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Relationship among Ballast Water, Bioincrustration and Invasion of Exotic Species

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ABSTRACT

Most species of seaweed that are transported through ballast water may have been transferred also by bioincrustration. Macroalgae of the genus Caulerpa, are native to the Mediterranean. C. taxifolia is an algae indicator of conditions, often harmful, and sometimes irreversible, to the ecosystems of the invaded areas. It is necessary to implement control measures to minimize damage to the endemic species and its im-pact on the areas of occurrence. This study aimed to assess the occurrence of exotic algae on and their relationship and distribution on the coast of Pernambuco, during periods of dry and rainy seasons from 2005 to 2009. Macroalgae were fixed in con-solidated and unconsolidated substrates, being also associated with other algae and even occurring as loose fragments in the sandstone reef. These fragments could be the result of anthropogenic activities or local hydrodynamics. The absence of sea ur-chins and other herbivores associated with C. taxifolia sites pointing to an allelopathic action in the process of colonization. We consider that Caulerpa taxifolia may have been introduced recently in our coast being in process of colonization growing itself most often in sandstone reefs, which suggests an action in inhibiting herbivory through the synthesis of allelochemicals.

Keywords: Macroalgae, Caulerpa racemosa, Caulerpa taxifolia, ecology, herbivory, allelochemicals.

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INTRODUCTION

The expansion of the frontiers of international trade created a need to develop maritime transport, vessels being responsible for 80% of the global transportation of load (PEREIRA *et al*, 2010).

The ballast is intended to increase or decrease the depth of the ship during navigation to ensure its stability, balance and structural integrity and the tanks are filled with water that work the same way, but that during the port operations. According to the International Maritime Organization, it is estimated that about 10 billion tons of ballast water are transferred annually through shipping. This water transports marine species that can interfere with the environment where they are released, and yet bring disease-causing microorganisms, which means about 5 billion m^3 of ballast water each year carrying around 3,000 species per day on a ship (ANVISA, 2002, GOMES 2004, LEAL NETO, 2007).

Marine species consisting of unicellular organisms, algae or invertebrates have a life cycle with a planktonic stage or more stages, can be conducted in these waters in the form of eggs, larvae and cysts and also in plant species macroscopic in the form of spores and gametophytes (GOMES, 2004).

The boats also carry organisms of other ecosystems to new environments through bioincrustration, currently, one of the major environmental problems found in international and domestic boats (Figure 1), which still accounts for losses as increasing fuel consumption, motor overload and more time for maintenance and cleaning (RUBINGER, 2009).

Figure 1. Domestic boats at the time of maintenance at the beach Barra de Sirinhaém.

Most species of algae that are transported through ballast water include the genus *Caulerpa*. According to Verlaque *et al.* (2003), *C. racemosa* is native to the Mediterranean, and coexists with varieties *turbinata*, *ulvifera,* and Western or *lamouruxii cylindracea* (Sonder) (RANIELLO *et al*., 2007). There are reports that other species of the genus, *Caulerpa taxifolia*, would originate from the Mediterranean, however, other authors report that the species was first seen in India and was widely used in Europe for ornamental aquariums.

It is said that during the washing of a aquarium of the Oceanographic Museum of Monaco, where the wastes were dumped at sea, the seaweed would have fallen and the weather was adapting and leading to a significant population. This population would have been brought to the Mediterranean, also accidentally, with the ballast water and would have created an overpopulation, as described for this region in 1984 (MEINESZ and HESSE, 1991; BOUDOURESQUE *et al*., 1996, MEINESZ *et al.,* 1993 ; BELSHE and MEINESZ, 1995, MEINESZ *et al*., 2001, IVES *et a*l., 2007). According to Raniello *et al.,* (2007) in the last decade the species *C. racemosa* has shown a pattern more invasive than a *C. taxifolia* (Figure 2).

Figure 2. Prevalence of *C. racemosa* in the consolidate substratum is associated with other algae on at the beach A Ver o Mar.

