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A N I N T E R N A T I O N A L J O U R N A L

Introduced and Cryptogenic Species and Their Management in Paranaguá Bay, Brazil

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ABSTRACT

The aim of this work was to identify the introduced and cryptogenic species in encrusting and associated communities of hard substrates in Paranaguá Bay, Brazil, and to attempt to determine which of these species could negatively affect the local community to suggest management strategies for these species. At least four introduced species were found – a large number in comparison with other port surveys. These were the hydrozoan Garveia franciscana *Torrey, 1902, the polychaete* Polydora cornuta *Bosc, 1902, the barnacles* Amphibalanus reticulatus *(Utinoni, 1967) and* Striatobalanus amaryllis *Darwin, 1854, all with potentially harmful impacts. Of the 33 cryptogenic species, four were also listed in the literature as causing negative effects. We propose the following management practices: periodic cleaning of all underwater structures, population monitoring of invasive species and potential substrates, an information database of potential sources of introduction.*

Key words: Bioinvasion, introduced species, management, biofouling, artificial substrates, Paranaguá Bay

INTRODUCTION

The introduction of marine organisms in new environments, such as ports and bays, has a long history, but recently the rate of introduction has increased dramatically and is largely due to the navigation (Carlton, 1989; Ruiz et al., 2000). Normally, after the introduction, only a small fraction of the exotic species manages to survive and become established in the new environment. [1]An even smaller number has a detectable negative impact on the local community. Nevertheless, the eradication of an established introduction is very difficult or even impossible (Critchley et al., 1986; Bax et al., 2001). Therefore, it becomes important to predict the species that may become problematic upon introduction and in which circumstances they may become so, in order to avoid the negative impact of an invasive species from the outset (Daehler and Strong, 1993; Williamson and Fitter, 1996; Ricciardi and Rasmussen, 1998; Marchetti et al., 2004).

The introduction and establishment of exotic species in any given location depends upon a variety of factors, including genetic variability (Huxel, 1999; Grosholz, 2002), body size (Grosholz and Ruiz, 2003), abundance, capacity for local adaptation and physiological tolerance (Lee, 2002) and reproductive strategies (Ruiz et al., 1997). Also, the local conditions, such as food availability, diversity of the local community, predators, and the level of perturbation of the local community will also influence the establishment of exotic species (Cohen and Carlton, 1998, Lee 2002).

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Many introduced species in Australia, New Zealand and Hawaii are encrusting. They, and their associated fauna, were probably introduced due to the incrustations that accumulated on the hulls of boats and other floating structures (Eldredge and Carlton, 2002). This vector is not very well regulated, if at all, and continues to be an important means by which exotic species reach new locations (Gollasch, 2002; Hewitt, 2002). Commercial or recreational boats, especially those that stay unused for extended periods in the port, are particularly important (Johnson et al., 2001; Gollasch, 2002; Floerl and Inglis, 2005). Many introductions may have occurred in this way, including many well-known problems today, such as *Undaria pinnatifida* (Ray, 1990) and *Codium fragile* spp *tomentosoides* (Carlton and Scalon, 1985). This problem is even greater when the boats or structures are rarely cleaned or are painted with older paints that do not avoid encrusting organisms (Floerl and Inglis, 2005; Floerl et al., 2005).

The port of Paranaguá in the southern state of Paraná, is one of Brazil's largest, the most important in the south and is the most important for grain export in South America, with ships coming from China, India, Spain, Italy, Holland, Iran and Korea, among others (Marone *et al*. 2000, Ministério dos Transportes, 2005). Thus, this port is a prime candidate for the introduction of exotic marine species. Indeed, *Coscinodiscus wailesii*, an exotic species of algae only recently found in South America was also recently found in Paranaguá Bay (Fernandes *et al.* 2001). Also, *Bostricobranchus digonas,* Abbott 1951, an ascidian from Florida, in the United States, was found in Paranaguá Bay and is probably introduced (Rocha, 2002). Two additional introduced ascidian species were found nearby, *Ascidia sydneiensis* and *Styela plicata* (Rocha and Kremer, 2005).

A marina near the port of Paranaguá provides an ideal place to search for exotic species. The combination of privately owned boats on whose hulls encrusting organisms may be transported and the proximity of the port itself provide a logical place to begin searching for the potential problems of introduction. Here, we sampled various substrates at this local marina to identify possible introductions and to suggest possible means of their management.

