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Research Article

Seaweeds in ornamental aquaria in Brazil: anticipating introductions

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ABSTRACT. Home and public sea aquaria are becoming more and more popular worldwide. Aquaria species are selected for their aesthetic appeal in terms of color, shape or behavior. In Brazil, most species are imported from remote places, usually tropical areas around the world. Water discarded from aquaria often includes organisms, or their propagula, that may become locally established. There have been extensive discussions concerning the vectors of species dispersion from their native areas, which includes ornamental aquaria. In order to evaluate the potential of local aquaria as a source of non native macro algae, we surveyed sea-aquaria shops and exhibition aquaria in São Paulo State. Thirty eight species of seaweeds were isolated in the aquaria surveyed. Among them, six have not been recorded from Brazil and nineteen were not reported for São Paulo littoral, including *Caulerpa scalpelliformis* var. *denticulata* the only species that so far deserves being designated as invasive in Brazil. The present paper should alert environmental agencies and aquaria shops about the risk of involuntarily introducing non-native species through aquariophyly.

Keywords: aquariophyly, *Caulerpa scalpelliformis*, exotic species, invasive macroalgae, species introduction, Brazil.

Algas de acuarios ornamentales en Brasil: previsión de las introducciones

RESUMEN. Por todo público cada vez son más populares los acuarios marinos, sean caseros o de exhibición. Las especies vivientes escogidas generalmente tienen algún atractivo tal como su color, aspecto general o comportamiento de interés. Se sabe que muchos organismos utilizados para esta actividad en Brasil vienen de sitios lejanos, generalmente tropicales. El agua descartada de los acuarios suele contener organismos vivos o sus propágulos, los cuales se pueden establecer localmente en una comunidad natural. La comunidad científica ha realizado investigaciones y discusiones al respecto de los vectores de dispersión de especies, los que incluyen a los acuarios ornamentales. Para evaluar el potencial de los acuarios brasileños como fuentes dispersoras de macroalgas no-nativas, se investigaron en tiendas de acuariofilia y en establecimientos de exposición al público. Treinta y ocho especies de algas marinas fueron encontradas; entre estas, seis no eran conocidas en Brasil y diecinueve no habían sido reportadas para el litoral de São Paulo, incluyendo *Caulerpa scalpelliformis* var. *denticulata*, la única especie conocida hasta el momento como macroalga invasora en Brasil. El presente trabajo debe alertar a los sectores ambientales y establecimientos comerciales ligados a la acuariofilia en cuanto al riesgo de introducciones involuntarias de organismos no-nativos por esta actividad.

Palabras clave: acuariofilia, *Caulerpa scalpelliformis*, especies exóticas, macroalgas invasoras, introducción de especies, Brasil.

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INTRODUCTION

Aquaria business is growing 14% annually worldwide, and it is credited as a source of around 150 species of marine organisms that have reached and become established in natural ecosystems; they comprise one third of the worst recorded aquatic cases (Padilla & Williams, 2004). The most publicized algal introduction is the "killer alga", *Caulerpa taxifolia* (Vahl) C. Agardh in the Mediterranean, which spread

within a short time, displacing many native species (Meinesz *et al.*, 1993, 2001). Everything indicates that the original source of propagula of *C. taxifolia* originated from discarded water from the Monaco Aquarium (Jousson *et al.*, 1998; Meusnier *et al.*, 2001; Wiedenmann *et al.*, 2001).

Exporting countries of a variety of marine aquarium specimens include Vietnam, Hong Kong, Taiwan, Thailand, Australia, New Zealand, Sri Lanka, Ethiopia, Saudi Arabia, Egypt, Kenya, Madagascar, Mauritius, Polynesia, Micronesia, Melanesia, Mexico, Honduras, Costa Rica, Venezuela, Colombia, several Caribbean islands, and Brazil (Lubbock & Polunin, 1975; Padilla & Williams, 2004). Although ballast water discharge and biofouling has long been seen as the major marine introducing vector, aquarium trade could carry out selectively resistant species, tolerant to stressing conditions during collection and transportation (Padilla & Williams, 2004).