The species *C. taxifolia*, typical of tropical seas, undergoes changes in size and density of fronds under the influence of the seasons. Other factors influencing their fast growth in the Mediterranean are the temperature and light intensity high, besides the various types of substrate (rocks, sand, etc.), allowing large variations in biomass throughout the year. This organism produces significant changes on surrounding ecosystems and diversity of echinoderms and other benthic organisms (BELSHE and MEINESZ, 1995; LONGEPIERRE *et al*, 2005, IVES *et al*, 2006).

The impact of *C. taxifolia* on Mediterranean ecosystems is considerable. This species causes a sharp decline in biodiversity in the media for it colonized. In 1991, there was an abundance in their distribution, covering the banks of *Cymodocea nodosa* and others algae, especially *Posidonia.* Initially, the banks of seaweed *Posidonia* seem to respond positively to contact with the algae, increasing its production. Then, after being completely overrun, shows signs of stress leading to a reduction and then the total disappearance of the bank of seaweed and others algae that grew together with the *Posidonia* (CUNY *et al*., 1995; IVESA *et al*, 2006, HOLMER *et al., 2009*).

The species *C. taxifolia* with great potential for toxicity was found on the beaches of Pernambuco in March 2007 during surveys carried out by our group. For Brazil, there were only records of this species to Fernando de Noronha and Espírito Santo (PEREIRA *et al.,* 2002).

This algae is an indicator of conditions, often harmful, and sometimes irreversible, to the ecosystems of the invaded areas. For this reason it is necessary to implement control measures to minimize possible damage to the endemic species and its consequent impact on the areas of occurrence. Given the above, this study is to identify the presence of alien algae in our coastal areas that may have been transferred through ballast water or bioincrustration.

This study aimed to assess the occurrence of exotic algae in thirteen beaches, as well as assess their relationship and distribution on the coast of Pernambuco.

MATERIAL AND METHODS

Data were collected during periods of dry and rainy seasons from 2005 to 2009, on the beaches of the coast north and south of Pernambuco. To the north shore beaches were visited the following: Carne de Vaca, Barra de Catuama, Enseada dos Golfinho, Sossego. On the southern coast collections occurred in their beaches: Pina, Boa Viagem, Pedra de Xaréu, Paiva, Enseada dos Corais, Muro Alto, Porto de Galinhas, Pontal de Serrambi, Barra de Sirinhaém, A Ver o Mar, Carneiros, São José da Coroa Grande. The area of coverage of the collections to the limits between the coordinates of Carne de Vaca (7 ° 34'40 "and 7 º 34'57" S, 34 ° 52'38 "and 34 ° 52'34" W), Goina 08 ° 41'S

and 8 ° 47'S, 35 ° 5'6"W and São José da Coroa Grande (7 ° 15'45 "-9 ° 28'18" S and 34 ° 48'35 "- 41° 19'54" W) in the range of Köppen (MACEDO *et al.,* 2004) Macroalgae were found distributed in bound substrates (sandstone reefs) and unconsolidated (sand banks), and made photographic records of the genus *Caulerpa*. Samples were collected in the morning during low tide. The samples packed in plastic bags and taken the laboratory for Toxicity and Cell Communication, Department of Histology and Embryology, UFPE and fixed in 70% alcohol for identification. The water temperature was measured, varying around 37 °C.

RESULTS

Tables 1 and 2 show the occurrence of two species of invasive algae *Caulerpa* genus, respectively *C. racemosa* and *C. taxifolia*.

Table 1 - Occurrence of *Caulerpa racemosa* on the beach during the study period from 2005 to 2009.

The figure 1 shows the frequency of occurrence between the two species of *Caulerpa* in the period studied.

Figure 1 - Frequency of occurrence of macroalgae of the genus *Caulerpa* in the from 2005 to 2009 in beaches of Pernambuco.

The table 3 presents the types of attachment to the substrate used by *C. taxifolia* during the study, that can be observed

Table 1 - Occurrence of *Caulerpa racemosa* on the beach during the study period from 2005 to 2009.