METHODS

The marina of the Paranaguá Yacht Club (25°31' S 48°30' W) is within Paranaguá Bay, in the state of Paraná, in southern Brazil. Founded in 1952, the yacht club welcomes all kinds of private boats, including sail, motor, and fishing boats. Sailboats and motorboats with a draft of 5 - 8 m are most common, with the majority being local, but with many from other regions in Brazil (Rio de Janeiro, São Paulo and Santa Catarina) and foreign (France, Germany and Holland, among others). The main underwater structure (substrate) comprises the various concrete pillars that support two main concrete walks with lateral boardwalks and floating docks. The floating structures are of fiberglass with the above-water portion of wood. The organisms were collected from the first 50cm from the water surface (sublitoral zone) of the floating substrates (hulls and piers), and from the intertidal zone of the concrete columns, by scraping 20 x 20cm of the substrate surface, with 10 samples from each substrate.

Status terminology (native, introduced, cryptogenic) followed Carlton (1996; 2001), in which introduced species are the result of historical intentional or unintentional human activities, with the species being transported and introduced into a new location. Cryptogenic species are those that lack clear evidence of introduction and that lack clear records of their distribution. The status of the identified species was determined by literature review. Due to the incomplete nature of the literature for Paranaguá Bay, the cryptogenic species here were further defined as those that had the following characteristics: widespread geographic distribution, but limited distribution in Brazil; strong association with artificial substrates or often found in ports; the species is known to be invasive in other localities.

More details about the biology and geographic distribution of the species can be found at http://zoo.bio.ufpr.br/invasores.

RESULTS AND DISCUSSION

Out of the 50 species found at the Yacht club on the three types of substrates, four species (8%) were introduced, 33 (66%) were cryptogenic and 13 (26%) were native (Table 1). This fraction of introduced species was greater than that (G = 3.99, $p < 0.05$) of the Sepetiba Port in the state of Rio de Janeiro, where five of 272 (~2%) species were introduced (Clarke et al., 2004).

Table 1 - A list of cryptogenic (C) and introduced (I) species found on the structures of the Yacht Club in Paranaguá Bay, in the state of Paraná, southern Brazil.

Group	Species		Group	Species	
Chlorophyta Ulvaceae	*Enteromorpha lingulata* J Agardh	C	Oithonidae	*Oithona hebes* Giesbrecht, 1891	C
Rhodophyta Delesseriaceae	*Caloglossa leprieurii* (Montagne) G. Martens	C	Amphipoda Gammaridea Melitidae	*Elasmopus brasiliensis* (Dana, 1853)	C
Rhodomelaceae	*Polysiphonia subtilissima* Montagne	C	Amphipoda Gammaridea Melitidae	*Quadrimaera miranda* (Ruffo, Krapp and Gable, 2000)	C
Rhodomelaceae	*Bostrychia radicans* (Montagne) Montagne	C	Amphipoda Gammaridea Hyalidae	*Parhyale hawaiensis* (Dana, 1853)	C
Phaeophyta Scytosiphonaceae	*Colpomenia sinuosa* (Mertens ex Roth) Derbès and Solier	C	Amphipoda Gammaridea Corophiidae	*Corophium acherusicum* Costa 1851	C
Hydrozoa Campanulariidae	*Clytia hemisphaerica* (Alder, 1856)	C	Amphipoda Caprellidea	*Caprella equilibra* Say, 1818	C
Hydrozoa Campanulariidae	*Obelia bidentata* Clarke, 1875	C	Amphipoda Caprellidae	*Caprella scaura* Templeton, 1836	C
Hydrozoa Campanulariidae	*Obelia dichotoma* (Linnaeus, 1758)	C	Tanaidacea Tanaidae	*Sinelobus stanfordi* (Richardson, 1901)	C
Hydrozoa Boungainviliidae	*Garveia franciscana* Torrey, 1902	I	Tanaidacea Paratanaidae	*Paratanais* cf. *oculatus* (Vanhoeffen, 1914)	C
Bivalvia Mytilidae	*Mytella charruana* d'Orbigny (1846)	C	Decapoda Xanthidae	*Hexapanopeus paulensis* Rathbun, 1930	C
Bivalvia Mytillidae	*Brachidontes* cf. *rodriguezi* (d'Orbigny, 1846)	C	Decapada Porcellanidae	*Porcellana sayana* (Leach, 1820)	C
Polychaeta Spionidae	*Polydora colonia* Moore, 1907	C	Cirripedia Balanidae	*Amphibalanus amphitrite* (Darwin, 1854)	C
Polychaeta Spionidae	*Polydora* cf. *cornuta* Bosc, 1902	I	Cirripedia Balanidae	*Amphibalanus reticulatus* (Utinoni, 1967)	I
Polychaeta Nereididae	*Neanthes* cf. *succinea* (Frey and Leuckart, 1847)	C	Cirripedia Balanidae	*Amphibalanus improvisus* (Darwin, 1854)	C
Polychaeta Nereididae	*Platynereis dumerilii* (Audouin and Milne-Edwards, 1834)	C	Cirripedia Archaeobalanidae	*Striatobalanus amaryllis* Darwin, 1854	I
Polychaeta Capitellidae	*Capitella capitata* (Fabricius, 1740)	C	Bryozoa Alcyonidiidae	*Alcyonidium polyoum* (Hassall, 1841)	C
Copepoda Harpacticoida Miraciidae	*Robertsonia hamata* Willey, 1931	C	Bryozoa Membraniporidae	*Conopeum reticulum* (Linnaeus, 1767)	C
Copepoda Ameiridae	*Nitokra affinis* Gurney, 1927	C	Bryozoa Hippoporinidae	*Hippoporina pertusa* (Esper, 1796)	C
Copepoda Ameiridae	*Nitokra spinipes* Boeck, 1865	C			

