verified that caprellids were not able to maintain themselves on hull in a mean velocity of 7, 4 km/h.

On contrast, *Sphaeroma walkeri* showed a similar pattern found with *B. amphitrite* and *B. trigonus*. In all Tubarão campaigns, *S. walkeri* had its density unaltered by times. In fact, many individuals of *S. walkeri* were observed sheltered in many dead hard carapace of *Balanus amphitrite*, probably, in an attempt to escape from the drag during voyages. Consequently, *S. walkeri* had no limitation in its population transport through Tubarão vessel hull.

The nematodes showed a consistent pattern. Their densities decreased by times in both campaigns B and C. These results are probably linked to their limited capability to keep themselves attached to any substratum (Brusca and Brusca, 2003), principally on hull while vessel is roaming.

Most of sessile and mobile benthic organisms found on hull of vessels studied showed either a homogeneous or a heterogeneous distribution pertaining to vertical and horizontal hull parts. The barnacles had homogeneous distribution on hull predominantly. The best example of this pattern was *Balanus* spp. because it was homogeneously distributed on vertical and on horizontal parts in all Tubarão campaigns. However, *B. amphitrite* was sited mainly on bilge, regarding to horizontal parts

Conversely, *Perna perna*, *Styela plicata*, *Bugula neritina*, the Chlorophyceae algae *Ulva* sp. and *Enteromorpha* sp. had heterogeneous distributions, predominantly, on the vessel hull. While *P. perna*, *S. plicata* and *Ulva* sp. were sited mainly in water line and on stern, *Bugula neritina* and *Enteromorpha* sp. were placed mainly on bow of water line. The preferential distribution of these species on water line is likely related with their natural distribution on the intertidal zone of rocky shores, mainly for *Ulva* sp. and *Enteromorpha* sp. as pointed out by Bold and Wynne (1985).

The hydroid *Obelia dichotoma*, in its turn, was placed mainly on bilge and stern. Therefore, it followed the pattern of heterogeneous distribution along hull. Although it is not easy to explain the *O. dichotoma*'s location on those parts, probably it is related to its preference for shaded areas of hull (Lewis et al., 2003), that is, mid-tide level depths (Cornelius, 1995).

The *Hydroides elegans* was homogeneously distributed on water line, but abundant on stern. However, its presence accentuated on stern might be explained by loosen of some *Ulva sp* fronds due to turbulence particularly on the water line of the stern ($p < 0.05$). It also agrees to a similar result found in an experiment with vessel hull in the 90's (Carlton and Hodder, 1995).

The amphipods were predominant as *Obelia dichotoma* on the bilge of Tubarão vessel. Additionally, the author observed in field many gammarids sheltered in tubes of an unidentified sediment on Tubarão bilge. Reise and Barnard (1979) stated that amphipods as *Corophium sp* spin tubes or cradles that often agglutinate silt particles that can become very thick when animal attach tube over tube, and it can be used as home of many domicolous gammarids. In addition, the author observed in lab that the mud tubes of amphipods were interlaced by colonies of *O. dichotoma*. The bivalve *Atrina seminuda* is characteristic of soft sand and mud (Rios, 1985; F.C. Fernandes, personal communication 2006), and it was found in the samples of Tubarão hull vessel. Probably, it was living between the mud tubs of amphipods.

The caprellid *Caprella penantis* and nematodes were homogeneously distributed, showing no clear relation with sessile organisms. However, tanaids were placed preferentially on water line, perhaps using as shelter some sessile species such as *Enteromorpha* sp. and *Ulva* sp.. The predominance of *S. walkeri* on bilge may be linked to *B. amphitrite* predominance on the same hull vertical part.