Praia	Ano				
	2005	2006	2007	2008	2009
Pontal de Serrambi	x		x	X	x
Carneiros	x	x	x		
Enseada dos Corais		x		X	x
Enseada dos Golfinhos		x	x		
Barra de Catuama			x	X	x
Sossego			x	X	
São José da Coroa Grande				X	
Paiva			x		
Muro Alto			x		
Barra de Sirinhaém			x		x
Porto de Galinhas			x		
Pedra de Xareu		x			
Carne de Vaca				X	
Praia do Pina	x	x	x	X	x
Praia de Boa Viagem	x	x	x	X	x
A Ver o Mar	x	x	x	X	x

***Table 2* - Occurrence of *Caulerpa taxifolia* on the beach during the study period from 2007 to 2009.**

Praia	Ano				
	2005	2006	2007	2008	2009
Barra de Sirinhaém			x	x	x
Pontal de Serrambi			x	x	x
Barra de Catuama				x	
São José da Coroa Grande				x	

Table 3 - Types of attachment to the substrate of species of seaweed *Caulerpa taxifolia,* occurring in the beaches studied during the period 2007 to 2009.

Types of attachment to the substrate of species of seaweed *Caulerpa taxifolia*			
Beaches	**consolid ate sediment**	**unconsolidate sediment**	**Loose**
Barra de Sirinhaém	2007; 2008; 2009	-	-
Barra de Catuama	-	2008	2007
Enseada dos Corais	2007; 2008; 2009	-	-
São José da Coroa Grande	2009	2009	2008

DISCUSSION

The colonization by *C. taxifolia* induces significant changes in ecosystems with serious threats to the diversity of habitat, as well as for echinoderms and other benthic fish and others benthic organisms (LONGEPIERRE, 2005; IVES *et al*, 2006). When an invasive species arrives at a new location its establishment self-sustaining in this ecosystem will be determined by interactions with resident species, the physical environment and evolutionary characteristics (WEST *et al*, 2007). West *et al.* (2007) report that the species can be dispersed in natural fragments or fragments transported by human activity (Figure 2), the latter having a greater potential dispersal distances reaching several miles underground, while the natural fragments have potential dispersion lower (meters)

Figure 2. Possible ways of spreading algae found on the beaches of Pontal de Serrambi (A) and A Ver o Mar.

The species *C. racemosa* had a higher frequency of occurrence (Figure 3) in relation to *C. taxifolia*, possibly *C. racemosa* has a greater potential to adapt than *C. taxifolia*, probably due to the time she settled on the Brazilian coast, while that for *C. taxifolia* records of occurrence are very recent, indicating that it is in the process of adaptation and accommodation in the area.

The major factors interfering in the distribution of the latter species are the abiotic parameters, morfogeográficas related to the characteristics of the physical environment, such as substrate type, depth, which is also related to light intensity and the hydrological characteristics (temperature, salinity, pH , etc.) essential for their establishment (THIABAUT *et al*, 2004, WEST and WEST, 2007). According to Belsher *et al.* (1995) this species has been found in tropical waters at depths which did not exceed 50 meters.

Figure 3. Adaptation of *C. racemosa* associated with marine invertebrates on the beach at A Ver o Mar (A) and fixed on the reefs of sandstone on the beach of Pontal de Serrambi (B)

In our study, we observed that *C. taxifolia* had a different distribution of those mentioned in the literature for temperate regions (WEST and WEST, 2007). This algae was found settling in two forms: fixed a consolidated and unconsolidated substrates (Table 3), being found also associated with other algae and even occurring as loose fragments in the sandstone reef (Figure 4), as observed on the beaches of Barra Catuama and São José da Coroa Grande. These fragments could be the result of anthropogenic activities or local hydrodynamics.

Figure 4. Aerial view of *C. taxifolia* fixed to the substratum (A) and unconsolidated (submerged) on the beach of Pontal de Serrambi (B).