The proportion was also greater than that in several ports in Australia: Darwin, with five of 879 (0.6%) introduced; Port Hedland, with 16 of 548 (~3%) introduced; Mackay, with 12 of 380 (~3%) introduced (Hewitt, 2002). Therefore, we suspect that due to our relatively small sample, the number of introduced species could be greater, and could be a relatively large fraction of the total number of species. For example, if the fraction of introduced species remains constant, while the number of total species grows with increased effort to that of Rio de Janeiro (272) then a total of ~22 introduced species that would be expect in this region.

The majority (66%) of the species was classified as cryptogenic, many of which were common, and they could be important for understanding the impacts of invasive species (Carlton, 1996). A large number of cryptogenic species were also found in Argentina, and three hypotheses were put forward to explain the origin of these species: 1) widespread distribution before further spread by humans, 2) species classified as cosmopolitan, when in reality they comprise a group of cryptic and less widespread species, 3) distributions today considered cosmopolitan, when in fact the species was already spread by human activities prior to the studies of their distributions (Orensanz et al. 2002). In general, the cryptogenic species found here had characteristics typical to invasive species: indirect development and planktotrophic larvae; suspension feeding; tolerance of wide variations in salinity and temperature; easily dispersed by human activities (Table 2). Also, several of these species are common in other ports around the world and some were introduced elsewhere, such as *Corophium acherusicum* in the western Pacific, Australia (NIMPIS, 2002) and Hawaii (Coles et al., 1999), *Neanthes succinea* in the eastern Pacific and Australia (NIMPIS, 2005), and *Amphibalanus improvisus* in the Baltic Sea (Zaiko, 2005), among others. As with the barnacles *Amphibalanus amphitrite* and *A. improvisus*, it is possible that these species were introduced in the past and today are widespread along the Brazilian coast (Rocha, 1999). The range of *Brachidontes rodriguezi* was restricted to Rio Grande do Sul and Argentina (Rios, 1994), and if its presence is confirmed in Paranaguá Bay, would represent an inter-regional introduction. *Polydora colonia* was found in 2001 at Ilha do Mel (25°34'S 48°20'W), Paranaguá Bay, PR (V.I. Radashevsky pers. comm., 2006) and was here also considered cryptogenic.