This study showed that vessel hulls remain as important vectors of benthic sessile and vagile species as many authors have pointed out (Elton, 1958; Carlton and Hodder, 1995; Rainer, 1995; Apte et al., 2000; Wotton et al., 2004; Lewis et al., 2003; 2005). Nevertheless, some studies minimized the importance of hull fouling in the spread of species at least for commercial vessels (Carlton, 1985; National Research Council, 1996; Krebs, 2001). Although the advent of ballast tanks and antifouling paintings in the 20th century had minimized much of the importance of vessel hull as vector of species, many scientists warned that this transfer through hull fouling is still a threat despite of the great focus on ballast water as species' mechanism of transfer (Bax et al., 2003; Godwin, 2003). Besides, hull fouling was similarly ranked with ballast water as vectors of high risk in the species' introduction for both international and domestic activities (APEC, 2001).

Antifouling paints might be effective in the beginning of interdocking period, but between 2 to 5 years, many organisms may start fouling on hull due the aged coating and the decreased efficiency of the biocide (Trentin et al., 2001). Rainer, 1995, verified that aged antifouling paints are likely to be colonized by animals and plants, and even well maintained vessels might be exposed to fouling by algae, barnacles and tubeworms. Floerl et al. (2005 c) pointed out the age of toxic antifouling paint as the principal risk for hull fouling. It was observed in both ships studied, because Frotargentina vessel last docking period was in July 2002 and, the Tubarão last docking was in August 2004. Nonetheless, the species richness of fouling organisms on Tubarão hull seemed like higher than Frotargentina hull (personal observation). It must be related to the fact the Frotargentina vessel was navigating most part of time, while Tubarão vessel navigated less and stayed moored most part of time, since they left docking period. Furthermore, Frotargentina is a commercial vessel and Tubarão is a military one, that is, many domestic vessels do not use antifouling paints correctly and are far copious of fouling than the commercial and military well-maintained vessels of this study.

The antifouling paints do not supply the assurance that, even in a short term, fouling organisms cannot be transported on hulls to different regions. Besides, the International Maritime Organization (IMO) does implanted a rigid and extensive program of studies with the aim to resolve the problem of introductions via ballast water, while hull fouling mechanism transfer is underestimated (Ferreira et al., 2004). Other big problem on sight is the international and national movements to phase out the use of TBT antifouling paints, which are likely going to increase both the chance of species' dispersal by vessel hulls (Hewitt and Martin, 1996, 2001) and the capital costs of commercial shipping due to their reduced velocity and cargo transport capacity (Strandenes, 2000). In addition, Floerl et al., 2005 a, demonstrated that current approaches to prevent colonization on boat hulls do not prevent the transport of all species. These studies emphasize the importance of hull fouling as transfer mechanism through intraregional transport of species (Wasson et al., 2001).

The use of water as vessel ballast, from the final of 20th century to nowadays, obfuscated the historical role of vessel hulls in the spread of species (Carlton, 1985; National Research Council, 1996; Krebs, 2001). While ballast water is pointed out as responsible for many species introductions throughout oceans, the underestimation of vessel hull as vector may conceal some introductions attributed to ballast water (National Research Council, 1996; Bax et al., 2003). Moreover, while vessels are supposed to obey to international, national laws and procedures that diminish ballast water threats (Bax et al., 2003), these same vessels need a mooring period in port regions. Thus, fouling species on hull might find positive conditions to start the process of their introduction on ports, maybe with larger chances than ballast water typical organisms (Minchim and Gollasch, 2003).

At last, the present study also supports the use of foul release coatings (silicone technology), as they prevent the strong attachment of fouling organisms due to their low surface energy. This way, as Candries et al. (2001) and Swain et al. (2003) observed, when a vessel reaches a high velocity (> 15 knots = > 27, 7 km/h) fouling organisms on hull are removed relatively ease by the hydrodynamic forces against surface. The vessels of the present study have not reached velocities above 15 knots. However, the experiments performed with them demonstrated the species that were resistant and the species that were not resistant to hydrodynamic forces generated with velocities below 15 knots. Thus, it is possible to predict which species are more capable to offer resistance to silicone coatings.

Therefore, the proper acknowledgement, the regulation and accomplishment of preventive actions, the phase out of TBT in 2008, and the investment on researches about hull fouling as species' vector are urgencies.