Several control measures have been used to reduce the spread of *C. taxifolia* through mechanical, chemical treatments and biological control, or by suffocation. These efforts have not succeeded in eradicating large-scale seaweed and also because they are not considered safe for all species (THEIL *et al*., 2007). Another aspect to be considered is the absence of sea urchins and other herbivores associated with *C. taxifolia* in the collection sites pointing perhaps to an allelopathic action in the process of colonization of the areas studied (LEME *et al*., 1996). According to Boudouresque *et al.* (1996) and Amade and Rudder (1998) the species is used in the diet of sea urchin *Paracentrotus lividus,* (Lamarck 1816), however, their consumption is low in summer and autumn, being significant in winter and spring, which leads to reply lethal and sublethal effects, including a marked loss of spines and low ratio gonosomatic. Besides the effects mentioned, there are indications that caulerpin interferes with cell division and reduces the recruitment and abundance of echinoderms in the areas of colonization.

Caulerpales are known to develop effective strategies for inhibiting growth of other organisms for the production of secondary metabolites. The caulerpenin (CYN) was identified in nine species of Caulerpales outside the Mediterranean, including the *C. taxifolia* in the Mediterranean. This produces epoxicaulerpenin, substance toxic compared to CYN (antibacterial activity). However, the main component of this species is the sesquiterpene whose toxicity shown to inhibit proliferation of fibroblast BHK 21/C13 of baby hamster kidney (AMADE & LEMÉE, 1998).

The intense colonization of the species in the Mediterranean should be introduced into the water significant amounts of secondary metabolites transferring toxins through the food chain causing a toxicological risk to marine organisms and humans should be evaluated, because these compounds shown to accumulate in herbivores. Cases of human intoxication by consumption of fish and marine invertebrates are recorded by the incorporation of these metabolites along the food chain (WEIGHING *et al.,* 1996).

Throughout the study period we believe that there was an increase in the number of specimens found on the beaches of Barra de Sirinhaém and São José da Coroa Grande. Perhaps the increase in the hydrodynamics (Fig. 5), is a factor of dispersion on these beaches, as it can disperse more fragments and facilitate their establishment through asexual reproduction. Although these organisms reproduce both sexually as asexually (SILVA *et al*, 2002, WILLIAMS and GROSHOLZ, 2002, WRIGHT, 2005). Zujevic and Antolic (2000) argue that no there is satisfactory *e*vidence of sexual reproduction in invasive populations. Asexual reproduction is by fragmentation of stems, followed by fixation and vegetative growth from fragments as small as 1 cm, such fragments can be formed naturally by the action of currents and through herbivory (ZUJEVIC and ANTOLIC, 2001).

Figure 5. Records of hydrodynamics observed on the beaches of Barra de Sirinhaém (A) and Pontal de Serrambi (B) at the time of collection.

Preliminary studies have been done by our team, in which it was observed that *C. taxifolia* has a greater toxicological potential *C. racemosa* when tested in mice.

CONCLUSION

In view of the occurrence of species of *Caulerpa racemosa* in all beaches studied we was verified that it is well established in our coast. in relation to *Caulerpa taxifolia* we consider that may have been introduced recently in our coast, possibly by an anthropogenic process through ballast water or bioincrustration, spreading also through natural processes of fragmentation promoted by hidrodinanism. The species is in the growing process of colonization in establishing itself most often in sandstone reefs, which suggests an action in inhibiting herbivory through the synthesis of allelochemicals.