Several native coastal species in Brazil were found the first time in Paraná: *Perinereis brevicirrata*, previously only recorded in São Paulo, *Harpacticus poppei*, only found in Santa Catarina, and *Fallotritella montoucheti*. The following cryptogenic species were also found for the first time in Paraná: *Obelia bidentata*, *Robertsonia hamata*, *Nitokra affinis*, *Nitokra spinipes*, *Paratanais* cf. *oculatus*, *Alcyonidium polyoum* and *Hippoporina pertusa* (Table 1). The genera *Dodecaceria*, *Perkinsiana* and *Terebella* were also firsts for Paranaguá Bay (C.S.G. Santos, pers. comm., 2005), even though the species *Dodecaceria concharum*, *Perkinsiana minuta* and *Terebella pterochaeta* were known from São Paulo, and *Terebella jucunda*, from Rio de Janeiro (Morgado, 1980). The classification as native in Brazil, yet without previous records in Paraná, illustrates the gaps in the knowledge of the regional marine fauna, as well as the possibility of regional introduction, such as may be the case with *B. rodriguezi*. Of the cryptogenic species, 64% were cosmopolitan, 24% common in ports and 42% reported as introduced in other locations.

Ballast water could be the source of all the species considered, while incrustation would also be possible, except for copepods; *Neanthes* cf. *succinea*, *Capitella capitata*, *Corophium acherusicum*, *Amphibalanus amphitrite* and *Amphibalanus improvisus* that have been found in ballast tanks. Most cryptogenic species (67%) were solitary, followed by colonial (18%) and macroalgae (15%; Table 2).

Asexual reproduction and high fecundity should be common in introduced species. Bryozoans, hydrozoans and macroalgae all reproduce asexually. Fecundity is high in *Platynereis dumerilii*, *Neanthes* cf. *succinea*, *C. capitata*, *C. acherusicum*, *A. amphitrite* e *A. improvisus*, and low only in *Caprella scaura* (Table 2).

The many filter-feeding animals (39%) suggested high potential for invasion, since filter-feeders are seldom specialists. Gammarids, caprellids, barnacles, bryozoans and bivalves were in this category (Table 2).

Table 2 – Biological characteristics of cryptogenic species found at the Yacht Club of Paranaguá.

	Distribution[1]	**Human dispersed**[2]	**Reproduction**[3]	**Larval type**[4]	**Fecundity**[5]	**Mobility**[6]	**Habit**[7]	**Abundance**[8]	**Feeding type**[9]	**Salinity Tolerance**[10]	**Temperature tolerance**[11]	**Environmental Modifications**[12]	**Potential Negative Impacts**[13]
Enteromorpha lingulata	?,C,?	?,?,?	A,S	-	?	S	S	L	-	?	?	?,N	N
Caloglossa leprieuri	?,C,?	?,?,?	A,S	-	?	S	S	L	-	H	?	?,N	N
Polysiphonia subtilissima	?,C,?	?,?,?	A,S	-	?	S	S	?	-	?	?	?,N	N
Bostrychia radicans	?,C,?	?,?,?	A,S	-	?	S	S	H	-	H	?	?,N	N
Colpomenia sinuosa	?,C,?	?,?,?	A,S	-	?	S	S	?	-	H		?,N	N
Clytia hemisphaerica	?,C,I	B,E,?	AS	P	?	S	C	L	S	H	?	?,N	E,O
Obelia bidentata	?,C,I	B,E,?	AS	P	?	S	C	?	S	H	?	?,N	E,O
Obelia dichotoma	?,C,I	B,E,?	AS	P	?	S	C	?	S	H	?	?,N	E,O
Mytella charruana	?,N,I	B,E,?	S	P	?	S	S	?	S	?	?	?,N	E,O
Brachidontes rodriguezi	N,N,?	?,?,?	S	P	?	S	S	?	S	?	?	?,N	N
Polydora colonia	N,N,?	?,?,?	S	P	?	S	S	?	D	?	?	?,T	N
Platynereis dumerilli	?,C,?	?,?,?	S	P	H	V	S	?	C	?	?	?,?	N
Neanthes cf. *succinea*	P,C,I	B,E,S	S	P	H	V	S	H	C	H	H	H,T	Nu,B
Capitella capitata	P,C,I	B,E,S	S	P	H	V	S	H	D	H	H	?,?	N
Robertsonia hamata	N,N,?	?,?,?	S	P	?	V	S	?	D	?	?	N,N	N
Nitokra affini	N,N,?	?,?,?	S	P	?	V	S	?	D	?	?	N,N	N
Nitokra spinipes	N,C,?	?,?,?	S	P	?	V	S	?	D	?	?	N,N	N
Oithona hebes	?,N,I	B,?,?	S	P	?	V	S	?	?	?	?	N,N	N
Caprella equilibra	?,C,I	B,?,?	S	D	L	V	S	R	S	?	?	N,N	N
Caprella scaura	?,N,I	B,?,?	S	D	L	V	S	?	S	?	?	N,N	N
Corophium acherusicum	P,C,I	B,E,S	S	D	H	V	S	H	S	H	H	H,T	Nu,B
Parhyale hawaiensis	N,C,?	?,?,?	S	D	?	V	S	?	S	?	?	N,N	N
Elasmopus brasiliensis	N,N,?	?,?,?	S	D	?	V	S	?	S	?	?	N,N	N
Quadrimaera miranda	N,N,?	?,?,?	S	D	?	V	S	?	S	?	?	N,N	N
Sinelobus stanfordi	P,C,I	B,E,?	S	D	?	V	S	L	?	H	H	?,?	Nu
Paratanais cf. *oculatus*	N,N,?	?,?,?	S	D	?	V	S	?	?	?	?	?,?	?
Porcellana sayana	N,N,?	?,?,?	S	P	?	V	S	?	D	?	?	N,N	N
Hexapanopeus paulensis	N,N,?	?,?,?	S	P	?	V	S	?	D	?	?	N,N	N
Amphibalanus amphitrite	P,C,I	B,E,S	S	P	H	S	S	L	S	H	H	N,N	E
Amphibalanus improvisus	P,C,I	B,E,S	S	P	H	S	S	?	S	H	H	N,N	E
Alcyionidium polyoum	P,C,?	?,?,?	A,S	P	?	S	C	?	S	H	H	?,N	E
Conopeum reticulum	P,C,I	B,E,?	A,S	P	?	S	C	?	S	H	H	?,N	E
Hippoporina pertusa	?,C,?	?,?,?	A,S	P	?	S	C	?	S	H	H	?,N	E