Although the introduction of non-native aquatic species is a recent concern in Brazil, the issue has reached popular media in the last decade. The concern is probably due to the dissemination of news about some dramatic ecological problem originated from invasive introduced species, as well as negative economic impacts from recent local introductions. Among those, we can mention the case of the "golden mussel", *Limnoperna fortunei* (Dunker), which invaded freshwater ecosystems, resulting in numerous events of clogging water pipes and pumps, from hydroelectric reservoirs to industrial and domestic use (Mansur *et al.*, 1999, 2003). Another case, is the bivalve *Isognomon bicolor* (C.B. Adams), which was probably introduced around the 1980's and is now one of the most pressing concerns among marine organisms. This invasive species is now rapidly expanding on rocky coasts from southeastern Brazil (Fernandes *et al.*, 2004).

The introduction of non-native seaweeds in Brazil has been documented by many authors, but approaches were made usually on commercial species or involuntary introductions via ballast water (Horta & Oliveira, 2000; Bellorin & Oliveira, 2001; Oliveira & Paula, 2003; Paula & Oliveira, 2004). A national review was recently summarized (Lopes, 2009; Silva *et al.*, 2010), including lists of species, as well as procedures, to avoid and restrict those events. Although the federal government, worried about the introduction of exotic organisms, has been organizing special forums to discuss this matter, since 2005, the emphasis is on agricultural pests and freshwater organisms. So far, only one case of invasive seaweed is confirmed for Brazil: *Caulerpa scalpelli-formis* (R. Br. ex Turner) C. Agardh *var. denticulata* (Decaisne) Weber-van Bosse. Considering that this seaweed is often used in aquaria and the potential that this activity has as a vector for invasive species, motivated us to carry on this investigation, aiming to: 1) disclose what kind of seaweed specimens are present in ornamental aquaria in Brazil; 2) provide a baseline to look for the sudden appearance of one of these taxa on the coast of the State of São Paulo; 3) alert local regulatory agencies about the risk of species introduction via aquaria; and 4) publicize this risk.

MATERIALS AND METHODS

In order to analyze the potential of aquaria as a vector of macro algal introductions in Brazil we have conducted the first survey of macro algae in public and commercial establishments within the country. Our sampling was concentrated to São Paulo, the main commercial city in the country and known to be the main port of entry and distribution of sea organisms in Brazil.

Samples of all the algae visible to the naked eye were collected in two exhibition aquaria and five shops, of which two are also national distributors. All shops are located in São Paulo city. The exhibition aquaria are located in the coastal cities of Guarujá and Ubatuba.

In an attempt to identify the macro algal species, live samples were scraped from the walls or removed with a forceps from various substrata and transported to the laboratory for identification. Information about the origin of the seaweeds, if known, and animals, usually fish and corals present in the aquaria, the source of seawater and substrata, was recorded (Table 1). In cases where specimens were not fully developed or reproductive structures were necessary for identification, the samples were cultivated *in vitro*, in sterilized seawater enriched with von Stosch medium, according to the conditions described in Oliveira *et al.* (1995). The medium was renewed weekly, aerated intermittently for 30 min and kept at 25 ± 1°C, salinity 33 psu, and photoperiod of 14 h per day.

RESULTS

We isolated 38 macroalgae species (Table 2), seven of which could not be identified. Six of the species identified were not previously reported from Brazil: *Caulerpa nummularia*, *Chaetomorpha spiralis*, *Cladophora submarina*, *Derbesia tenuissima*, *D. turbinata* and *Halimeda goreaui*. Of the total list, 18 species have not been reported for the coast of the State of São Paulo, although reported northward in the

Table 1. Conditions find in tanks during sampling. The names of establishments have been abbreviated – shops: EM, EA and AI; shop and distributor: ON and AI; exhibition aquaria: AM. Tanks from aquaria of Ubatuba are not computed due to the absence of seaweeds. Tanks with no seaweed entries are related to fail on isolating specimens.