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REFERENCES

1. AMADE, P. & LEMÉE, R. Chemical defence of the mediterranean alga Caulerpa taxifolia: variations in caulerpenyne production. Aquatic Toxicology. 1998, v. 43, p. 287 - 300.
2. ANVISA. Diretrizes para o Controle e Gerenciamento de Água de Lastro de Navios. Brasil. Água de Lastro – Projetos GGPAF, 2002.
3. BELSHER, T. & MEINESZ, A. Deep-water dispersal of the tropical alga Caulerpa taxifolia introduced into the Mediterranean. Aquatic Botany. 1995, v. 51, p. 163-169.
4. BOUDOURESQUE, C. F.; LEMKE, R.; MARI, X.; MEINESZ, A. The invasive alga Caulerpa taxifolia is not a suitable diet for the sea urchin Paracentrotus lividus. Aquatic Botany. 1996, v. 53, p. 245-250.
5. CUNY, P., SERVE, L., JUPIN, H., BOUDOURESQUE, C-F. Watersoluble phenolic compounds of the marine phanerogam Posidonia oceanica in a Mediterranean area colonised by the introduced. Aquatic Botanic. 1995, v. 52, p. 237-242
6. GOMES, A. P. A. Trabalho de meio ambiente: água de lastro. Diretoria de Portos e Costas: Santos. 2004, p.9
7. HOLMER, M.; MARBÀ, N.; LAMOTE, M. Deteriotion of sediment quality in seagraass meadows (Posidonia oceánica) invaded by macoalgae (Caulerpa sp.). Estuaries and Coasts. 2009, v. 32, p. 456-466.
8. IVES, A, L.; JAKLIN, A.; DEVESCOVI, M. Vegetation patterns and spontaneous regression of Caulerpa taxifolia (Vahl) C. Agardh in Malinska (Northern Adriatic, Croatia). Aquatic Botany. 2006, v.85, p. 324–330.
9. IVESA, L.; JAKLIN, A., DEVESCOVI, M., Vegetation patterns and spontaneous regression of Caulerpa taxifolia (Vahl) C. Agardh in Malinska (Nortern Adriatic, Croatia). Aquatic Botanic. 2006, v. 85, p. 324-330.
10. LEAL NETO, A.C. Identificando similaridades: Uma aplicação para a avaliação de risco de água de lastro. Tese (Doutorado) apresentada a Universidade Federal do Rio de Janeiro em Ciências em Planejamento Energético. 2007.
11. LEMÉE, R. BOUDOURESQUE, C.F. GOBERT, J. et al., Feeding behavior of Paracentrotus lividus in the presence of Caulerpa taxifolia introduced in the Mediterranean, Oceanol. Acta. 1996, v. 19 (3), p. 245–253.
12. LONGEPIERRE, S.; ROBERT, A.; LEVI, F.; FRANCOUR, P How an invasive alga species (Caulerpa taxifolia) induces changes in foraging strategies of the benthivorous fish Mullus surmuletus in coastal Mediterranean ecosystems. Biodiversity and Conservation. 2005, v. 14, p. 365 - 376.
13. MACÊDO, S. J.; MUNIZ, K. and MONTES, M.J.F. Hidrologia da região costeira e plataforma continental do estado de Pernambuco. In: ESKINAZI–LEÇA, E.; NEUMANN-LEITÃO, S. & COSTA, M.F. (Orgs.). Oceanografia: Um cenário tropical. Recife: Bagaço, 2004. p. 255- 258.
14. MEINESZ, A., DE VAUGELAS, J., HESSE, B., MARI, X., Spread of the introduced tropical green alga Caulerpa taxifolia in northern Mediterranean waters. J. Appl. Phycol. 1993, v. 5, p. 141–147.
15. MEINESZ, A.; BELSHER, T.; THIBAUT, T.; ANTOLIC, B.; MUSTAPHA, K.B.; BOUDOURESQUE, C.F.; CHIAVERINI, D.; CINELLI, F.; COTTALORDA, J.M.; DJELLOULI, A., E.L; ABED, A.; ORESTANO, C.; GRAU, A.M.; IVESA, LJ.; JAKLIN, A.; LANGAR, H.; MASSUTI-PASCUAL, E.; PEIRANO, A.; TUNESI, L., DE VAUGELAS.; J., ZAVODNIK, N.; ZULJEVIC, A. The introduced green alga Caulerpataxifolia continues to spread in the Mediterranean. Biol. Inv. 2001. v. 3, p. 201–210.