Trait not present = N, not known = ?, not applicable = -; [1]widespread in ports = P, cosmopolitan or circumtropical = C, introduced elsewhere = I; [2]ballast waters = B, encrustation = E, ballast water sediments = S; [3]asexual = A, sexual = S, alternating generations = AS; [4]planktotrophic = P, direct development = D; [5]high = H, low = L; [6]sessile = S, vagile = V; [7]solitary = S, colonial = C; [8]high = H, low = L, rare = R; [9]suspensivorous = S, detritivorous = D, carnivore = C; [10]eurihaline = H, estenohaline = L; [11]euthermic = H, estenothermic = L; [12]spatial heterogeneity = H, gallery construction or tubiculous = T; [13]changes in nutrients of the sediments = Nu, promote bacterial activity = B, encrustation or degradation of metals = E, pipe obstruction = O.

Some of the species were potentially important economically as well as environmentally. Species, such as *Neanthes* cf. *succinea* and *C. acherusicum*, that build extensive galleries and tunnels in the sediments, could change nutrient availability, sediment dynamics, and promote bacterial activity (Bartoli et al., 2000). While incrustation is a natural marine process, when it occurs in artificial structures it often causes problems associated with the cleaning and control. On boats, the incrustation will reduce velocity due to the friction, and thus increase the costs of fuel (as much as 40%) and maintenance (Stupak et al., 2003). Additionally, incrustation favors the corrosion of the hulls and metal surfaces, such as those used in water retention and electricity generation (Yebra et al., 2004). The most important encrusting groups are the cirripeds (barnacles), bryozoans, hydrozoans, sponges, ascidians and macroalgae. *Clytia hemisphaerica*, *O. dichotoma*, *O. bidentata*, *Mytella charruana*, *A. amphitrite*, *A. improvisus*, *A. polyoum*, *C. reticulum* and *H. pertusa* found in this study have already been mentioned as typical members of the encrusting communities on artificial structures in other areas. Most of the species were found on the floating docks or boat hulls, and only barnacles were common on the fixed concrete columns. A detailed account on substrate preferences is found in Neves et al. (2007).