Tank	Establish-ments	Date	N° of seaweed spp.	Water temp. (°C)	Salinity (psu)	Water source	Substrata source	Animals	Animals source
A	EM	02/25/04	3	26	31,9	Artificial	Brazil (northeastern coast)	fish	Unknown
B	EM	02/25/04	1	26	31,9	Artificial	Brazil (northeastern coast)	fish, corals, crustaceans	Unknown
C	EA	03/02/04	4	26,8	33,5	São Paulo coast	Artificial	corals	Hawaii, Indonesia
D	EA	03/02/04	0	26,8	33,5	São Paulo coast	Artificial	fish, corals, molluscs	Hawaii, Indonesia
E	EA	03/02/04	1	26,8	33,5	São Paulo coast	Artificial	fish	Hawaii, Indonesia
F	EA	05/11/04	0	26,8	33,5	São Paulo coast	Artificial	fish, coral, sea anemones	Brazil
G	EA	05/11/04	6	26,8	33,5	São Paulo coast	Artificial	corals	Indonesia
H	EA	05/11/04	1	26,8	33,5	São Paulo coast	Artificial	fish, corals,	Indonesia
I	EP	08/06/04	6	25,5	35,6	Artificial	Artificial	fish, corals, sea anemones, polychaetes	Indonesia, Fiji, Australia, Saudi Arabia; Brazil (northeastern coast)
J	AM	01/03/05	1	30	34,5	São Paulo coast	Brazil (northeastern coast)	fish, O*ctopus*	Brazil (northeastern coast), other distributors in São Paulo
K	AM	01/03/05	2	25,5	35,5	São Paulo coast	Brazil (northeastern coast)	fish, sea anemones	Unknown (other distributors in São Paulo)
L	AM	01/03/05	1	31	32	São Paulo coast	Brazil (northeastern coast)	fish	Unknown (other distributors in São Paulo)
M	AI	01/21/05	0	27	33,5	Artificial	Artificial	fish, corals	Asia, Australia (directly or from other distributor)
N	AI	01/21/05	13	26	30,6	Artificial	Brazil (northeastern coast)	fish, polychaetes	Asia, Australia (directly or from other distributor)
O	ON	01/24/05	8	25	31,5	Artificial	Natural substrata of unknown origin	fish, corals	Red Sea, Caribbean, Indonesia, Falklands, Sri Lanka; Brazil (northeastern coast)

Table 2. List of species collected from various evaluated aquaria. The non-native column indicates species unknown from the São Paulo State coast (SP) or from Brazil (BR). The list of tanks with its corresponding conditions is presented in Table 1. Abundance was visually estimated.

Species	Non-native	Tanks	Abundance
Chlorophyta			
Anadyomene stellata (Wulfen) C. Agardh	SP	N	low
Avrainvillea sp.	SP	O	low
Bryopsis pennata J.V. Lamouroux		I, O	high
Bryopsis plumosa (Hudson) C. Agardh		G	high
Caulerpa nummularia Harvey ex J. Agardh	BR	G	low
Caulerpa racemosa (Forsskål) J. Agardh		C	high
Caulerpa scalpelliformis var. *denticulata* (Decaisne) Weber-van Bosse	SP	B, I, N	high
Caulerpa webbiana Montagne	SP	O	low
Chaetomorpha spiralis Okamura	BR	N	low
Cladophora coelothrix Kützing		E	high
Cladophora prolifera (Roth) Kützing		N	high
Cladophora submarina P.L. Crouan & H.M. Crouan	BR	L	high
Derbesia marina (Lyngbye) Kjellman		G	medium
Derbesia tenuissima (Moris & De Notaris) P.L. Crouan & H.M. Crouan	BR	I	medium
Derbesia turbinata M. Howe & Hoyt	BR	C, N	medium
Halimeda goreaui W.R. Taylor	BR	N	low
Halimeda tuna (J. Ellis & Solander) J.V. Lamouroux	SP	C, N	high
Ulva flexuosa Wulfen		O	low
Ulva rigida C. Agardh	SP	O, N	low
Valonia aegagropila C. Agardh	SP	A, N	medium
Valonia ventricosa (J. Agardh) J.L. Olsen & J.A. West	SP	H, O	low
Phaeophyceae			
Canistrocarpus cervicornis (Kützing) De Paula & De Clerck		G	high
Dictyota bartayresiana J.V. Lamouroux		C, I	high
Dictyota mertensii (Martius) Kützing	SP	I	high
Sargassum vulgare C. Agardh		O	low
Rhodophyta			
Acanthophora spicifera (M. Vahl) Børgesen		A	low
Amansia multifida J.V. Lamouroux	SP	N	low
Amphiroa sp.		N, O	low
Digenea simplex (Wulfen) C. Agardh	SP	N	medium
Gelidiaceae (two species)		A, G, I, J, K	medium
Gracilaria birdiae Palastino & Oliveira	SP	N	low
Gracilaria spp. (three underproductive species)		K	low
Hypnea spinella (C. Agardh) Kützing		I	medium
Palisada gemmifera (Harvey) K.W. Nam	SP	I	high
Peyssonelia sp.		N	low

country (Horta *et al.*, 2001; http://www.algaemarisbrasilis.ccb.ufsc.br).