5. Conclusions

- The hulls of regional vessels are efficient vectors of marine species, and so are threats in the process of bioinvasion.
- Hull fouling has a large variety of sessile benthic organisms: barnacles, macroalgae, mussels, ascidians, bryozoans, crabs, sea spiders, polychaetes, hydroids, anemones, brittle stars, and the associated vagile fauna of amphipods, caprellids, isopods, tanaids and nematods. Besides, exotic species as *Megalanus coccopoma*, *Perna perna, Styela plicata* and *Isognomon bicolor* were transported on hull of vessels studied as well.
- In general, sessile species maintained their population densities steady along voyages. On the other hand, the most part of vagile species/groups had their population densities unsteady along voyages.
- The barnacles *B. amphitrite* and *Balanus* spp., the tubeworm *Hydroides elegans* and the macroalgae *Ulva* sp., *Enteromorpha* sp. and *Polysiphonia* sp. were the most susceptible sessile organisms to be transported to other regions through vessel hulls. Regarding to vagile species, the isopod *Sphaeroma walkeri* also showed a large susceptibility to be transported by this vector due to its habit of sheltering within dead barnacles carapaces.
- Some hull parts are occupied preferentially by certain species. Nonetheless, there are species distributed homogeneously along the hull of vessels.
- Species as the Chlorophyceae *Enteromorpha* sp. may settle rapidly the hull of vessel while it is moored and be transported to other regions.

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Considerações Finais

Os resultados do presente estudo mostraram que tanto espécies sésseis como vágeis foram transportadas no casco dos navios, embora algumas das espécies tenham sido mais resistentes às viagens. No caso do navio Frotargentina, a craca *Balanus amphitrite*, a rodofícea *Polysiphonia* sp. e a clorofícea *Enteromorpha* sp. não apresentaram nenhuma limitação à longa viagem de aproximadamente 4.000 km. Um fato importante foi a detecção da clorofícea *Enteromorpha* sp. na segunda e na terceira amostragem, pois não foi detectada na primeira amostragem. Provavelmente, esta alga colonizou rapidamente o casco do Frotargentina no período de nove dias em que ficou fundeado na Baía da Guanabara (RJ), entre o tempo 1 e o tempo 2. Outro importante aspecto foi a presença de *Megabalanus coccopoma* fazendo parte da biota incrustante do casco deste navio, mostrando que espécies exóticas como esta podem ter sua dispersão facilitada por navios domésticos.

Nas campanhas da lancha Tubarão verificou-se que as cracas *B. amphitrite*, *Balanus* spp. (agrupamento de *Balanus improvisus* e *Balanus eburneus*), o poliqueto *Hydroides elegans*, as algas *Enteromorpha* sp. e *Ulva* sp. foram as espécies sésseis com grande potencial de transporte no casco para diferentes regiões. Contudo, as cracas *Megabalanus coccopoma*, *Balanus trigonus*, o bivalve *Perna perna* e o hidróide *Obelia dichotoma* apresentam alguma limitação no seu transporte, como demonstrado pelas reduções significativas de suas densidades em algumas campanhas. Por outro lado, o briozoário *Bugula neritina* e a ascídia *Styela plicata* apresentaram uma redução mais severa de suas densidades nas viagens, sobretudo quando a população era predominantemente adulta. Também foram transportadas espécies exóticas nos cascos dos navios estudados: *Megabalanus coccopoma* em ambos os navios, *Perna perna*, *Isognomon bicolor* e *Styela plicata* somente no navio Tubarão.