Geographical Distribution and Ecology of Introduced Species

Garveia franciscana (Torrey, 1902): This hydrozoan was first described in San Francisco Bay in California, while it is thought that this species is native to estuaries of the northern Indian Ocean (Cohen and Carlton, 1995). Widely distributed in brackish as well as salt waters, this species is now known from a variety of locations, including both east and west coasts of North America, in the Gulf of Mexico, Venezuela and northeastern Europe, western Africa, India and Australia (Vervoort, 1946; Cohen and Carlton, 1995; de Rincon and Morris, 2003; Baker et al., 2004). In Brazil, *G. franciscana* was first found in the estuary formed by the Formoso, Arinquidá and Porto Alegre rivers in the state of Pernambuco (Calder and Mayal, 1998). Prior to that study, the species had already been collected in 1985 on an artificial anchorage in the Paranaguá Bay (M.A. Haddad, pers. comm., 2005). It is quite likely, due to the proximity of the port, that this hydrozoan was introduced in the form of planula larvae in the ballast waters of ships, or possibly originating from adults on the hulls of ships. *Garveia franciscana* has separate sexes, without alternating generations, and produces fixed gonophores that release planulae directly (Vervoort, 1946). This species supports a wide range of salinities, from low, such as in the Chesapeake Bay and Florida (Baker et al., 2004) to the high salinity of the Mediterranean Sea (Morri, 1982).

Polydora cf. *cornuta* Bosc, 1802: This polychaete was originally described from Charleston Bay in the state of South Carolina, USA, in the intertidal region. Its distribution today includes the estuaries of the eastern coast of North America, the Gulf of Mexico and the Caribbean, Argentina, Europe, India, Korea, Japan, China, Russia (Pacific coast) and Australia (Radashevsky and Hsieh, 2000; Radashevsky, 2004). In Brazil, it was first reported from the states of Espírito Santo, Rio de Janeiro and São Paulo, and was first found near Paranaguá Bay in 1998 (Radashevsky, 2004). The most likely vectors of this species are ballast waters and incrustations. This species builds tubes on the surfaces of other organisms, including the tubes of other species of polychaetes and the shells of cultivated mussels. While hermaphrodite, the species mostly reproduces sexually. Sex ratios vary from 1:1 to 2.4:1 female:male, and the females are typically larger than the males (Zajac, 1991). Fertilization is internal with planktotrophic larvae. In the laboratory, gametes are produced after one to two weeks after settling (Radashevsky, 2004). Thus, with a combination of rapid reproduction after the colonization, and tube building, this species has a high invasive potential.

Striatobalanus amaryllis Darwin, 1854: The original distribution of this barnacle was limited to the Indian Ocean and the western Pacific Ocean, from the shore to 500 m (Young 1989). This species was first reported in the Atlantic Ocean in 1982, and first in Brazil in the state of Piaui in 1987 (Young, 1987; 1989), in the intertidal zone together with *Megabalanus tintinnabulum* (Linnaeus, 1758). Later, in 1993, it was also found in Pernambuco (Farrapeira-Assunção, 1990) and Bahia (Young, 1998). Prior to this study, the species was only reported in the Brazilian north and northeast, and while ours is the only record in southern Brazil, it quite probably occurs undetected elsewhere. While *S. amaryllis* is relatively large (6 - 45 mm in diameter) and colorful (pinkish with pink bands), the species somewhat resembles *Megabalanus* and so may have been mistakenly identified.

The encrusting fauna on ships and fishing boats, along with ballast water, are the most likely sources for this species' introduction. In Piauí, introduction was probably due to boat traffic (Young, 1989). Due to the encrusting nature, and reproductive mode with motile larvae, and the nearness to the port, it is impossible to determine exactly how this species became introduced in the Yacht Club.

Striatobalanus amaryllis co-occurs with the native species, such as the Brazilian endemic *Fistulobalanus citerosum* (Henry, 1973). Typically, this species, as with other representatives of *Fistulobalanus*, occurs in waters of low salinity, such as mangroves and estuaries (Young, 1989; 1994).

Amphibalanus reticulatus Utinoni, 1967: Another introduced barnacle, it is found worldwide in tropical latitudes (Young, 1998) and is considered to be recently introduced in the Brazilian waters. First reported in Pernambuco in 1990 and Bahia in 1993 (Farrapeira-Assunção, 1990; Young, 1998), this species reached Rio de Janeiro by 1997 (F.B. Pitombo, pers. comm., 2005). *A. reticulatus* is dominant on artificial substrates and with various degrees of eutrophication in Ilha Grande Bay, in the state of Rio de Janeiro (Mayer-Pinto and Junqueira, 2003). This is the first record of this species in southern Brazil.