DISCUSSION

The brown algae were the least represented group within the sampled aquaria. Such a pattern was expected as the Phaeophyceae are less diversified than other seaweed groups on Brazilian coast, and because they are usually rather bulky and difficult to maintain within aquaria. Green algae were the most diverse group, despite the fact that red algae are the most diverse group in Brazil (Horta *et al.*, 2001). One hypothesis to explain the larger diversity of green algae in marine aquaria comes from their higher tolerance to a broader variation of light, temperature and salinity (Davison & Pearson, 1996; Taylor *et al.*, 2001). Although we did not measure nutrient contents in the sampled aquaria, it may well be the case that their water is rather eutrophic due to a relatively large proportion of animals. Such conditions would favor opportunistic species with short life cycles, as are the ones we found. In fact, aquarium hobbyists need to actively control the nutrients equilibrium and adopt other procedures to avoid dissemination of blue-green algae. Temperatures ranged from 25° to 31°C and salinities from 30 to 36 psu (Table 1), which were adequate for tropical organisms.

The algal species found in aquaria stores are kept as ornamental species or on the assumption that they would contribute to the health of the mesocosm, mainly by the absorption of soluble phosphorus and nitrogen from animal excreta. Among the sampled aquaria, the preferred species for those purposes were two green algae, *Caulerpa scalpelliformis* var. *denticulata* and *Halimeda tuna*. Most of the other species we found are considered as a nuisance, and are periodically removed and discarded. Many were collected from large acclimatization and quarantine tanks for newly arrived material. Such species probably arrive as contaminating propagules, especially on rhodoliths, that are locally known as "living-rocks". Most aquaria owners use rhodoliths as an obligate component of marine aquaria for aesthetic purposes and to balance the carbonate system. Most particulate calcareous substrates at the bottom are also biogenic and made out of rhodoliths, and dead *Halimeda* fragments, collected at the coast of the states of Espírito Santo and Pernambuco. They are usually not sterilized before being dumped in aquaria. Such a usage pattern could explain why the large majority of the species we found are also present on Espírito Santo and on Pernambuco coasts. On the other hand, sea animals come from various distant places such as the Red Sea, the Caribbean, Indonesia, Hawaii and Australia.

It is relevant to register that we did not find any seaweed in the public aquaria of Ubatuba, which documents the effectiveness of their water treatment, including the usage of ozone. Other treatments commonly adopted, such as filtration and decanting, proved to help, but did not eliminate micro propagules from water. On the other hand the use of artificial marine water was not completely efficient against seaweed contamination due to the utilization of live-rocks, certainly a source of propagules and plantlets.

The case of *Caulerpa scalpelliformis* var. *denticulata* is emblematic because this species, known to occur from the State of Espírito Santo to the north and found recently in the State of Rio de Janeiro, is spreading and displacing other species (Falcão & Széchy, 2005). As the occurrence spot (Ilha Grande Bay), is a popular tourist area, biofouling on boats hulls has been considered as the introduction vector. However, the hypothesis of an introduction via aquariophily cannot be discarded, considering its common presence in aquaria, due to its beautiful color and shape (Oliveira *et al.*, 2009). Nevertheless, the disseminated use of *Caulerpa* species in aquaria in Brazil is a motive of concern.

Therefore, our observations contribute to disseminate the idea that aquaria may effectively work as a vector for species introduction not only of seaweeds, the matter of our concern here, but also of other organisms including microorganisms, as have already been remarked by Corrêa *et al.* (1980) and Stewart (1991). Although it is well known that the effective establishment of a species in a new locality depends on many factors, such as tolerance to changes in various local environmental parameters, absence of predators, competitiveness vis a vis to other local organisms that utilize a similar ecological niche, and other factors. There is a rich literature supporting successful establishment of transplanted species (*e.g.*, Bellorín & Oliveira, 2001; Oliveira & Paula, 2003). Nevertheless, caution should be taken, and educational procedures established, concerning the discharging of various substrata, seawater and live or dead organisms, especially in locations close to the sea. Such steps should be enforced in order to avoid the introduction of undesired organisms that could become pests and are impossible to eradicate. Introductions from aquaria can be avoided with simple measures, once there is an understanding and acceptance from aquarists to suggestions that contribute to the ecological safety of their hobby (Weigle *et al.*, 2005).

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