Houve uma grande variação entre as espécies em relação a sua distribuição horizontal e vertical ao longo do casco dos navios. Em relação à distribuição vertical, as cracas *Balanus* spp. estiveram distribuídas homogeneamente na linha d'água em todas as campanhas, enquanto que *B. trigonus*, *M. coccopoma* e *Hydroides elegans* tiveram uma maior ocorrência na linha d'água somente em algumas campanhas. Por outro lado, a craca *B. amphitrite* e o hidrozoário *O. dichotoma* se apresentaram abundantes nas obras vivas. Em todas as campanhas Tubarão, *P. perna*, *S. plicata*, *B. neritina*, e as algas *Ulva* sp. e *Enteromorpha* sp. foram encontradas em maior número na linha d'água, provavelmente por ser um ambiente semelhante às faixas entremarés dos costões rochosos. Em relação à distribuição horizontal, as cracas estiveram homogeneamente distribuídas da proa à popa, *B. neritina* e *Enteromorpha* sp. foram encontradas principalmente na proa, enquanto *S. plicata*, *O. dichotoma*, *H. elegans* e *Ulva* sp. estiveram abundantes na popa. A maior presença de organismos sésseis na popa pode estar relacionada com a menor turbulência, nesta parte do casco. De fato, os resultados mostraram uma maior abundância e riqueza de espécies sésseis na popa.

Com relação às espécies vágeis, somente o isópode *Sphaeroma walkeri* demonstrou ser resistente às viagens. O hábito desta espécie de se abrigar em carapaças de cracas mortas certamente contribuiu para a manutenção da sua densidade populacional. Por outro lado, os nematódeos sofreram redução significativa de suas densidades nas duas campanhas em que foram testados. Embora possa haver uma colonização de organismos vágeis ao longo das campanhas, foi possível verificar que eles não resistem bem à turbulência gerada pela água, provavelmente por não terem mecanismos de fixação em substrato. Os anfípodes, o caprelídeo *Caprella penantis* e os tanaidáceos não apresentaram um padrão claro em relação às viagens. O aumento da densidade destes grupos, verificado em algumas viagens, pode resultar da colonização pela fauna local de substratos artificiais dos portos visitados. Contudo, a subseqüente diminuição da abundância destes organismos, depois de determinadas viagens, deveu-se a sua dificuldade de se manterem eficientemente associados ao casco dos navios. Com relação à distribuição vertical dos organismos vágeis no casco dos navios, alguns deles tais como *C. penantis*, os nematódeos e os tanaidáceos foram mais abundantes na linha d'água, enquanto que anfípodes e isópodes foram abundantes nas obras vivas. Quanto à distribuição horizontal ao longo do casco, todas as espécies/grupos vágeis estiveram homogeneamente distribuídas, com exceção de *S. walkeri* que foi mais abundante na proa.

Conclusões

- Os cascos de navios regionais são eficientes transportadores de espécies marinhas, sendo uma ameaça no processo de bioinvasão.
- As incrustações nos cascos foram compostas de uma grande variedade de organismos bentônicos sésseis: cracas, bivalves, macroalgas, ascídias, briozoários, caranguejos, picnogonídeos, poliquetos, hidrozoários, anêmonas, ofiuróides, e a fauna associada composta de anfípodes, caprelídeos, tanaidáceos e nematódeos. Espécies exóticas tais como *Megabalanus coccopoma*, *Perna perna*, *Isognomon bicolor* e *Styela plicata* também foram transportadas no casco dos navios estudados.
- As espécies sésseis, em geral, mantiveram suas densidades populacionais estáveis ao longo das viagens. Por outro lado, a maior parte das espécies/grupos vágeis tiveram suas densidades populacionais instáveis ao longo das viagens.
- As cracas *B. amphitrite* e *Balanus* spp., o poliqueto *Hydroides elegans* e as macroalgas *Ulva* sp., *Enteromorpha* sp. e *Polysiphonia* sp. foram os organismos sésseis mais susceptíveis ao transporte para outras regiões no casco de navios. O isópode *Sphaeroma walkeri* também mostrou grande susceptibilidade para este tipo de transporte, devido ao hábito de abrigar-se dentro de carapaças de cracas mortas.
- Algumas partes do casco do navio são ocupadas preferencialmente por determinadas espécies. Contudo, há espécies que são distribuídas homogeneamente ao longo do casco.
- Espécies como a clorofícea *Enteromorpha* sp. podem colonizar rapidamente o casco do navio, enquanto este estiver fundeado num porto e ser transportadas para outra região.