Negative Impacts of Introduced Species

Garveia franciscana, *A. reticulatus*, *S. amaryllis* form incrustations on artificial substrates, including petroleum platforms, hulls of ships and boats, pipes for energy production and other structures. *Garveia franciscana*, for example, is responsible for the obstruction of pipes in hydroelectric plants, the corrosion of metal structures, and the high costs associated with their removal, in Chesapeake Bay (Baker et al., 2004) and in Venezuela (de Rincon and Morris, 2003). While the impact of *S. amaryllis* and *A. reticulatus* incrustations are unknown as are the associated costs of their control, they are likely to be similar to those of other fouling species (Stupak et al., 2003).

Polydora cornuta has important and direct impact on the mussel, oyster and clam cultivations due to their extensive and massive tube construction (Nelson and Stauber, 1940). The tube construction causes the accumulation of sediments and feces and inhibits the bivalve growth. Decomposition of the accumulated sediments results in anaerobic fermentation and the production of hydrogen sulfide gas, which can kill the bivalves (Nelson and Stauber, 1940).

Along with economic costs, these species can also disturb the natural community. Thus, it is very important that these species be monitored (Young 1994). Both observational and experimental studies must be carried out to understand the interactions, such as competitive exclusion, and perturbations associated with the introduction of these species and the species with which they share space. The occurrence of these species on artificial substrates indicates the availability of larvae, which then suggests that breeding populations exist somewhere in the region. Therefore, monitoring of these species throughout Paranaguá Bay is recommended.

Management recommendations

A variety of mechanisms exist for the introduction of the species that form incrustations. Adult and egg transport may occur on incrusted surfaces or in ballast waters, or through the sporadic cleaning of hulls, as well as by the equipment and animals used in aquaculture (Ferreira et al., 2004). Thus it is highly recommended that the hulls be cleaned regularly and preferably within the same location where the incrustations formed (Floerl and Inglis, 2005).

At the Yacht Club, boat cleaning is sporadic and carried out by the boat owners themselves twice each year (Yacht Club administration, pers. comm.). The permanent structures (columns and floats) are cleaned three times per year. During these cleanings, the scraped material is collected and discarded elsewhere (not in the water). To control invasive species, this cleaning regime should be more frequent, especially on boats. A guide to how often should be based on the generation or breeding time of the organisms. That is, cleaning should occur more frequently than reproduction or dispersion. Of the species discussed here, only one species (*Polydora cornuta*) has a known maturation period of 1 – 2 weeks after the larvae settle on the substrate, suggesting that care to avoid invasion should also occur frequently. The species *Amphibalanus trigonus* matures in three weeks after the fertilization (El-Komi and Kajihara, 1991), hence *A. reticulatus* probably also has a rapid development to maturity. Clearly, for the control of invasives, their life-histories must be reasonably well-known to inform the decisions on cleaning rates of the potential substrates. The current and large cleaning intervals are probably too infrequent to control any invasive species.

It is also recommend that campaigns inform the marina and boat owners of the inefficiency of boats with encrusted hulls. If the owners were informed of revenue lost due to the drag and subsequent increased fuel costs, perhaps they would be more inclined to clean more regularly. Also, if they understood the invasive organisms better, through informal education campaigns, they would be more likely to avoid introductions.

In Brazil, regulations for anti-incrustation paints do not exist, and so, many boat owners do not use them. Thus, dispersal events are more likely, especially when the boats stay for long time at one place (Floerl and Inglis, 2005; Floerl et al., 2005). At the Yacht Club, it is quite likely that many boats are encrusted with potentially invasive species due both to the infrequent cleaning regimes and proximity to the port of Paranaguá. And, since the Yacht Club receives boats from other states in Brazil, as well as other countries, the Yacht Club may serve both as a source and a destination for invasive organisms.