16. MEINESZ, A.; HESSE, B. Introduction et invasion de l'algue tropicale Caulerpa taxifolia en Me´diterrane´e nord-occidentale. Oceanol. Acta. 1991, v. 14, p. 415–426.
17. PEREIRA, S. M. B., CARVALHO, M. F. O., ANGEIRAS, J. A. P., PEDROSA, M. E. B., OLIVEIRA, N. M. B., TORRES, J., GESTINAR, L. M. S., COCENTINO, A. L. M., SANTOS, D., NASCIMENTO, P. R. F., CAVALCANTI, D. R. 2002. Algas marinhas bentônicas do Estado de Pernambuco. In TABARELLI, M., SILVA, J. M. C. (orgs) Diagnóstico da biodiversidade de Pernambuco. Editora Massangana, Recife, 5: 99-124.
18. PESANDO, D; LEMÉE, R; FERRUA, C.; AMADE, P.; GIRARD, J-P. Effects of caulerpenyne, the major toxin from Caulerpa taxifolia on mechanisms related to sea urchin egg cleavage. Aquatic Toxicology. 1996, v. 35, p. 139-l 55.
19. RANIELLO, R.; MOLLO, E.; LORENTI, M.; GAVAGNIN, M.; BUIA, M. C. Phytotoxic activity of caulerpenyne from the Mediterranean invasive variety of Caulerpa racemosa: a potential allelochemical. Biol Invasions. 2007, v. 9, p. 361-368.
20. RUBINGER, C. F., Seleção de métodos biológicos para a avaliação toxicológica de efluentes industriais. UNIVERSIDADE FEDERAL DE MINAS GERAIS PROGRAMA DE PÓS - GRADUAÇÃO EM SANEAMENTO MEIO AMBIENTE E RECURSOS HÍDRICOS. Belo Horizonte. 2009, p. 89.
21. SHER, T. and MEINESZ, A. Deep-water dispersal of the tropical alga Caulerpa taxifolia introduced into the Mediterranean. Aquatic Botany. 1995, v. 51, p. 163-169.
22. SILVA, P. C. Overview of the genus Caulerpa. Proceedings of the International Caulerpa taxifolia Conference, 2002. San Diego, California (from the Sea Grant Non-Indigenous Site, www.sgnis.org).
23. THEIL, M.; WESTPHALEN, G.; COLLINGS, G. E.; CHESHIRE, A. Caulerpa taxifolia responses to hyposalinity stress. Aquatic Botany. 2007, v. 87, p. 221-228.
24. THEIL, M.; WESTPHALEN, G.; COLLINGS, G.; CHESHIRE, A. Caulerpa taxifolia, responses to hyposalinity stress. Aquatic Botany. 2007, v. 87, p. 221 – 228.
25. THIBAUT, T., MEINESZ, A., COQUILLARD, P., Biomass seasonality of Caulerpa taxifolia in the Mediterranean Sea. Aquatic. Bot. 2004, v. 80, p. 291–297.
26. VERLAQUE M, DURAND C, HUISMAN JM, BOUDOURESQUE CF, Le PARCO Y On the identity and origin of the Mediterranean invasive Caulerpa racemosa (Caulerpales, Chlorophyta). Eur J Phycol. 2003, v. 38, p. 325–339.
27. WEST, E. J and WEST, R.J. Growth and survival of the invasive alga, Caulerpa taxifolia, in different salinities and temperatures: implications for coastal lake management. Hydrobiologia. 2007, v. 577, p.87–94
28. WEST, E. J.; BARNES, P. B.; WRIGHT, J. T.; DAVIS, A. R. Anchors aweigh: Fragment generation of invasive Caulerpa taxifolia by boat anchors and its resistance to desiccation. Aquatic Botany. 2007, v. 87, p. 196–202.
29. WILLIAMS S.L, GROSHOLSZ E.D. Preliminary reports from the Caulerpa taxifolia invasion in southern California. Mar Ecol Prog Ser. 2002, v. 233, p. 307–310.
30. WRIGHT, J. T. Differences between native and invasive Caulerpa taxifolia: a link between asexual fragmentation and abundance in invasive populations. Marine Biology. 2005, v. 147: p. 559–569.
31. ZULJEVIC, A. and ANTOLIC, B. Synchronous release of male gametes of Caulerpa taxifolia (Caulerpales, Chlorophyta) in the Mediterranean Sea.Phycologia. 2000. v. 39, p. 157–159.
32. ZULJEVIC, A., THIBAUT, T., ELLOUKAL, H., MEINESZ, A. Sea slug disperses the invasive Caulerpa taxifolia. J. Mar. Biol. Ass. UK. 2001, v. 81, p. 343–344.