To date, international directives do not exist with respect to introductions of exotic species due to encrusting organisms. Tributyl-tin (TBT) based paints are among the most efficient anti-incrustation paints available. However, the organo-tin based compounds are known to have their own harmful effects. Thus, the International Convention on the Control of Harmful Anti-fouling Systems on Ships of 2001 recommended the suspension of the use of organo-tin based products beginning in the year 2003, with total prohibition by 2008 (IMO, 2001). With TBT-based paint restrictions in many countries, the efforts to find alternatives have increased (Standing et al., 1984; Yebra et al., 2004). Non-toxic compounds, such as sodium benzoate and tannins, have been shown to be effective in the inhibition of settling by larvae of *Balanus amphitrite* and *Polydora ligni* (synonym of *P. cornuta*) on the painted surfaces (Stupak et al., 2003). In Venezuela, copper has been used to inhibit growth in *Garveia franciscana* (de Rincon and Morris, 2003).

While paint may help reduce invasive species, a better understanding of the invasive and native fauna and flora is fundamental for the effective control. In this first study of marine introductions in southern Brazil, most species were cryptogenic. This large number of cryptogenic species is due to the lack of information of these species. Few, if any, studies have attempted to describe the entire benthic community (Lana et al., 1996). Also, only recently have researchers in Brazil began to examine the problem of invasive species, and data are still in an early stage (Silva et al., 2004), as is also the case in many regions. The majority of studies of invasives are concentrated in Australia, the United States of America, Western Europe, the Mediterranean and the northwestern Pacific (Orensanz *et al.* 2002). Thus, large areas, including the Indian Ocean, the southern Pacific, Africa and Latin America, are poorly studied with even less monitoring of the invasive species. In part this problem is due to the lack of understanding of the systematics and biogeography of the species involved (Ruiz et al., 2000).

A clear example is found in the southwestern Atlantic, where poor understanding of the native biota makes identification of the introduced species difficult, and where already introduced species are causing serious problems (Orensanz et al., 2002). Thus, detailed information at places such as the Yacht Club, of the boats and their points of origin and destination, cleaning schedules and so on would be very helpful in biocontrol. This information could be easily gathered through the cooperation of the Yacht Club by means of questionnaires that could be given to the boat owners, similar to that carried out in Australia (Floerl and Inglis, 2005).

In order to evaluate the impact that exotic species may have on natural communities as well as on man-made structures, environments potentially exposed to introductions must be constantly monitored. Periods of colonization by species must be known or estimated to understand the temporal dynamics of invasion, which in turn must be understood for effective control of the invasive species. A corollary to this problem is that more research is required of the potentially invasive species in their natural environments, as well as the communities that they are likely to invade, especially in terms of systematics and biogeography. Only the better understanding the origins and ecology of invasive species will lead to an early recognition of invasion and help to identify tools to control it.

In general, the cryptogenic species found here have several characteristics that are typical of invasive species as well as having cosmopolitan or circumtropical distributions. It is quite possible that several of these species were introduced in the past and have since become so widespread as to be considered "naturalized." Only through biogeographical studies will this question be resolved. Also, population monitoring is necessary for these species, since *Neanthes* cf. *succinea* and *Corophium acherusicum*, for example, are known to have harmful environmental impacts in other regions.

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RESUMO

Espécies marinhas exóticas (= não-nativas) podem afetar drasticamente as comunidades das regiões em que são introduzidas. Prever quais espécies possuem maiores chances de causar impactos negativos é extremamente importante. Neste estudo, identificamos espécies introduzidas e criptogênicas entre as espécies incrustantes e associadas das comunidades que ocorrem nos substratos consolidados da marina do Iate Clube de Paranaguá. Com base em literatura, verificamos quais destas espécies são capazes de afetar negativamente a comunidade local e sugerimos recomendações para seu manejo adequado. Quatro espécies introduzidas foram identificadas, o que é uma cifra elevada quando comparada a outros levantamentos de biotas portuárias: o hidrozoário *Garveia franciscana* Torrey, 1902, o poliqueta *Polydora cornuta* Bosc, 1902, e as cracas *Amphibalanus reticulatus* (Utinoni, 1967) e *Striatobalanus amaryllis* Darwin, 1854, todas com efeitos negativos já registrados em outros locais. Entre as 33 espécies criptogênicas, quatro também são relatadas na literatura pertinente como causadoras de impactos negativos. Ações de manejo propostas incluem limpeza periódica dos cascos das embarcações e estruturas da marina, monitoramento das populações de espécies com potencial invasor, monitoramento dos substratos naturais para detecção de espécies introduzidas, criação de um banco de dados com informações sobre as viagens dos barcos de recreio e possíveis rotas de dispersão das espécies.

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